

ALAN RUSHTON | PHIL CROUCHER | PETER BAKER

THE HANDBOOK OF LOGISTICS AND DISTRIBUTION MANAGEMENT

7TH EDITION

UNDERSTANDING THE SUPPLY CHAIN



**The Chartered
Institute of Logistics
and Transport**

The Handbook of Logistics and Distribution Management

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Seventh edition

The Handbook of Logistics and Distribution Management

Understanding the supply chain

Alan Rushton, Phil Croucher and Peter Baker



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With the creation of the Cranfield Centre for Logistics and Transportation (later the Cranfield Centre for Logistics and Supply Chain Management, CLSCM) he became the Director of Graduate Programmes for the new Centre where he set up and, for many years, ran the Executive MSc in Logistics and Supply Chain Management. He became the Director of eLearning for CLSCM and chaired the eLearning Committee for the Cranfield School of Management.

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Phil Croucher

Phil Croucher is an independent supply chain consultant and trainer. He has 44 years' experience in the field of logistics and supply chain management, the last 20 years at senior management or board level, working, travelling and living in many different countries.

He has worked in many different industries, countries and functions within those industries. On the third-party logistics side he has worked in express parcels in the UK, as Managing Director of a freight forwarder in Oman, as General Manager of

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Although at heart a practitioner, it has not stopped him developing a parallel career in training and academia. He has worked for the Chartered Institute of Logistics and Transport (UK) (CILT) on many projects. In 2002 CILT chose him to represent them in China at the inception of a prestigious training contract with the Chinese Government. This was followed by four further two-week trips delivering training in Beijing, Shanghai, Shenzhen and Dalian. He has also delivered training in Taiwan for CILT.

More recently (2011) CILT sent him to Somaliland to train United Nations International Children's Emergency Fund (UNICEF) staff, in 2012 he was sent to Bangkok to train Plan International staff and in 2013 he was sent to Qatar four times for Maersk Oil.

He has taught Masters courses in procurement, supply chain management and operations management.

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Peter Baker

Peter Baker spent the early part of his career in international freight forwarding, conducting export and import freight movements and ship's agency work. He became an office manager prior to taking an MSc degree in Distribution Technology and Management at Cranfield University.

After a period with a specialist materials handling and distribution consultancy, he worked for 12 years with Deloitte Consulting in their Supply Chain and Consumer Business divisions. During his period in consultancy, he has conducted over 100 supply chain projects across a wide range of industries and public sector organizations. He has undertaken projects in many European countries, as well as in North America, the Far East, Central Asia, West Africa and the Middle East. These projects have included supply chain strategy, procurement, international logistics, distribution centre design, inventory control, transport operations and supporting computer systems.

He became a lecturer, senior lecturer and then visiting fellow, at the Centre for Logistics and Supply Chain Management at Cranfield School of Management, where he completed his PhD on the subject of the role, design and operation of distribution centres in agile supply chains. He has continued his consultancy work during this period. He is a Fellow of both the CILT (UK) and the Higher Education Academy. He has published regularly in books, trade journals and academic journals.



PREFACE

The scope of logistics continues to change and grow, and covers a wide range of different topics. In this book, we discuss key aspects of supply chain philosophy and practice, but also focus on the detailed elements of distribution and logistics. The objectives of the original book remain unchanged: to provide a text with both simplicity of style and relevance of context. In addition, we have attempted to reflect the general principles of logistics and distribution that can be applied in any country throughout the world, recognizing that in some instances there are practical differences that cannot be generalized effectively. As before, we have included a substantial and detailed Index, which we know makes the book very attractive to students and practitioners who wish to identify specific subjects for reference.

We hope, once again, that this book will help in logistics managers' quest to improve service and reduce cost while reducing the environmental impact, as well as keeping them aware of the many different facets of logistics and the supply chain. It should be of interest and use to practising managers and supervisors, to candidates undertaking examinations for the various professional institutes, and to undergraduate and graduate students who are reading for degrees in logistics, distribution, transport and supply chain management or where these subjects are an integral part of their course. It should also provide major support for those participating in web-based training in logistics.

The book is divided into seven distinct parts, each covering a broad subject area in logistics. Each part is made up of a series of interlinking chapters. The main topics in each chapter can be seen in the list of contents at the beginning of this book.

In Part One the key **concepts of logistics and distribution** are considered. After an introduction to logistics and distribution, the integrated nature of logistics and the supply chain is discussed. The important aspects of customer service within logistics are covered in some detail and the use of different channels of distribution is examined. Finally, the key issues and challenges for logistics and the supply chain are outlined.

Part Two covers the ways and means of **planning for logistics**. An overview of logistics planning is provided including a specific logistics design framework. This is followed by a discussion of the key logistics processes. The important area of supply chain segmentation is reviewed. The various costs of the key logistics elements are outlined and the concept of logistics trade-off analysis is described. A particular approach to logistics network planning is developed and then the key elements of logistics management and organization are examined. The various issues concerning

omnichannel fulfilment are investigated and this part of the book concludes with a consideration of manufacturing logistics.

Part Three concentrates on those issues that are involved with **procurement, inventory and demand forecasting** decisions. The main principles concerned with the procurement and supply of raw materials and other goods are explored. The basic concepts behind the inventory-holding decision are investigated, including the reasons for holding stock and the different types of stock. Key developments in inventory planning are reviewed, particularly the way that inventory is viewed across the supply chain as a whole. Finally, there is a discussion of the use of demand forecasting to help determine the amount of inventory that should be held in the logistics network to meet customer service needs.

Part Four covers **warehousing and storage**. The main warehousing principles are introduced and an outline of the main warehouse operations is provided. Palletized and non-palletized storage and handling systems are considered, including descriptions of the various types of equipment that are available. Then, order picking, replenishment and packing are reviewed in some detail, in particular, the main order picking concepts, and the various order picking methods. The major factors related to receiving and dispatch are outlined. A step-by-step approach to warehouse and distribution centre (DC) design is described. Finally, there is a review of the key elements involved in warehouse management, together with the supporting information systems, for both automated and conventional operations.

Part Five concentrates on those areas of logistics and supply chain management specifically related to **freight transport**. International logistics and the choice of transport mode are considered, including a simple approach for modal choice. An overview and description of the major modes of international transport – maritime, air and rail – are given. For each of these, the basic infrastructure of the industry is reviewed, together with a variety of other aspects such as equipment, safety, pricing, security and documentation. Intermodal transport is also discussed. There are several chapters concerned with aspects of road freight transport. Vehicle selection factors are described, including the main types of vehicle and vehicle body, different types of operation, load types and characteristics. Vehicle and fleet costing is explained. Methods for the planning and resourcing of road freight transport operations are outlined. Following from this, the routeing and scheduling of vehicles within this process is described, including examples of both manual and computer routeing and scheduling. Finally, in this section, the key aspects of international freight forwarding are considered.

Part Six of the book covers the **outsourcing of logistics**, when the key decision of whether to use an own-account (in-house) operation or whether to outsource to a third-party logistics (3PL) service must be made. This begins with a review of the different outsourcing operations, activities and services that are available. The key decision criteria for outsourcing are then reviewed. The actual process of selecting a

service provider is described, including a step-by-step guide from the initial scoping of outsourcing requirements through to final negotiation and contract agreement. The all-important question of contractor management provides the finale to this section. The need to manage an outsourced contract is explained and the key factors required in managing a successful relationship are examined.

The final part of the book, Part Seven, considers a number of aspects related to the **operational management** of logistics and the supply chain. The cost and performance monitoring of logistics and distribution operations is discussed, together with the use of benchmarking as a major technique for identifying best practice in logistics. The different information and communication systems that can be used in the supply chain are outlined, indicating how the development of the digital supply chain has evolved from the many different threads of technological development. Key factors concerning security and safety, a very important area of responsibility in logistics, are discussed. Another important aspect that is considered is the impact of logistics operations on the environment, as well as the environmental regulations that may impose on logistics operations. The final chapter of the book provides an overview of humanitarian logistics and compares this with commercial logistics.

Once again, we hope that this new edition of *The Handbook of Logistics and Distribution Management* will continue to serve as an essential aid to understanding this wide-ranging and increasingly important business area.

Alan Rushton

PART ONE

**Concepts of
logistics and
distribution**

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Introduction to logistics and distribution

01

Introduction

The key components of logistics – transport, inventory, warehousing – have been fundamental elements of industrial and economic life for countless years. However, these components and their sub-functions were treated as individual elements and rarely as part of a bigger and broader concept whereby they are connected together to provide the means to an end. That end is the satisfactory supply of goods or products to a customer at an acceptable time and an acceptable cost. Thus, in those early years, logistics was not recognized as a major business function in its own right. The main reason for this is the nature of logistics itself. It is a function made up of many sub-functions and many subsystems, each of which has been, and may still be, treated as a distinct management operation. Both the academic and the business world accept that there is a need to adopt a more holistic view of these different operations in order to take into account how they interrelate and interact with one another and to ensure that the overall operation, whatever it may be, is optimized.

The appreciation of the scope and importance of logistics and the supply chain has led to a more scientific approach being adopted towards the subject. This approach has been aimed at the overall concept of the logistics function as a whole but, importantly, also includes the interrelationship of the individual subsystems. Much of this approach has addressed the need for, and means of, planning logistics and the supply chain, but has necessarily included the consideration of the major operational issues as well.

Continuous advances in technology and the development of new ideas and concepts, however, mean that there is a constant change in thinking with regard to the most effective approaches that should be adopted for logistics and the supply chain. Some of these key ideas and issues are described in Chapter 5. This first chapter of the book provides an introduction to the very basic aspects of distribution, logistics and the supply chain. Initially there is a review of the scope and definition of

distribution, logistics and the supply chain. Next is a discussion of the key elements that are fundamental to the logistic function. A brief description of the historical growth of distribution and logistics is followed by an assessment of its importance throughout the world. Finally, a typical distribution and logistics structure is described and discussed.

Scope and definition

Parallel to the growth in the importance of distribution, logistics and the supply chain has been the growth in the number of associated names and different definitions that are used. Among the many different names can be found:

- physical distribution
- logistics
- business logistics
- materials management
- procurement and supply
- product flow
- marketing logistics
- supply chain management
- demand chain management

and there are several more.

There is, realistically, no 'true' name or 'true' definition that can be pedantically applied to these different terms because the elements that are covered can be so variable. Every industry has its own characteristics, and for each company in that industry there can be major variations in strategy, size, range of product, market coverage, etc. Logistics is, therefore, a diverse and dynamic function that has to be flexible and has to change according to the various constraints and demands imposed upon it and with respect to the environment in which it works.

Thus, these many different terms are used, often interchangeably, in literature and in the business world. One of the key relationships can be described as follows:

$$\text{Logistics} = \text{Materials Management} + \text{Distribution}$$

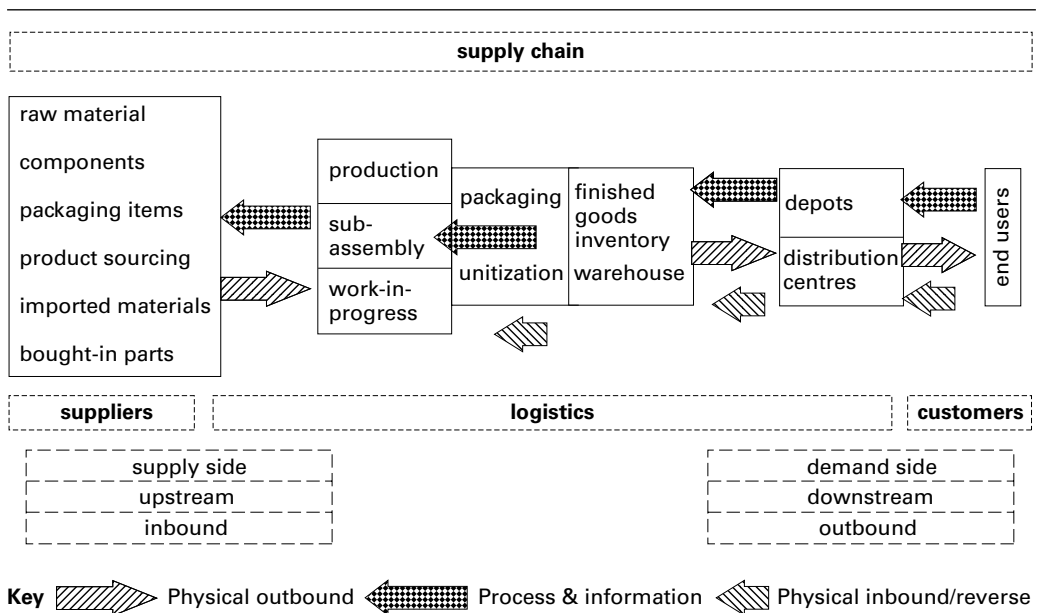
where 'materials management' represents the activities concerning materials going into and through the production process and 'distribution' represents the process of making a product available to the consumer or business that needs it.

An extension to this idea helps to illustrate that the supply chain covers an even broader scope of the business area. This includes the supply of raw materials and components as well as the delivery of products to the final customer. Thus:

$$\text{Supply Chain} = \text{Suppliers} + \text{Logistics} + \text{Customers}$$

It should also be noted that logistics and the supply chain are concerned not only with physical flows and storage from raw material through to the final distribution of the finished product, but also with information flows and storage. Indeed, major emphasis is now placed on the importance of information as well as physical flows and storage. This is reflected in the content throughout this book. An additional and very relevant factor is that of reverse logistics – the flow of used products and returnable packaging back through the system. Figure 1.1 illustrates these different elements and flows, as well as indicating how some of the associated logistics terminology can be applied.

Figure 1.1 A flow representation of logistics for a fast-moving consumer goods (FMCG) manufacturer. This shows the key components, the major flows and some of the different logistics terminology



Having indicated above that there is no ‘true’ definition of logistics that can be universally applied, it would be remiss not to consider some of the alternatives! The question of what is the most appropriate definition of logistics and its associated namesakes is always an interesting one. There is a multitude of definitions to be found in textbooks and on the internet. Several early definitions referred to the

ability of logistics to help create time and place utility for products in the marketplace. A selection of more recent definitions is:

Logistics is the management of the flow of goods between point of origin and point of destination to meet customer and corporate requirements.

COLLINS DICTIONARY

Logistics management is that part of supply chain management that plans, implements and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.

COUNCIL OF SUPPLY CHAIN MANAGEMENT PROFESSIONALS (USA), 2021

Logistics is defined as the time-related positioning of resources. It is also described as the 'five rights'. Essentially, it is the process of ensuring that goods or a service is: in the right place, at the right time, in the right quantity, at the right quality, at the right price.

CHARTERED INSTITUTE OF LOGISTICS AND TRANSPORT (UK), 2021

For many definitions it is possible to detect the different biases – military, economic, academic... An appropriate modern definition that applies to most industries and that we might use for this book is that:

logistics concerns the efficient transfer of goods from the source of supply through the place of manufacture to the point of consumption in a cost-effective way while providing an appropriate service to the customer.

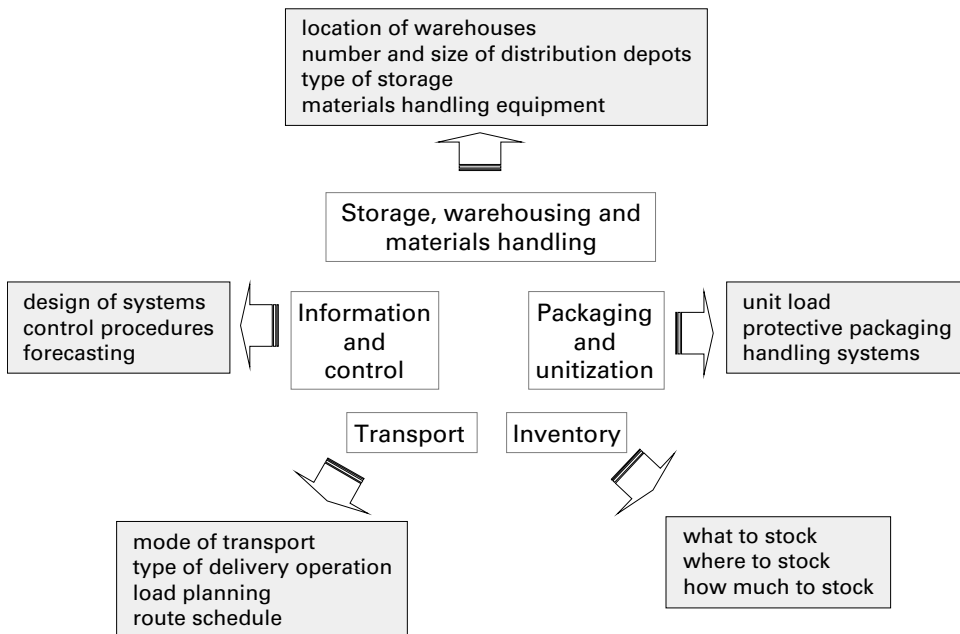
This focus on cost-effectiveness and customer service will be a point of emphasis throughout this book.

A more critical consideration of the difference between logistics and the supply chain is given at the end of Chapter 2. It is developed using some of the ideas that are discussed in that chapter.

For most organizations it is possible to draw up a familiar list of key areas representing the major components of distribution and logistics. These will include transport, warehousing, inventory, packaging and information. This list can be 'exploded' once again to reveal the detailed aspects within the different components. Some typical examples are given in Figure 1.2.

All of these functions and sub-functions need to be planned in a systematic way, in terms both of their own local environment and of the wider scope of the distribution system as a whole. A number of questions need to be asked and decisions made. The different ways of answering these questions and making these decisions are addressed in the chapters of this book as consideration is given to the planning and operation of the logistics and supply chain function. In addition, the total system interrelationships and the constraints of appropriate costs and service levels are discussed.

Figure 1.2 The key components of distribution and logistics, showing a few of the associated detailed elements



Historical perspective

The different elements of logistics and the supply chain have, of course, always been fundamental to the manufacturing, storage and movement of goods and products. For most companies they are recognized as vital functions that contribute to the business and economic environment. The role of logistics has developed such that it now plays a major part in the success of many different operations and organizations. In essence, the underlying concepts and rationale for logistics are not new. They have evolved through several stages of development, but still use the basic ideas such as trade-off analysis, value chains and systems theory together with their associated techniques. Of course, many of these ideas, concepts and techniques have altered, almost beyond recognition, from their original format.

There have been several distinct stages in the development of distribution and logistics.

1950s and early 1960s

In the 1950s and early 1960s, distribution systems were unplanned and unformulated. Manufacturers manufactured, retailers retailed, and in some way or other the

goods reached the shops. Distribution was broadly represented by the haulage industry and manufacturers' own-account fleets. There was little positive control and no real liaison between the various distribution-related functions.

1960s and early 1970s

In the 1960s and 1970s the concept of physical distribution was developed with the gradual realization that the 'dark continent' (as distribution was described in early academic literature) was indeed a valid area for managerial involvement. This consisted of the recognition that there was a series of interrelated physical activities such as transport, storage, materials handling and packaging that could be linked together and managed more effectively. In particular, there was recognition of a relationship between the various functions, which enabled a systems approach and total cost perspective to be used. Under the auspices of a physical distribution manager, a number of distribution trade-offs could be planned and managed to provide both improved service and reduced cost. Initially the benefits were recognized by manufacturers, who developed distribution operations to reflect the flow of their product to their customers.

1970s

The 1970s was an important decade in the development of the distribution concept. One major change was the recognition by some companies of the need to include distribution in the functional management structure of an organization. The decade also saw a change in the structure and control of the distribution chain. There was a decline in the power of the manufacturers and suppliers, and a marked increase in that of the major retailers. The larger retail chains developed their own distribution structures, based initially on the concept of regional or local distribution depots to supply their stores.

1980s

In the 1980s fairly rapid cost increases and the clearer definition of the true costs of distribution contributed to a significant increase in professionalism within distribution. With this professionalism came a move towards longer-term planning and attempts to identify and pursue cost-saving measures. These measures included centralized distribution, notable reductions in stockholding and the use of the computer to provide improved information and control. The growth of the third-party distribution service industry was also of major significance, with these companies spearheading developments in information and equipment technology. The concept

of and need for integrated logistics systems were recognized by forward-looking companies that participated in distribution activities.

Late 1980s and early 1990s

In the late 1980s and early 1990s advances in information technology enabled organizations to broaden their perspectives in terms of the functions that could be integrated. In short, this covered the combining of materials management (the inbound side) with physical distribution (the outbound side). The term ‘logistics’ was used to describe this concept (see Figure 1.1). Once again, this led to additional opportunities to improve customer service and reduce the associated costs. One major emphasis made during this period was that informational aspects were as important as physical aspects in securing an effective logistics strategy.

1990s

In the 1990s the process of integration was developed even further to encompass not only the key functions within an organization’s own boundaries but also those functions outside that also contribute to the provision of a product to a final customer. This became known as ‘supply chain management’ (see Figure 1.1). The supply chain concept gave credence to the fact that there may be several different organizations involved in getting a product to the marketplace. Thus, for example, manufacturers and retailers should act together in partnership to help create a logistics pipeline that enables an efficient and effective flow of the right products through to the final customer. These partnerships or alliances should also include other intermediaries within the supply chain, such as third-party contractors.

2000s

As the new millennium dawned, business organizations faced many challenges as they endeavoured to maintain or improve their position against their competitors, bring new products to market and increase the profitability of their operations. This led to the development of many new ideas for improvement, specifically recognized in the redefinition of business goals and the re-engineering of entire systems.

Logistics and the supply chain were confirmed as key elements to overall business success. Indeed, for many organizations, changes in logistics and the supply chain provided the catalyst for major enhancements to their business. Leading organizations recognized that there was a positive ‘value-added’ role that logistics could offer, rather than the traditional view that the various functions within logistics were merely a cost burden that had to be minimized regardless of any other implications. Logistics was seen as a key enabler for business improvement.

2010s and beyond

This period saw the confirmation of the importance of a number of concepts and many businesses developed and improved their systems and operations to embrace these. Many of these concepts remain key and are covered in the relevant chapters of this book. Some examples are:

- environmental concerns resulted in the development of many green initiatives in logistics
- the important role of the supply chain was reflected in new approaches to humanitarian logistics
- the recognition of the difference between lean and agile supply chains brought about revised structures to relevant businesses
- the concept of the networked economy was also embraced, acknowledging that the success of a company is intrinsically linked to others so that enterprises need to cooperate and collaborate across their traditional boundaries
- significant technology developments began to impact on logistics and supply chain activities
- e-commerce, e-fulfilment, AI, Big Data analytics

The key recent and likely future issues to be faced in distribution, logistics and supply chain management are reviewed and discussed in Chapter 5.

Importance of logistics and distribution

Importance in the economy

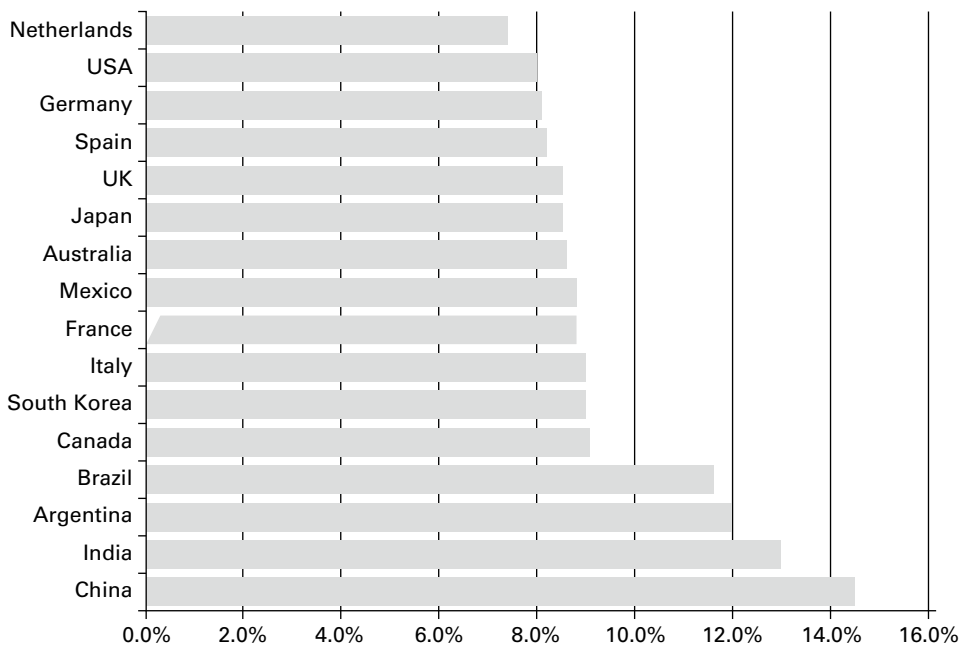
Logistics is an important activity making extensive use of the human and material resources that affect a national economy. Due to the difficulty of data collection, only a limited number of studies have been undertaken to try to estimate and compare the extent of the impact of logistics on the economy.

One study in the UK has indicated that about 30 per cent of the working population were associated with work that is related to logistics. A study undertaken by Armstrong and Associates (2021a) was able to present data at a country level, which indicated that, for the many economies reviewed, logistics represented somewhere between 7.4 and 20 per cent of the gross domestic product (GDP) of that country. The information, for the latest year available, is summarized in Figure 1.3 for certain key countries.

Figure 1.3 shows that, for the main European and North American economies, logistics represented between 7.4 per cent and 9.5 per cent of GDP. For the larger

South American nations this range was higher at around 12 per cent, with India at 13 per cent and China at 14.5 per cent. These numbers represent some very substantial costs, and serve to illustrate how important it is to understand the nature of logistics costs and to identify means of keeping these costs to a minimum. Countries with the lowest costs are generally those where the importance of logistics was recognized relatively early and where there has been time to create more efficient systems. It is already apparent that the logistics costs of developing nations will continue to decrease over the next few years as they have decreased in the past few years. About 25 years ago, if the same statistics had been available, these percentage elements would undoubtedly have been a lot higher in all of these countries. In the UK records go back for about 40 years, and logistics costs were then around the 18 to 20 per cent mark.

Figure 1.3 Logistics costs as a percentage of GDP for selected countries



SOURCE Armstrong and Associates, 2021a

The Council of Supply Chain Management Professionals in the United States, in its *Annual State of Logistics Report* (2020), provided figures indicating that logistics costs as a percentage of GDP for the United States had fallen from 8.1 per cent in 2008 to 7.4 per cent in 2009. There was a brief rise to 7.9 per cent for 2018, due to fast growth and capacity shortages, before a return to a more normal level of 7.6 per cent for 2019. The report notes that this final measure indicated ‘an unrecognized last hurrah of the *old normal*’ before the global pandemic.

Importance to industry

The breakdown of the costs of the different elements within logistics has also been addressed, but again only in a very limited number of surveys, so data is hard to find. One survey of US logistics costs undertaken by Establish Davis (2016) indicated that in the United States transport was the most important element at 48.4 per cent, followed by inventory carrying cost at 22.9 per cent, storage/warehousing at 22.6 per cent, customer service/order entry at 3.9 per cent and administration at 2.3 per cent.

In past studies of this nature, the transport cost element of distribution has always been the major constituent part in the United States. US transport costs are especially affected by the long distances travelled, so the transport cost element is markedly higher there than it is in Europe.

The statistics described above are useful to provide a broad perspective on the importance of the relative logistics components. When looking at industry and company level, however, it is essential to be aware that these costs are average figures taken across a number of companies.

The relative make-up of these costs can vary quite significantly between different industries. Listed in Table 1.1 are some examples of the major logistics costs from different types of company, shown as a percentage of sales turnover. These are taken from an industry cost audit carried out in the UK by Dialog Consultants Ltd and they illustrate how extreme these variations can be. There are some quite major variations among the results from the various companies and there can be a number of reasons for these cost differences. For example:

- Logistics structures can and do differ quite dramatically between one company and another, and one industry and another.
- Channels can be short (i.e. very direct) or long (i.e. have many intermediate stocking points).
- Supply chains may be operated by different players: manufacturers, retailers, specialist third-party distribution companies, or indeed by a mixture of these.

Also, it should be noted that in the examples shown in Table 1.1 the relative importance of logistics is measured in relationship to the overall value of the particular products in question, which has implications for comparing relative importance between different companies. For example, cement is a low-cost product (as well as being a very heavy one!), so the relative costs of its logistics are very high. Spirits (whisky, gin, etc) are very high-value products, so the relative logistics costs appear very low.

Two key factors related to the relative importance of logistics in industry are:

- Small companies tend to have proportionately higher logistics costs than large companies (about 13 per cent of the cost of sales compared to about 4.5 per cent).

Table 1.1 Logistics costs as a percentage of sales turnover

Cost as Percentage of Turnover					
Main Company Business	Transport Cost	Warehouse/ Depot Cost	Inventory Investment/ Holding Cost	Administration Cost	Overall Logistics Cost
	%	%	%	%	%
Office equipment	3.20	10.70	0.87		14.77
Health supplies	1.36	9.77	0.66	0.19	11.98
Soft drinks	2.53	2.71	0.44		5.68
Beer (food and drink)	8.16	2.82	0.56	2.19	13.74
Spirits distribution	0.37	0.27	0.07	0.10	0.81
Cement	25.20	9.10	7.10	4.60	46.00
Automotive parts	2.07	6.35	1.53		9.96
Gas supply (non-bulk)	9.41	2.45	0.02		11.98
Computer maintenance	0.45	0.10	0.29	0.05	0.88
Computer supply	0.65	0.78	0.09		1.52
Healthcare	0.96	1.08	1.21		3.25
Specialist chemicals	7.23	1.95	0.20	0.49	9.87
Fashion	0.38	1.31	0.33		2.02
Food packaging	3.14	3.73	0.85		7.72

SOURCE Benchmark survey of UK companies by Dialog Consultants Ltd (unpublished)

This is principally because large companies can benefit from economies of scale.

- Companies with high product values tend to have proportionately lower logistics costs than those with low product values (about 4.5 per cent of the cost of sales compared to about 10.5 per cent). This is because the high value of their goods tends to distort downwards the importance of the respective logistics costs.

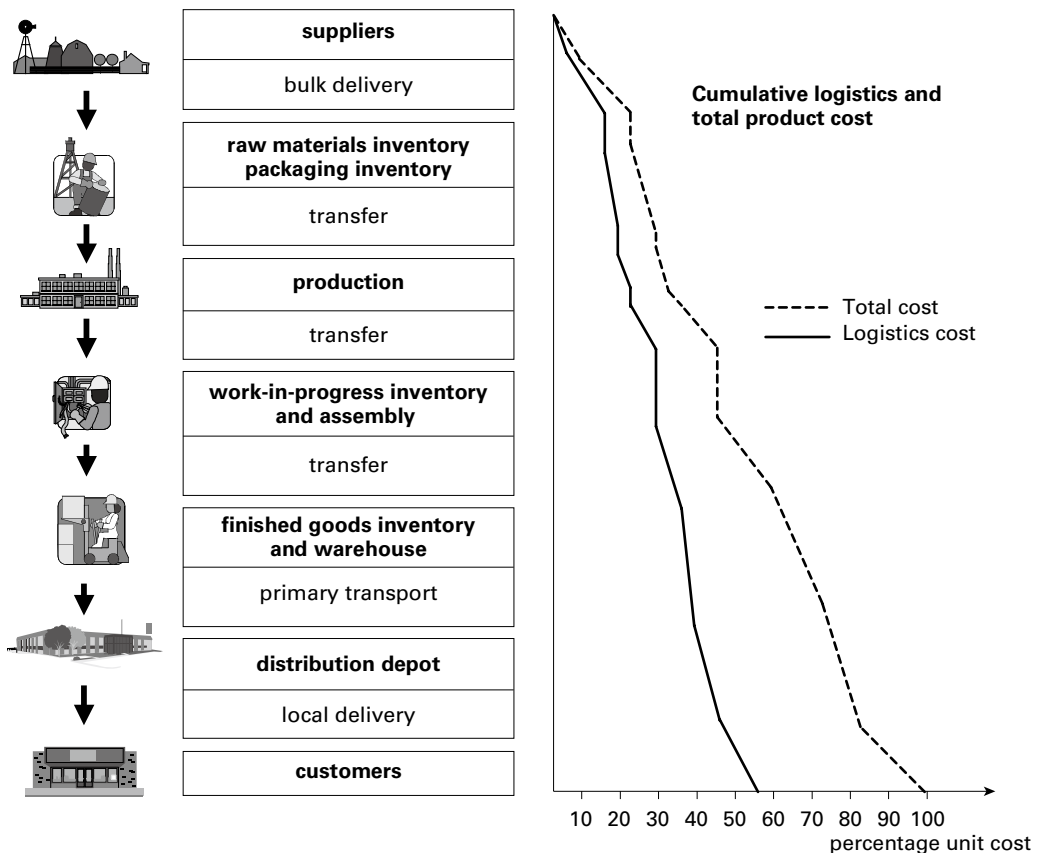
These and other associated aspects are discussed in subsequent chapters.

Logistics and supply chain structure

The discussion in the previous sections of this chapter has illustrated the major components to be found within a logistics or supply chain system: transport, warehousing, inventory, etc. The fundamental characteristics of a physical distribution structure are illustrated on the left-hand side of Figure 1.4, and can be considered as the flow of material or product, interspersed at various points by periods when the material or product is stationary. This flow is usually some form of transportation of the product. The stationary periods are usually for storage or to allow some change to the product to take place – manufacture, assembly, packing, break bulk, etc.

This simple physical flow that is illustrated thus consists of the different types of transport (primary, local delivery, etc) and stationary functions (production, finished goods inventory, etc).

Figure 1.4 A typical physical flow of material from suppliers through to customers, showing stationary functions and movement functions, linked to a diagram that reflects the ‘value-added’ nature of logistics



There is also, of course, a cost incurred to enable the distribution operation to take place. The importance of this distribution or logistical cost to the final cost of the product has already been highlighted. As has been noted, it can vary according to the sophistication of the distribution system used and the intrinsic value of the product itself. One idea that helps to emphasize the importance of distribution and logistics is that these different elements of logistics are providing an ‘added value’ to a product as it is made available to the final user – rather than just imposing an additional cost. This is a more positive view of logistics and is a useful way of assessing the real contribution of logistics and distribution services. Figure 1.4 also provides an example of this cost or added value for a typical low-cost product.

Figure 1.4 concentrates on the physical flows of goods and materials, demonstrating some of the different links and functions that are fundamental to logistics. What is not shown, but will be seen as vital to the success of the process, is the vast amount of information that is essential to enable and support logistics operations. This is key, and will be considered in detail in many chapters of this book.

Integrated logistics and the supply chain

02

Introduction

In Chapter 1, different definitions of logistics were introduced, and the main components of logistics were outlined. It was shown that the various logistics and supply chain functions are part of a flow process operating across many business areas. In this chapter, the emphasis is on the integration of the various logistics components into a complete working structure that enables the overall system to run at the optimum. Thus, the concept of 'total logistics' is described, and the importance of recognizing the opportunities for appropriate trade-offs is discussed. Some key aspects of planning for logistics are reviewed, and the financial impact that logistics has in a business is described. Finally, a number of key developments in logistics integration are considered, including the impact of the globalization of many companies, the use of integrated planning systems, how logistics can help to create competitive advantage and the concept of supply chain (SC) management.

The total logistics concept

The total logistics concept (TLC) aims to treat the many different elements that come under the broad category of distribution and logistics as one single integrated system. It is a recognition that the interrelationships between different elements, for example delivery transport and storage, need to be considered within the context of the broader supply chain. Thus, the total system should be considered and not just an individual element or subsystem in isolation.

An understanding of the concept is especially important when planning for any aspect of distribution and logistics. The simple, practical example in the box helps to emphasize the point.

EXAMPLE The total logistics concept

A company produces plastic toys that are packaged in cardboard boxes. These boxes are packed onto wooden pallets that are used as the basic unit load in the warehouse and in the transport vehicles for delivery to customers.

A study indicates that the cardboard box is an unnecessary cost because it does not provide any significant additional protection to the quite robust plastic toys and it does not appear to offer any significant marketing advantage. Thus, the box is discarded, lowering the unit cost of the toy and so providing a potential advantage in the marketplace.

One unforeseen result, however, is that the toys, without their boxes, cannot be stacked on to wooden pallets, because they are unstable, but must be stored and moved instead in special trays. These trays are totally different to the unit load that is currently used in the warehouse and on the vehicles (i.e. the wooden pallet). The additional cost penalty in providing special trays and catering for another type of unit load for storage and delivery is a high one – much higher than the savings made on the product packaging.

This example illustrates a classic case of *sub-optimization* in a logistics system. It shows that if the concept of total logistics is ignored, this can be a significant cost to a company. As the product packaging costs have been reduced, those concerned with this company function will feel that they have done their job well. However, the overall effect on the total logistics cost is, in fact, a negative one. The company is better served by disregarding this potential saving on packaging, because the additional warehouse and transport costs mean that total costs increase.

This simple example of sub-optimization emphasizes the importance of understanding the interrelationships of the different logistics elements. A more positive action would be to measure and interpret these and other interrelationships using a planned approach to identifying and determining any *cost trade-offs*. This approach will be a benefit to the logistics system as a whole. Such a trade-off may entail additional cost in one function but will provide a greater cost saving in another. The overall achievement will be a net gain to the system.

This type of trade-off analysis is an important part of planning for logistics. Four different levels of trade-off can be identified:

- 1 *Within logistics components*: this refers to the trade-offs that occur within single functions (e.g. warehousing). One example would be the decision to use random storage locations compared to fixed storage locations in a depot. The first of these provides better storage utilization but is more difficult for picking; the second is easier for picking but does not provide such good storage utilization.

- 2 *Between logistics components*: these are the trade-offs that occur between the different elements in logistics. To reverse the earlier packaging example, a company might increase the strength and thus the cost of packaging but find greater savings through improvements in the warehousing and storage of the product (i.e. block stacking rather than a requirement for racking).
- 3 *Between company functions*: there are a number of areas of interface between company functions where trade-offs can be made. This is illustrated in Figure 2.1, which lists some potential trade-offs and indicates how the different company functions might be affected. One example is the trade-off between optimizing production run lengths and the associated warehousing costs of storing the finished product. Long production runs produce lower unit costs (and thus more cost-effective production) but mean that more product must be stored for a longer period (which is less cost-effective for warehousing).
- 4 *Between the company and external organizations*: there may be opportunities for a trade-off between two companies that are directly associated with each other. For example, a change from a manufacturer's products being delivered direct to a retailer's stores to delivery via the retailer's distribution depot network might lead to a cheaper solution overall for the two companies.

These types of trade-offs are thus at the heart of the total logistics concept. For the planning of distribution and logistics, it is important to take this overall view of a logistics system and its costs. The other side of the equation is, of course, the need to provide the service level that is required by the customer. This balance of total logistics cost and customer service level is essential to successful logistics.

Planning for logistics

In order to ensure that the concept of total logistics is put into practice and that suitable trade-offs are achieved, it is essential that a positive planning approach is adopted. In this section, the various planning horizons with their associated logistics decisions are described. In Chapter 6, a more formalized planning framework is discussed. This is developed in subsequent chapters into a more practical and detailed approach to logistics planning.

Planning should be undertaken according to a certain hierarchy that reflects different *planning time horizons*. These are generally classified as strategic, tactical and operational. They are represented on the left side of Figure 2.2. There is an overlap between the different levels, which emphasizes that there are some factors that can be considered at different stages in this planning hierarchy. The relative importance of these various elements can differ between one company and another. For example, the choice of transport mode might be a strategic decision for a company that is

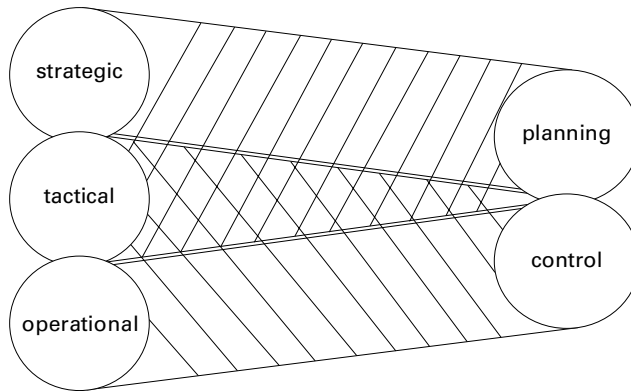
Figure 2.1 Some potential trade-offs in logistics, showing how different company functions might be affected

Trade-off	Finance	Production	Distribution	Marketing
Longer production runs	Lower production unit costs	Lower production unit costs	More inventory and storage required	Lower prices
Fewer depots	Reduced depot costs (though transport costs likely to increase)	No impact	Less complicated logistics structure	Service reduction due to increased distance of depots from customers
Reducing stocks of finished goods	Reduced inventory costs	Shorter production runs so higher production unit costs	No need to expand storage facilities	Poorer product availability for customers
Reducing raw material & component stocks	Reduced inventory costs	Less efficient production scheduling due to stock unavailability	Lower stock-holding requirements	No direct impact
Reducing protective transport packaging	Reduced packaging costs	No impact	Reduced transport modal choice	Increase in damaged deliveries
Reducing warehouse supervision	Cost savings through lower headcount	No impact	Reduced efficiency due to less supervision	Lost sales due to less accurate order picking

setting up a new global logistics operation, but might just be a tactical decision for another company that is principally a supplier to a locally based market and only occasionally exports over long distances. Choice of transport mode could even be an initial strategic decision and also a subsequent tactical decision for a single company.

Figure 2.2 also indicates the interrelationship of *planning and control* within this hierarchy. Both of these different elements are essential to the running of an effective and efficient logistics operation. One way to envisage the difference between these two concepts is as follows: *planning* is about ensuring that the operation is set up to run properly – it is ‘doing the right thing’ or preparing for and planning the operation ‘effectively’; *control* is about managing the operation in the right way – it is ‘doing the thing right’ or making sure that the operation is being run ‘efficiently’.

Once again it is not relevant to define exactly which strategic, tactical and operational decisions or tasks within a company should be classified as either planning or control. Most elements need to be planned correctly in the first place, and then subsequently they need to be monitored and controlled to ensure that the operation is running as well as it should be. The practical means of monitoring and controlling logistics are described in Chapter 38.

Figure 2.2 Logistics planning hierarchy

Some of the major aspects and differences between the three time horizons are summarized in Figure 2.3. The importance and relevance of these different aspects will, of course, vary according to the type and scale of business, product, etc. It is helpful to be aware of the planning horizon and the associated implications for each major decision that is made.

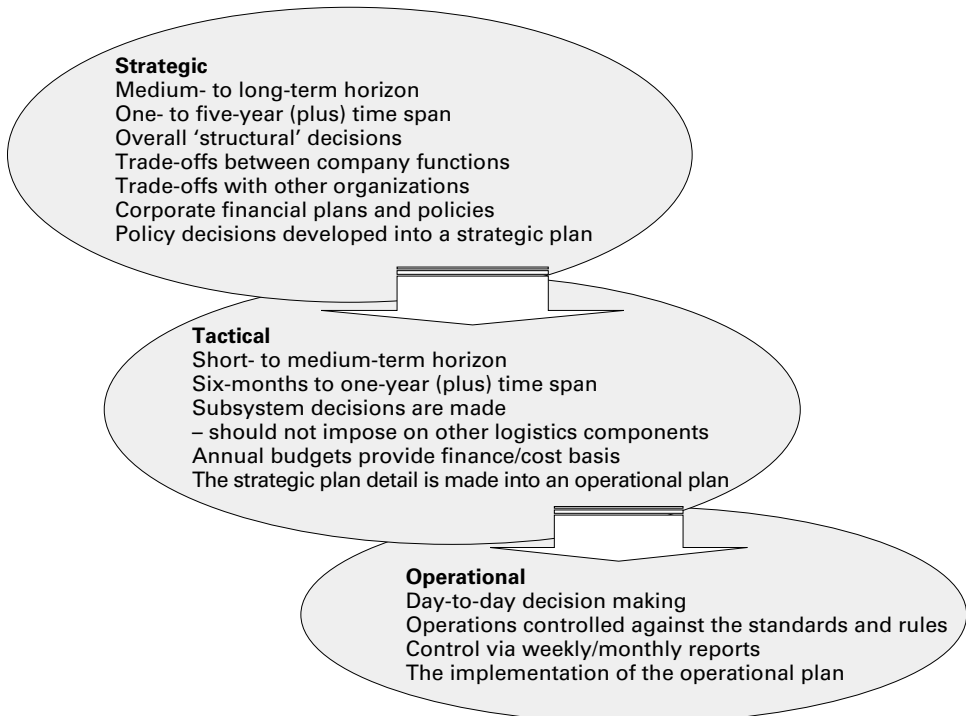
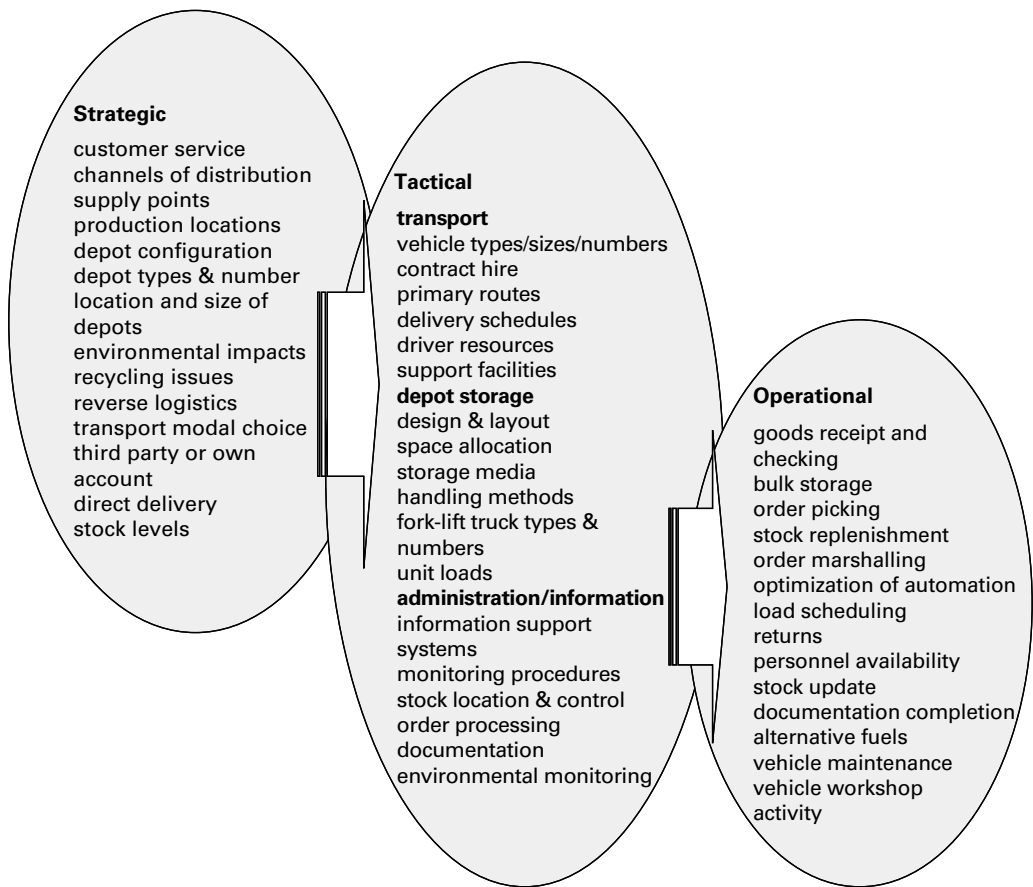
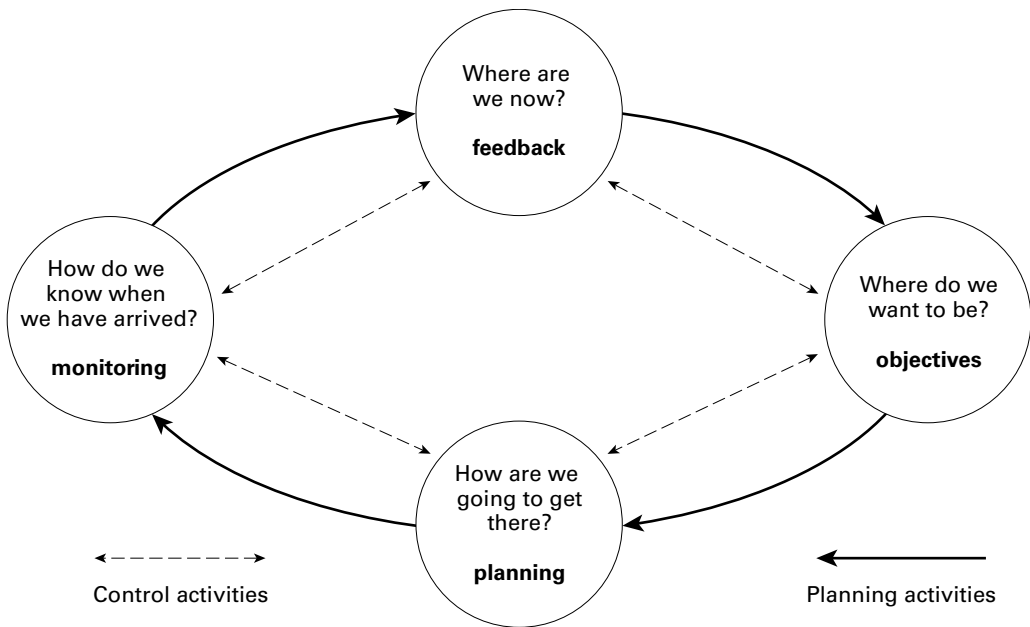
Figure 2.3 The major functions of the different planning time horizons

Figure 2.4 Some of the main logistics elements for the different planning time horizons

It is possible to identify many different elements within distribution and logistics that can be broadly categorized within this planning hierarchy. As already indicated, these may vary from one company to another and from one operation to another. Some of these – in no particular order – are as indicated in Figure 2.4.

These examples serve to emphasize the complexity of distribution and logistics. In addition, they underline the need for appropriate planning and control. Distribution and logistics are not merely the transportation of goods from one storage point to another. There are many and varied elements that go together to produce an effective distribution and logistics operation. These elements interrelate, and they need to be planned over suitable time horizons.

The planning and control of an operation can also be described within the context of a broader planning cycle. This emphasizes the need for a systematic approach, where continual review takes place. This is a particularly important concept in logistics, because most operations need to be highly dynamic – they are subject to

Figure 2.5 The planning and control cycle

continual change, as both demand and supply of goods and products regularly vary according to changes in customer requirements for new products and better product availability. One example of a fairly common framework is shown as the planning and control cycle in Figure 2.5. The key stages in the cycle are as follows:

- 1 The cycle begins with the question ‘Where are we now?’ Here the aim is to provide a picture of the current position. This might be through a regular information feedback procedure or, initially, through the use of a specific logistics or distribution audit.
- 2 The second stage is to determine the objectives of the logistics process, to identify what the operation should be trying to achieve. These objectives need to be related to such elements as customer service requirements, marketing decisions, etc.
- 3 The third stage in the cycle is the planning process that spans the strategic and operational levels previously discussed.
- 4 Finally, there is a need for monitoring and control procedures to measure the effectiveness of the distribution operation compared to the plan. This should be undertaken on a regular weekly, monthly and annual basis.

The cycle has then turned full circle, and the process is ready to begin again. This takes account of the dynamic nature of logistics, the need for continual review and

revision of plans, policies and operations. This must be undertaken within a positive planning framework in order to ensure that continuity and progress are maintained.

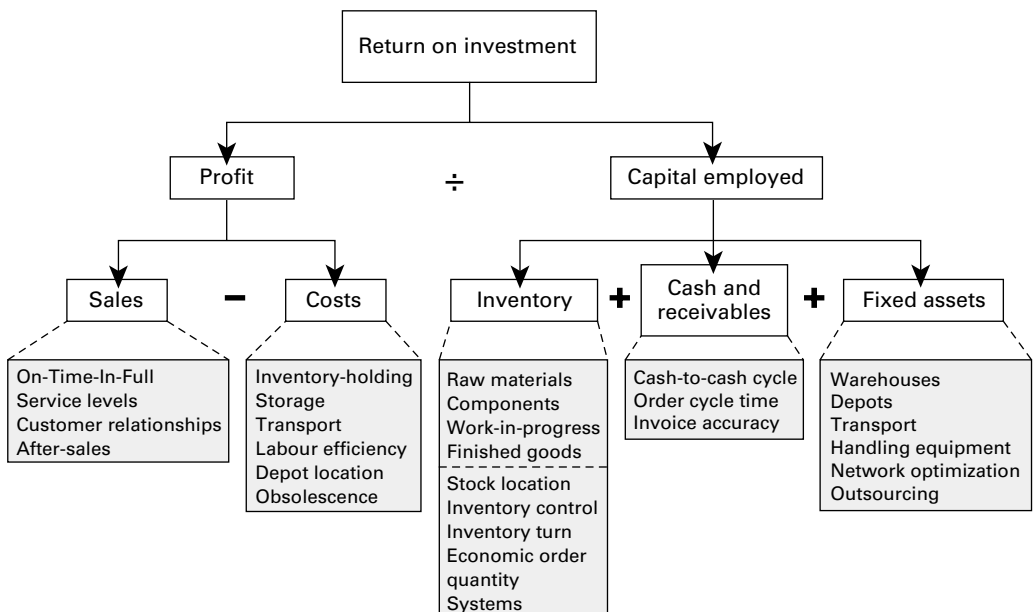
The financial impact of logistics

Logistics can have a variety of different impacts on an organization's financial performance. Logistics was traditionally seen as an operational necessity that cannot be avoided; however, a good logistics operation can also offer opportunities for improving financial performance.

For many companies, a key measure of success is the return on investment (ROI): the ratio between the net profit and the capital employed in the business. For improved business performance, this ratio needs to be shifted to increase profits and reduce capital employed. There are many different ways in which logistics can have both a positive and a negative impact on the ROI. These are outlined in Figure 2.6. This shows ROI as the key ratio of profit and capital employed, with the main elements broken down further as sales revenue *less* cost (representing profit) and inventory *plus* cash and receivables *plus* fixed assets (representing capital employed).

Profit can be enhanced through increased sales, and sales benefit from the provision of high and consistent service levels. One of the aims of many service level

Figure 2.6 The many ways in which logistics can provide an impact on an organization's return on investment



agreements is to try to achieve on-time-in-full (OTIF) deliveries – a key objective of many logistics systems. On the other hand, costs can be minimized through efficient logistics operations. There are a number of ways that this might happen, including:

- more efficient transport, thus reducing transport costs
- better storage and handling leading to reduced storage costs
- reduced inventory holding leading to less cash being tied up in inventory
- improved labour efficiency, thus reducing costs

The amount of *capital employed* can also be affected by the different logistics components. For example, there are many different types of inventory held by companies, including raw materials, components, work-in-progress and finished goods. The key logistics functions impact very significantly on the stock levels of all of these. This impact can occur with respect to stock location, inventory control, stockholding policies, order and reorder quantities and integrated systems, among others. Cash and receivables are influenced by cash-to-cash and order cycle times – both of these being key logistics processes. Finally, there are many fixed assets to be found in logistics operations: warehouses, distribution centres/depots, transport and materials handling equipment. The number, size and extent of their usage are fundamental to effective logistics planning. Also, there may be good opportunities to outsource some or all of these operations, which has a significant effect on reducing fixed assets.

Much of this book is taken up with the practical logistics issues that enable the maximization of profit, the minimization of costs and thus the improvement of ROI.

Globalization and integration

One notable element is the number of companies that operate in the global marketplace. This necessitates a broader perspective than when a national company operates internationally. In the latter, although companies may have a presence across a wide geographic area, this is supported on a local or regional basis through local or regional sourcing, manufacturing, storage and distribution. In the former, the company is truly global, with a structure and policy that represent a global business. Typical global attributes will include: global branding, global sourcing, global production, centralization of inventories and the centralization of information, but with the ability to provide for local requirements, be these electronic standards for electrical goods, language on packaging or left-/right-hand-drive alternatives in the automotive industry. All of these aspects serve to emphasize the added difficulty of operating effectively in a global environment. Global logistics and supply chain networks are far more complicated and it is necessary to plan and manage logistics as a complete and integrated system.

To service global markets, logistics networks become, necessarily, far more expansive and far more complex. Once again, the need is to plan and manage logistics as a complete and integrated system. As well as the attributes already mentioned, companies operating in a global market are often involved with the outsourcing of some manufacturing and the use of ‘focused’ factories that specialize in a limited number of products.

Linked closely to the globalization of business is the increase in the complexity of supply chain management. As already indicated, globalization almost certainly leads to greater complexity. Complexity provides some significant implications for logistics operations. These include:

- extended supply lead times
- production postponement with local added value
- complicated supply chain networks
- multiple freight transport options
- extended and unreliable transit times
- environmental and ethical issues
- the need for greater visibility in the supply chain

It is probably clear from this that there is a direct conflict between globalization and the move to the quick-response, just-in-time operations that are being sought by many companies. In global companies there is a tendency to see order lead times increase and inventory levels rise because of the distances involved and the complexity of logistics. In companies espousing the just-in-time philosophy there is a desire to reduce lead times and to eliminate unnecessary stock and waste within their operations. For those companies trying to achieve both goals, there is a clear challenge for logistics.

Integrated systems

There are a number of logistics and distribution information systems that have the concept of total logistics as their basis. Thus, quite revolutionary ‘trade-offs’ can be practised. These have come about because of the realization of the importance, cost and complexity of logistics and also due to the use of Big Data analytics, real-time information and artificial intelligence (AI). This has brought about the development of sophisticated information systems to support and enhance the planning and management of logistics operations, whereby very detailed data collection and analysis can be undertaken that was previously impossible. Some of these alternative approaches to integrated physical and information systems are further described in Chapter 40, where information systems in the supply chain are discussed. In

addition, some key aspects of integration are reviewed in Chapter 13, which considers recent developments in manufacturing techniques. Many of the origins of integrated systems have a background in manufacturing. A number of the key systems are outlined briefly:

- *Direct product profitability*: DPP is a technique of allocating all of the appropriate costs and allowances to a given product. All distribution costs (storage, transport, etc) are therefore assigned to a specific product rather than taking an average over a whole product range. DPP techniques can provide the real costs of supplying specific products to individual customers and so provide invaluable information for effective marketing and pricing strategies (see Chapter 38 and also an example with regard to road transport at the end of Chapter 30).
- *Materials requirements planning (MRP) and distribution requirements planning (DRP)*: MRP/DRP systems are computerized planning tools that aim to make the necessary materials or inventory available when needed. Also, manufacturing resource planning (MRP II) was developed with the objective of improving productivity through the detailed planning and control of production resources. Distribution requirements planning is the application of MRP II techniques to the management of inventory and material flow – effective warehousing and transportation support (see Chapter 13 for further discussion on these).
- *Just-in-time (JIT)*: the overall concept of JIT is to provide a production system that eliminates all activities that neither add value to the final product nor allow for the continuous flow of material – in simple terms, that eliminates the costly and wasteful elements within a production process. The objectives of JIT are vitally linked to distribution and logistics and have been adapted and adopted accordingly. This is explained in Chapter 13.
- *Cost-to-serve[®]*: this is a process-driven accountancy tool used to calculate customer profitability using the actual business activities and overhead costs that are involved. For distribution and logistics, it can be used to assess how costs are consumed throughout the supply chain. It takes into account that each product and each customer have a different cost profile and use different activities (see Chapter 38).
- *Distributed order management (DOM)*: DOM systems are designed to arrange orders across the multiple systems and processes utilized by those involved in replenishing an order. DOM can analyse every transaction and determine the most efficient shipping location considering multiple factors, including speed of delivery, the distance between the shipping point and the customer, as well as stock levels in stores. This clearly requires a unified view of stock across multiple channels in order to know exactly where the products are (see Chapter 40).

- *Supply chain control tower*: the essence of the control tower concept is to provide supply chain visibility across divisions, countries and modalities. The heart of the control tower is an information hub supported by a set of detailed decision-making rules. Thus, SC and logistics decisions can be made automatically (by AI) from Big Data systems to deliver customer service while minimizing inventory (see Chapter 40).

Competitive advantage through logistics

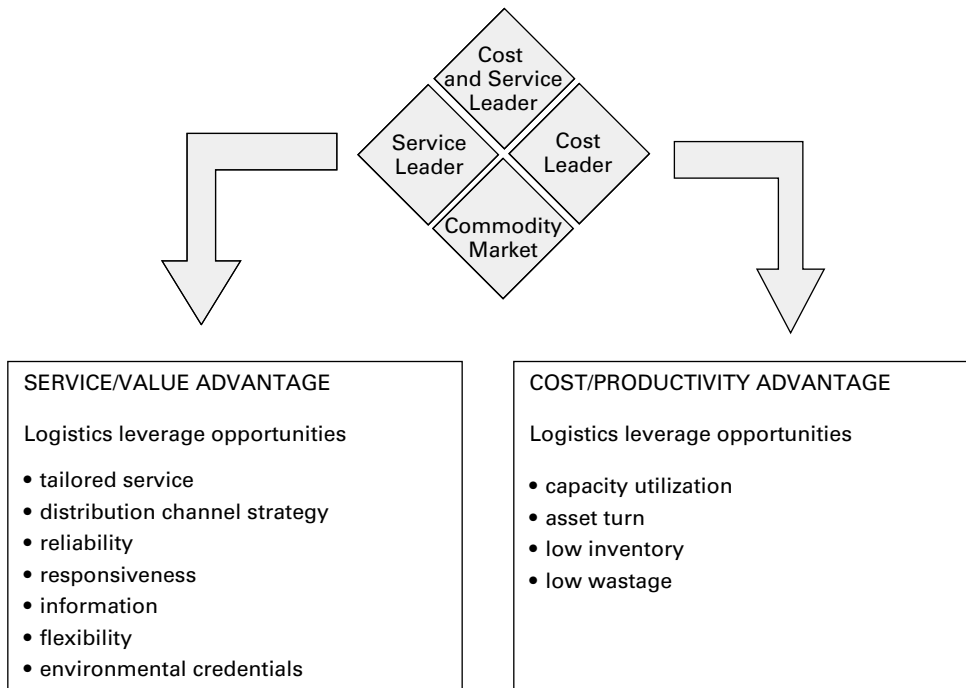
Attitudes towards distribution and logistics have changed quite dramatically over the years. It was formerly thought that the various elements within logistics merely created additional cost for those companies trying to sell products in the marketplace. Although there is, of course, a cost associated with the movement and storage of goods, it is now recognized that distribution and logistics also provide a very positive contribution to the value of a product. This is because logistics operations provide the means by which the product can reach the customer or end user, in the appropriate condition and required location.

It is therefore possible for companies to compete on the basis of providing a product either at the lowest possible cost (so that the customer will buy it because it is the least expensive) or at the highest possible value to the customer (e.g. if it is provided exactly where, when and how the customer wants it). Some companies may, perhaps unwisely, try to achieve both of these cost and value objectives and probably succeed in neither! It is particularly important to understand which competitive stance a company is trying to achieve when planning a logistics operation.

These ideas are illustrated in Figure 2.7. This shows that a company may compete as a service leader or as a cost leader. As a *service leader* a company is trying to gain a value advantage over its competitors by providing a number of key service elements to differentiate its product. As a *cost leader* a company is trying to utilize its resources so that it offers the product at the lowest possible cost, thus gaining a productivity advantage. Examples of how this might be achieved are given in Figure 2.7.

For a *service or value advantage*, this might include the provision of a specially tailored service or the use of several different channels of distribution so that the product is available in the marketplace in a number of different ways. It might include a guaranteed service level or a regular update on the status of orders.

For a *cost or productivity advantage*, this may include a number of different means of cost minimization, such as maintaining very low levels of inventory and ensuring that all manufacturing and distribution assets are kept at a high utilization.

Figure 2.7 The logistics implications of different competitive positions

It should also be emphasized that for many companies it is necessary to develop differently configured logistics structures to cater for the variety of service offerings that they need to provide to different markets. It is now appreciated that a ‘one-size-fits-all’ approach to logistics is usually too limited, because suppliers need to take account of a range of different customer requirements. They need to make sure that they clearly understand the key competitive advantage that they have to offer and they need to ensure that it is applied appropriately in all the market segments that they serve. One-size-fits-all policies rarely work when they are applied in a world where markets can differ so radically. Thus, successful companies are most likely to segment their supply chains according to the particular service and cost requirements of their customers. This important point is discussed in more detail in Chapter 8.

Logistics and supply chain management

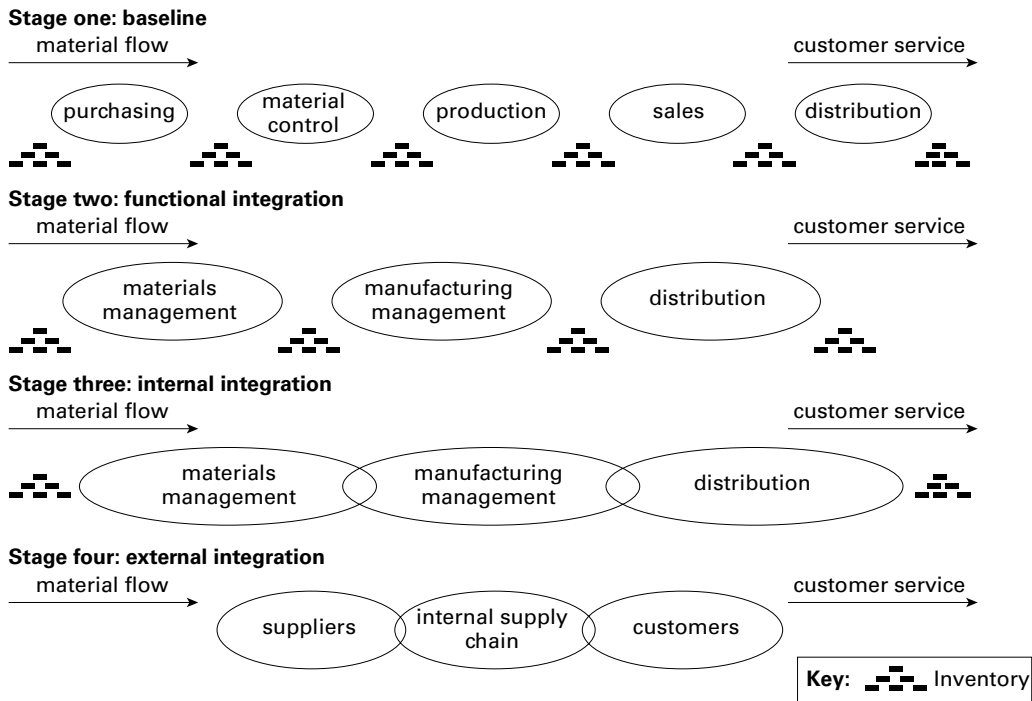
The term ‘supply chain management’ is commonly used to cover many if not all of the various logistics functions. The concept of the supply chain is really an extension of the ideas that have been developed in this and the previous chapter concerning the

integrated nature of logistics. The total logistics concept advocates the benefits of viewing the various elements of logistics as an integrated whole. Supply chain management is similar, but also includes the supplier and the end user in the process, or, as indicated in Figure 1.1, the upstream (supply side) and downstream (demand side) partners in the supply chain. This is the major difference between supply chain management and traditional logistics.

There are four distinct differences claimed for supply chain management over the more classic view of logistics, although some of these elements have also been recognized as key to the successful planning of logistics operations. These four are:

- 1** The supply chain is viewed as a single entity rather than a series of fragmented elements such as procurement, manufacturing, distribution, etc. This is also how logistics is viewed in most forward-looking companies. In an integrated supply chain, however, both the suppliers and the end users are included in the planning process, thus going outside the boundaries of a single organization in an attempt to plan for the supply chain as a whole.
- 2** Supply chain management is very much a strategic planning process, with a particular emphasis on strategic decision-making rather than on the operational systems.
- 3** Supply chain management provides for a very different approach to dealing with inventory. Traditionally, inventory was used as a safety valve between the separate components within the pipeline – thus often leading to large and expensive stocks of products. Supply chain management aims to alter this perspective so that inventory is used to optimize the level of inventory in order to balance the integrated flow of product through the pipeline.
- 4** Effective supply chain management uses integrated information systems that reflect the whole supply chain rather than merely acting in isolation for each of the separate components. These enable visibility of product demand and stock levels throughout the full length of the pipeline made possible through the use of real-time information and Big Data analytics.

Figure 2.8 illustrates the different extent of integration that might exist within a company, from a very simple baseline where there is little integration to one where integration spreads from a company's suppliers into its own operations and through to its customers. The move towards integration within different supply chains has, however, been relatively slow; indeed, some companies still have fairly limited integration within their own organizations. Full external integration thus generally remains a 'Holy Grail' that most organizations are still striving to achieve. Many companies have moved to functional integration, with some achieving an element of full internal integration. The extent of integration has a big impact on the logistics structure of a company. A company with limited integration will hold stocks in many

Figure 2.8 The different levels of supply chain integration

SOURCE Based on Stevens, 1989

parts of its operation. A highly integrated company will hold very limited stocks, with the emphasis on the steady flow of product throughout the physical system. The figure illustrates this problem that poorly integrated baseline organizations hold large, expensive, inventories at frequent intervals throughout their supply chain.

The importance of integration

The realization of the need for the effective planning and control of logistics, coupled with the recognition of the important interrelationships that exist within logistics systems, has led to the development of several new approaches towards integrated systems. Big Data applications and analytics have made the practical application of these new approaches feasible. All in all, there has been a very positive move towards an integrated approach to logistics, although for many companies, both large and small, there is still considerable scope for improvement.

More complex and sophisticated systems and concepts have been adopted by a number of large, generally multinational companies. Smaller companies have been

slower to adopt these concepts, despite the clear benefits to be gained. The main reasons for this are:

- a lack of organizational integration that reflects the role and importance of logistics
- a failure to develop adequate long-term plans for logistics strategy
- insufficiently developed information structures and support systems to provide the appropriate data systems for good logistics planning and management

For many small and medium-sized companies, there is also the very pertinent factor that they need to learn to walk the logistics path before they attempt to run on it. However, even for companies such as these, there is a great deal to be gained from taking those first few steps towards recognizing that logistics should be viewed as an integrated system and that there is a strong interrelationship between the different elements of transportation, storage, information, etc. In addition, there is the need to adopt a positive approach to the planning and control of those systems.

Fortunately, in the past few years, companies have, to a greater or lesser extent, realized the importance and relevance of logistics to their business as a whole. Thus, organizational structures and planning policies are now beginning to reflect this integrated approach.

Customer service and logistics

03

Introduction

The vast majority of companies consider customer service to be an important aspect of their business. When pressed, however, there are many companies that find it difficult to describe exactly what they mean by customer service or provide a precise definition of customer service measures. Also, traditionally, service provision has been based on very broad assumptions of what customers want, rather than taking into account the real requirements of customers or at least customers' perceptions of what they require.

For any company or organization, it is vital, therefore, to have a clear definition of customer service and to have specific and recognized customer service measures. It is also important to understand that customer service and customer service requirements can and will differ, not just between industries and companies, but additionally between the various market segments that a business might serve. Thus, it must be recognized that customer service provision can be very complex. Customer service is also inextricably linked to the process of distribution and logistics. Within this process, there are many influences that may be relevant to customer service. These range from the ease of ordering to stock availability to delivery reliability. Finally, there is the need to balance the level of service provided with the cost of that provision. The downfall of many a service offering is often the unrealistic and unrecognized high cost of providing a service that may, in the event, be greater than is required by the customer.

The key to achieving a successful customer service policy is to develop appropriate objectives through a proper framework that includes liaison with the customer, and then to measure, monitor and control the procedures that have been set up.

In this chapter, the importance of customer service is introduced, with particular reference to logistics-related customer service elements. The key components of logistics customer service are then described.

Two conceptual models of customer service are considered. The first is a fairly basic model; the second a more sophisticated one that includes an approach to identifying the different service gaps that can be associated with logistics customer

service. The need for an appropriate customer service policy is emphasized and a six-part approach for developing such a policy is outlined in some detail.

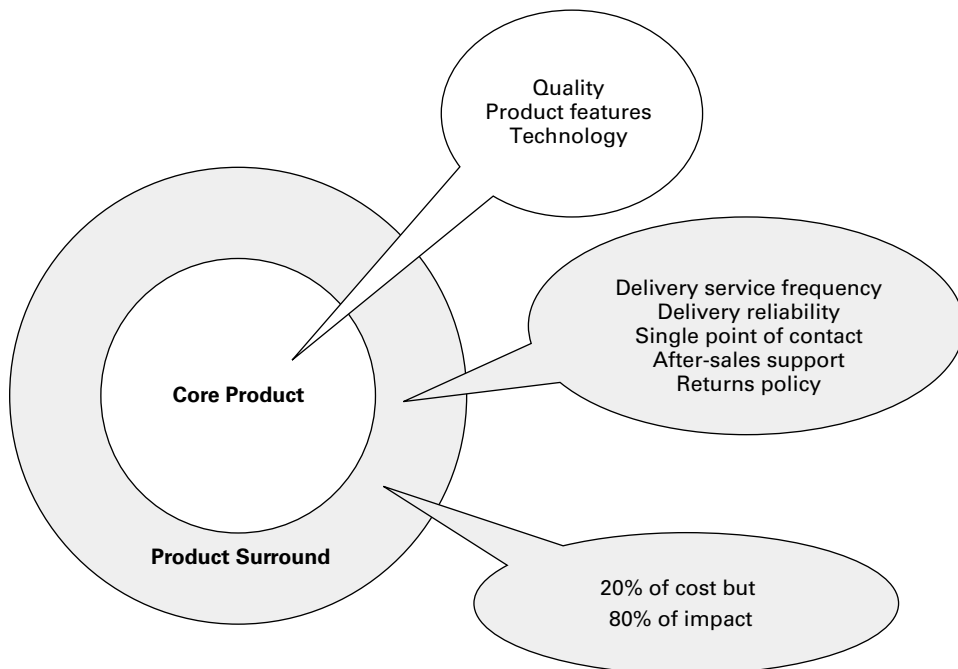
The importance of accurate customer service measurement, in a logistics context, is discussed. Different measures of order fulfilment are described, and the concept of 'the perfect order' is introduced.

The importance of customer service

As already suggested, there are few companies that do not recognize the importance of the provision of good customer service. But why is it so important? There are many different answers to this question. Examples include the growth in competition, the raising of customers' expectations and the similarity of the basic products that are offered.

One way of considering customer service is to differentiate between the core product itself and the service elements related to the product. This is depicted in Figure 3.1. The core product concerns the item itself: the technical content, the product features, the ease of use, the style and the quality. The service elements, which can be called the 'product surround', represent the availability of the product, the ease of

Figure 3.1 Core product versus product 'surround', illustrating the importance of the logistics-related elements



ordering, the speed of delivery and after-sales support. There is a long list (as we shall see later in this chapter), and clearly not all of the service items on our list are relevant to all products.

The marketing departments of many companies recognize that the product surround elements are very important in determining the final demand for a product. In addition, these aspects can sometimes represent only a small percentage of the cost of a product. Based on the Pareto 80/20 rule, the product surround or logistics elements can represent about 80 per cent of the impact of the product but only 20 per cent of the cost. This obviously varies dependent on the product value, but no matter how attractive the product may be, it is essential that the customer service elements are satisfactory and, as we shall see, logistics plays a crucial role in providing good customer service.

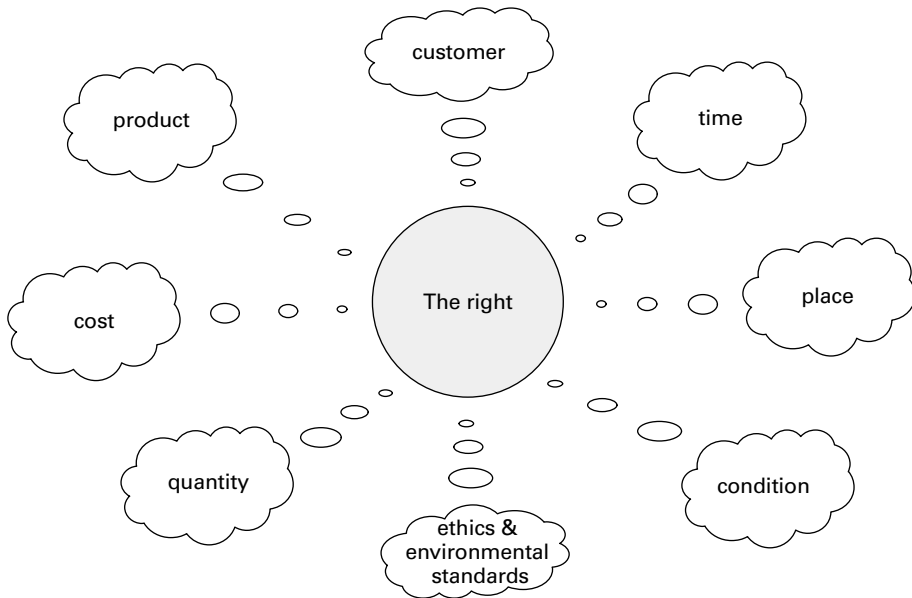
One of the definitions of logistics that was provided in Chapter 1 referred to 'the positioning of resources *in the right place, at the right time, in the right quantity, at the right quality, at the right price*'. This definition can be expanded into what might be considered as the eight 'rights' of customer service. These are the right quantity, cost, product, customer, time, place, condition and, finally, ethics and environmental standards. These summarize and categorize the key logistics-related customer service elements and are shown in Figure 3.2. All of these different aspects can be key requisites of a good customer service offering – indeed, many of them will be essential to ensure that a product achieves its expected sales in the various markets where it is made available. It is notable that all of these elements are affected by the standard and quality of the logistics operations that are essential to getting a product to market. Thus, these elements can provide the basis for identifying the different aspects of logistics that should form a part of any customer service offering, and also, and this is of equal importance, these elements should become the basis of the key measurements that are used to monitor operational success or failure. This will be considered in the final sections of this chapter.

The components of logistics-related customer service

The logistics components of customer service can be classified in several different ways but the two key approaches are, firstly, as transaction-related components and, secondly, as multifunctional dimensions.

Transaction-related components can be divided into *direct* transaction-related elements, where the emphasis is on the specific physical service provided, such as on-time delivery, or they may be seen as *indirect* support (e.g. non-transactional, or

Figure 3.2 The eight 'rights' of customer service, showing the main service classifications



pre- and post-transactional) attributes that are related to overall aspects of order fulfilment, such as the ease of order taking.

This classification is useful to help identify the key logistics customer service elements, which can be divided into three chronological categories. These reflect the nature and timing of the particular service requirements (before, during and after delivery of the product):

- 1** *Pre-transaction* elements are logistics customer service factors that arise prior to the actual transaction taking place. They include written customer service policy, accessibility of order personnel, single order contact point, organizational structure, method of ordering, order size constraints and system flexibility.
- 2** *Transaction* elements are the elements directly related to the physical transaction itself and are those that are most commonly associated with distribution and logistics. Under this heading would be included order cycle time, order preparation, inventory availability, delivery alternatives, delivery time, delivery reliability, delivery of complete order, condition of goods and order status information.
- 3** *Post-transaction* elements involve those elements that occur after the delivery has taken place, such as availability of spares, call-out time, invoicing procedures, invoicing accuracy, product tracing/warranty, returns policy, customer complaints and procedures and claims procedures.

Logistics customer service elements can also be classified by their *multifunctional dimensions*. The intention is to assess the different components of customer service across the whole range of company functions, to try to enable a seamless service provision. Time, for example, constitutes a single requirement that covers the entire span from order placement to the actual delivery of the order – the order cycle time. One of the main advantages of this approach is that it enables some very relevant overall logistics measures to be derived. These will be considered later in this chapter. The four main multifunctional dimensions are:

- 1 *time*: usually order fulfilment cycle time
- 2 *dependability*: such as guaranteed fixed delivery times of accurate, undamaged orders
- 3 *communications*: such as the ease of order taking or effective queries response
- 4 *flexibility*: the ability to recognize and respond to a customer's changing needs

Each of these can be broken down into further detailed elements. One example of this is shown in Figure 3.3, which describes the different time-related components.

The total order fulfilment cycle time has been split into the five main time-related components from order receipt to final delivery. In addition, there is a preliminary step from order placement to order receipt, although this is not considered by some companies because it is deemed to be part of their customers' ordering process rather than their own. When identifying and measuring order fulfilment cycle time it is important to be able to break it down to all of the key components. Thus, if there is a customer service problem it can be measured and traced quickly and easily and the actual detailed problem can be identified and remedied.

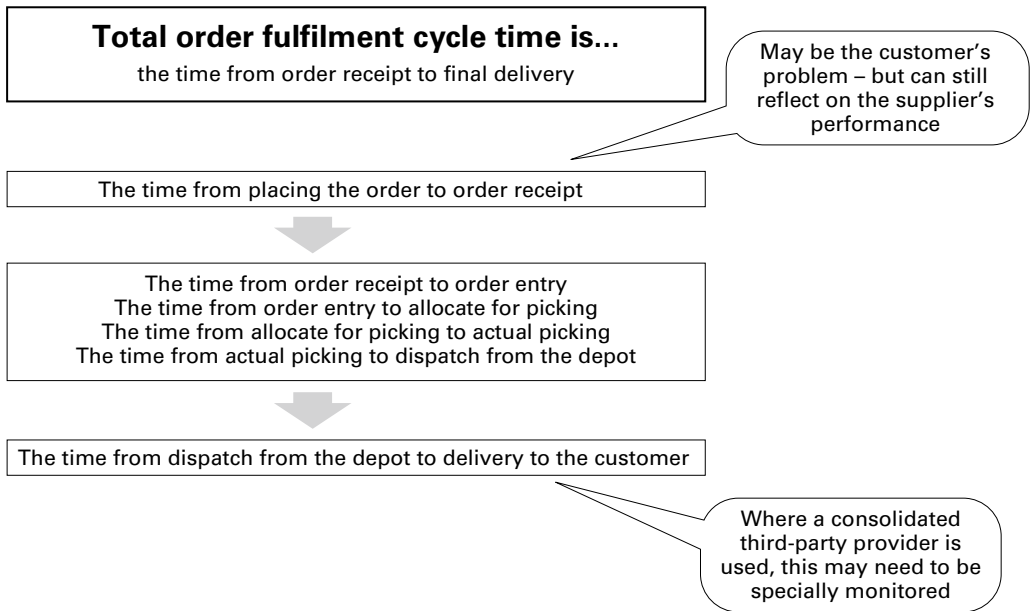
As indicated already in this chapter, there are many different elements of customer service, and their relevance and relative importance will vary according to the product, company and market concerned.

Two conceptual models of service quality

Service quality is a measure of the extent to which the customer is experiencing the level of service that they are expecting. Two different models of service quality are considered: a very basic model and a more complicated, extended model.

Basic service model

A very simple, yet effective, view of service quality is that it is the match between what the customer expects and what the customer experiences. Any mismatch from this can be called the 'service quality gap'. Note that the customer viewpoint is what

Figure 3.3 The constituent parts of total order fulfilment cycle time

the customer perceives or believes to be happening, not necessarily what is actually happening in terms of what the supplier is providing (or thinks they are providing). Perceived quality is always a judgement that the customer makes – whatever the customer thinks is reality, no matter what the supplier may believe to the contrary! This is another reason why careful measurement of customer service is necessary: to be able to demonstrate that certain agreed standards are being achieved.

Thus, service quality is what the customer thinks that it is:

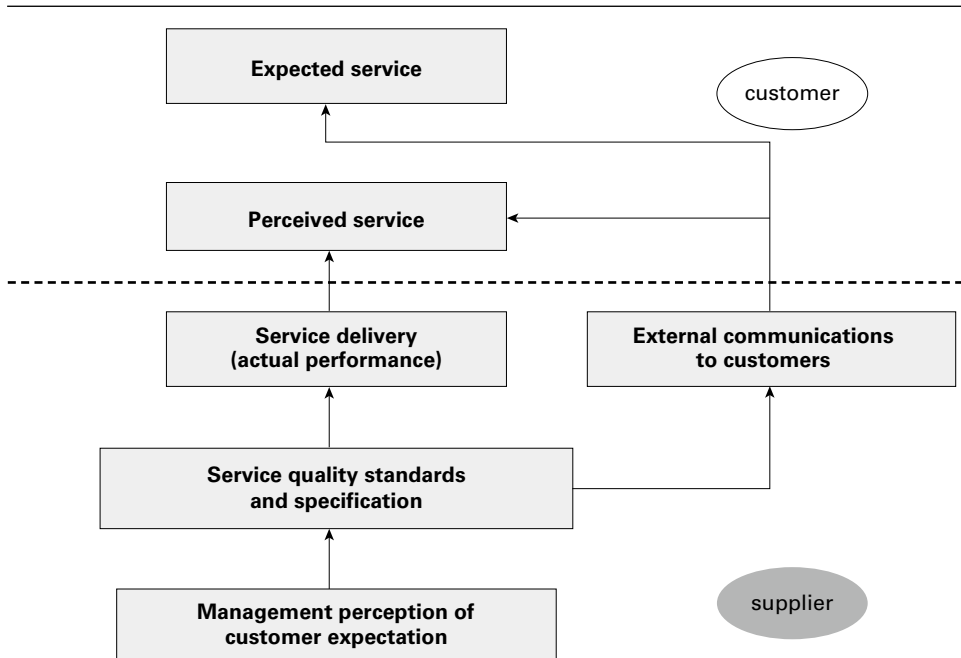
$$\text{Service quality} = \frac{\text{perceived performance}}{\text{desired expectations}} \times 100$$

Extended service model

A rather more complicated approach can also be used as a conceptual model of service quality. This is particularly useful in helping to identify and measure the critical elements of service for key customers. The main factors are outlined in Figures 3.4 and 3.5. The aim of this approach is to identify the various different service gaps that can or might appear throughout the customer service process. Measures are then set up to assess the relative importance of each of these gaps and to monitor them on a regular basis.

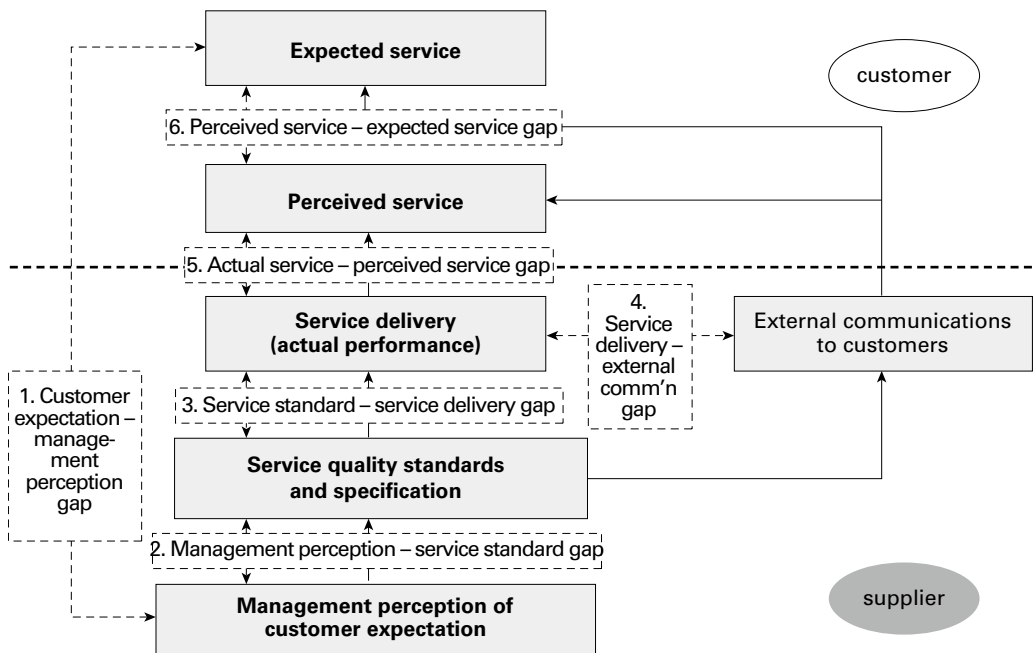
The boxes in Figure 3.4 represent the key factors in the process of providing a service to customers. The starting point is the supplier's perception of what they think is the customer's service expectation. From this, the supplier should develop appropriate service quality standards and specifications. These should then be communicated to and agreed with the customer. Subsequently, the service is provided by the supplier via the logistics operation. The customer will then have a certain expectation of the service level to be provided and can compare this to the service that he or she perceives is being received.

Figure 3.4 A conceptual model of service quality: the basic elements



(Based on work by Parasuraman and Zeithaml)

In Figure 3.5, this concept is developed to illustrate the potential areas for service failure. Working backwards, the main issue is likely to be the one between the service that the customer expects and the service that the customer perceives to be provided (Gap 6). This is the perceived service–expected service gap, and for both the customer and the supplier it is the major aspect of service quality that needs to be measured. How is this undertaken? As described later in this chapter, there are a number of different types of customer service studies that can be carried out to achieve this. However, it is also important to be able to identify why any such service failure has occurred, and the different reasons can be identified by measuring the other service gaps that appear in Figure 3.5. These are as follows:

Figure 3.5 A conceptual model of service quality: the service gaps

SOURCE Based on work by Parasuraman and Zeithaml

- **Gap 5: actual service–perceived service gap:** this is the difference between the service that the supplier is providing and the service that the customer thinks is being received. This gap may, typically, be caused because the supplier and the customer are measuring service in a different way.
- **Gap 4: service delivery–external communication gap:** this is the difference between the actual service that is provided and the promised level of service that was communicated to the customer. This gap may be caused by a misunderstanding in communication.
- **Gap 3: service standard–service delivery gap:** this is the difference between the actual service that is provided and the planned level of service based on the service specification that has been set. The cause for this gap may be inefficiency within the delivery service.
- **Gap 2: management perception–service standard gap:** this is the difference between the service specification that is set and the supplier management assessment of customer service requirements. This gap is likely to be caused by an inadequate initial operational set-up.

- Gap 1: customer expectation–management perception gap: this is the difference between the service that the customer expects and the service level that the supplier thinks that the company wants. This gap is usually caused because the supplier does not understand the real customer requirements.

Conceptual models of this nature are valuable to help the understanding of the underlying issues that are involved. They need to be interpreted into a practical format to enable actual service policies to be derived. The remaining sections of this chapter address this requirement.

Developing a customer service policy

Every company that provides products and services to its customers should have an appropriate customer service policy. Such a customer service policy needs to be developed based on identifiable customer service requirements, and a suitable logistics operation must be established to provide this service. The next few sections of this chapter describe how this can be done.

A customer service policy must be very clearly and carefully defined because there are many different elements of customer service and because there are many different types of customer, even for the same product. A can of fizzy drink, for example, may be bought in a supermarket, a bar/pub, a corner shop, a petrol station or from a self-service dispensing unit. It is unlikely that a manufacturer of fizzy drinks would wish to provide exactly the same level and style of service to all of these very different customer types. This is why many companies segment their customers into different customer categories. It is also an additional reason for having a distinct customer service policy so that it is clear to both the supplier and the customer exactly what level of service will be provided.

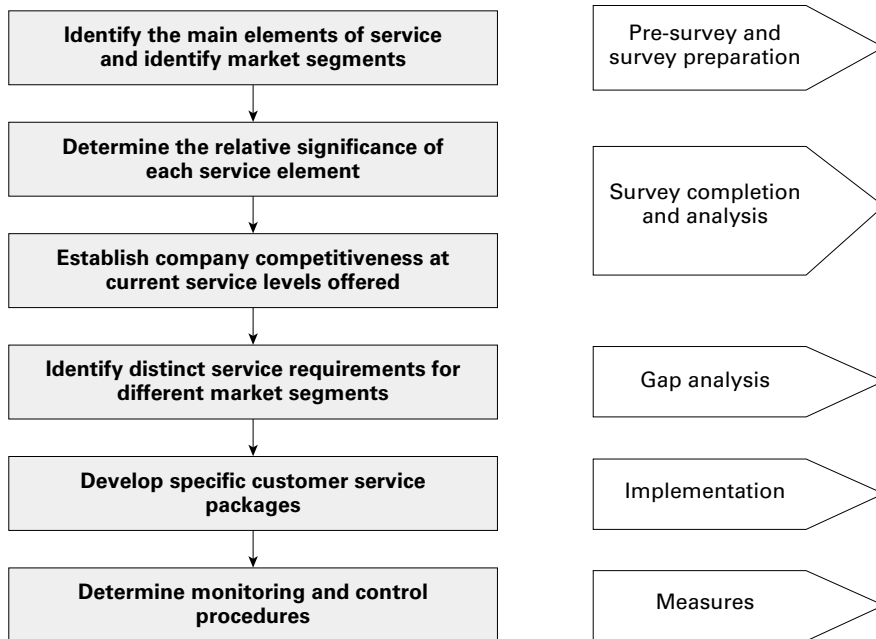
Many studies have been undertaken to measure the effects of poor customer service. These studies conclude, quite categorically, that where stock is not available or where delivery is unreliable many buyers will readily turn to an alternative supplier's products to fulfil their requirements.

It is also important to understand what minimum requirements are necessary when identifying any particular service policy. A supplier is really working towards meeting customers' minimum requirements to cross the threshold of customer satisfaction. If these minimum requirements are not met, the supplier cannot even expect to be considered as a feasible supplier. Once these requirements are met and the supplier begins to exceed them, it then becomes possible to achieve customer satisfaction and begin to add value to the supply relationship.

Once the positive need for a customer service policy has been accepted, it is useful to adopt a recognized approach to determine the basic requirements and format of this policy. One such approach is outlined in Figure 3.6 and described in the

remainder of this section. As well as showing the major steps that should be taken, the figure also indicates how these steps can be carried out. This is a six-step plan to identify key customer service components and then to design and maintain a suitable customer service package.

Figure 3.6 An overall approach for establishing a customer service strategy



The main steps are:

- 1 Identify the main elements of service and identify suitable market segments.** The first step is to identify those elements of service that are most highly rated by customers. Only then can the company's resources be concentrated on these key factors. The main means of determining these key elements are by market research techniques. A typical approach might be:
 - a** the identification of the main decision-maker or buyer of the product
 - b** the use of personal interviews to determine the importance of customer service and the different elements within customer service
 - c** the use of group interviews to determine the same

The importance of this stage is to identify relevant measures of service that are generated by customers themselves and not imposed arbitrarily by 'best guesses' from outside. A major output from this stage of the study is to enable an appropriate survey questionnaire to be designed.

In addition, it is important at this stage to identify the different market segments or customer types that exist. It is highly unlikely that a universal level of customer service will be appropriate for all customers. Most customer populations consist of a range of customers of different size and importance. Part of this preliminary stage is, therefore, to try to identify broad customer categories and to ensure that any questionnaire is designed to enable the different requirements of these different categories to be identified.

It should be noted that there is a variety of types of customer service study that can be used. These are summarized in Table 3.1. For some companies it is relevant to use several of these for different purposes.

Table 3.1 Different types of customer service study

Approach	Comment
Complaint analysis	Qualitative. Statistically limited. Limited to those who do complain.
Critical incident studies	Qualitative. Relevant to individual customers only. Limited scope.
Customer panels	Limited coverage. Qualitative information. Would not show priorities.
Key client survey	Useful Pareto approach. Not valid across whole client base. Qualitative and quantitative.
Customer survey/questionnaire	Good overall coverage (statistical sampling). Qualitative and quantitative.

The most common approach for the major element of a study is likely to be a detailed questionnaire-based customer survey. This can be undertaken in a number of different ways including telephone, email, mail/post, face-to-face, web-based or mobile phone. The key advantages and disadvantages of these different approaches are described in Table 3.2. In addition, information may be gained, with care, through the evaluation of customer reviews on company websites or independent review sites.

Survey or questionnaire design is a vital part of the overall process, and when putting together a questionnaire it is sensible to refer to one of the many books that have been written that address the topic specifically. The major steps can be summarized as follows:

- clarify the purpose and objectives
- identify any specific information required
- select the most appropriate survey type

- determine the resources required to undertake the survey
- determine who should undertake the survey
- determine who should complete the survey
- identify key customer/market segments
- identify key service elements to include
- prepare the question and answer format
- design the analysis and reporting format
- determine the sample size and selection
- pilot the survey
- adjust and finalize

Table 3.2 The advantages and disadvantages of different survey approaches

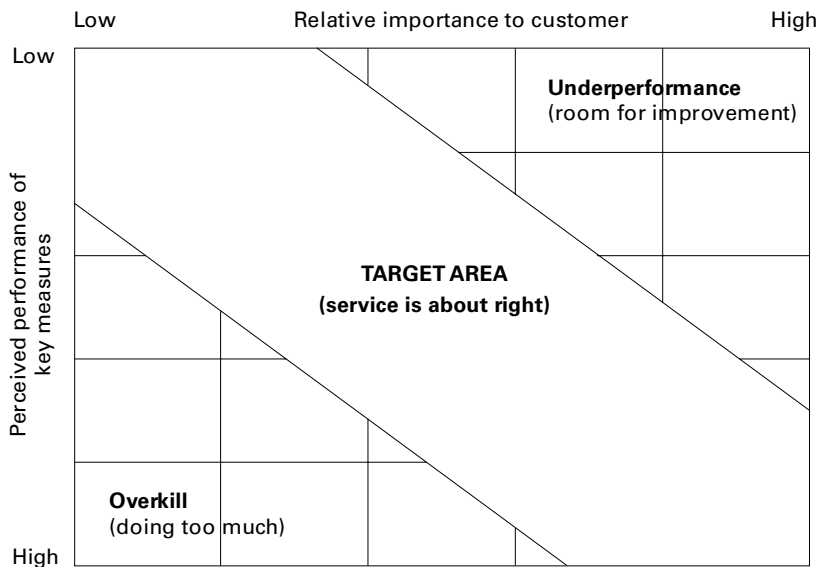
Type	Advantages	Disadvantages
Fixed phone	Can probe interviewee. Control over response rates. Can control questions answered. Can ensure appropriate respondent. Can be quick.	Expense. Possible interviewer bias. Time restrictive. Not anonymous
Email	Inexpensive. Fast response.	Limited interaction. Limited response. Not anonymous.
Faxed	Inexpensive. Quite fast response. Flexible time for respondent to complete.	Can't probe/clarify answers. Low response rates. Non-response to some questions
Web	Inexpensive. Quick response. Flexible time for respondent to complete.	No control over respondents. Limited to internet/computer users
Mail	Inexpensive. Flexible time for respondent to complete. Anonymous. No interviewer bias.	Time consuming. Limited response. Non-response to some questions. Can't probe/clarify answers.
Face-to-face	Can probe. Can ensure appropriate respondent. Can control questions. Allows greater complexity. All questions answered.	Expensive. Limited sample. Very time consuming. Possible interviewer bias. Not anonymous
Mobile phone	Easy to administer. Versatile response (pictures, diaries by respondent). Real-time response (immediate, on-the-go).	Smartphone variety. Different operating systems. Network speeds and availability. Difficult implementation. Low response rates.

- 2 Determine the relative significance of each service element.** Recognized research techniques can be used within the questionnaire to enable the measurement of the relative importance of the different service components that are identified. For a fairly small list of components a simple rating table can be developed. This uses some form of order ranking ('most' to 'least' important) or rating scale (1 to 6 according to importance). An alternative technique is the development and use of a repertory grid. This method provides a much more sophisticated format for considering and measuring the relative importance of different combinations of service components, rather than just scoring them on an individual basis. A particular strength of this approach is that it enables the inclusion of interviewee perceptions without researcher interference or bias. A simple example of a basic rating table is shown in Figure 3.7. It is also possible at this stage of the customer service review to identify what the minimum requirements are for customer service – that threshold below which it is unlikely that a customer will consider a company as a feasible supplier.

Figure 3.7 Rating table for selected customer service factors

How would you rate these different elements of customer service?						
(Score from 1 to 6: 1 = Not at all important, 6 = Extremely important)						
			Please Highlight			
Frequency of delivery	1	2	3	4	5	6
Reliability of delivery	1	2	3	4	5	6
Stock availability and continuity of supply	1	2	3	4	5	6
Orders filled completely	1	2	3	4	5	6
Accuracy of invoices	1	2	3	4	5	6
Customer query handling	1	2	3	4	5	6

- 3 Establish company competitiveness at current service levels offered.** Having identified the key service components and their relative importance to the customer, the next step is to measure how well the supplier company is performing for each of these key components. This can also be achieved using the questionnaire. The list of key components can be rated by the respondent on perceived performance. This will provide an indication of where the company is underperforming and overperforming and where it has got it about right. Figure 3.8 shows that there is a target area for service in which the company should be operating. It also highlights those areas where there is room for improvement and those areas where too much effort is being spent. It is important to be performing well in key areas, but there is also little benefit in performing extremely well in those areas that are of little consequence to the customer.

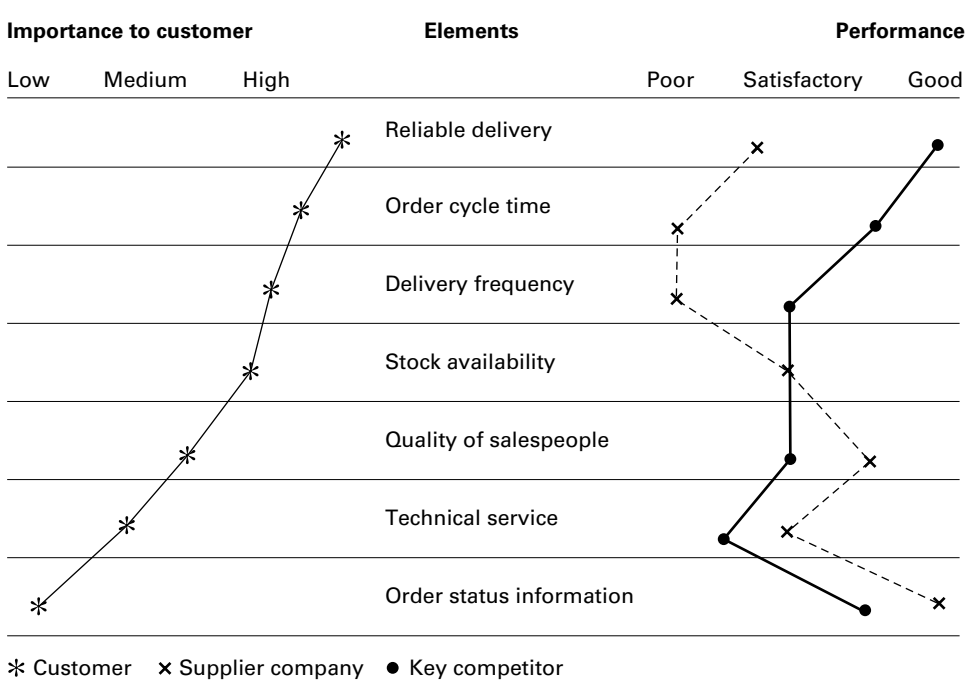
Figure 3.8 Company competitiveness at current service levels: target chart

It is also important to be aware of the supplier company's own position compared to that of its major competitors. Customer respondents can be asked to rate each competing supplier company in a similar way as part of the questionnaire. The results will indicate how each competitor performs with respect to the different service components. The supplier company's performance can then be compared to the competition's performance, especially in the key service elements that were identified in the previous stage of the study. This will provide some very useful information on how well the company is performing compared to its competitors, but more importantly this can be related directly to the customers' key customer service requirements. Figure 3.9 gives an example of this.

Here it can be seen that the supplier company is performing reasonably well overall compared to its key competitor (the right-hand side of the figure), but that the competitor is actually performing much better than the supplier company in those elements that are most important to the customer (the left-hand side of the figure). The usefulness of such an approach is clearly demonstrated by this simple example. This is often known as competitive benchmarking. Results from this type of survey can be used to develop a detailed customer service strategy.

- 4 Identify distinct service requirements for different market segments.** As already indicated, the needs of different customer types can vary quite substantially. This may be true in terms of product quality, method of ordering, level of service or any other of the many different service elements that can be identified. Within a total market, it is possible to identify distinct sub-markets or segments.

Figure 3.9 Competitive benchmarking showing opportunities for improving service when comparisons are made with customer requirements and the performance of key competitors



A typical example is the supply of stationery items. These might be supplied to retailers for sale to the public, to wholesalers for further distribution or direct to public-service bodies or private companies for their own consumption. Each segment of the overall market may require a distinctly different level of service, or may react differently to certain deficiencies of service. The fizzy drink example discussed earlier in this chapter provides another illustration of markets requiring different types of service requirement. Once distinct market segments have been identified, a number of specific customer service policies can be developed, each of which should suit the relevant groups or segments.

Determining the detailed service requirements can be undertaken by what is known as 'gap analysis'. This is the practical means of enabling actual service policies to be derived based on the approach discussed in the conceptual models described earlier and in Figure 3.5. This is achieved by using the survey results to identify the major performance gaps (such as 'reliable delivery' in our example in Figure 3.9) for each market segment or customer group that is being considered. The key customer service elements should be ranked in order of importance to the customer (to identify the essential ones) and degree of change required (to identify the easy ones or 'quick wins'). Brainstorming and/or some form of process analysis can then be used to identify appropriate remedies or solutions for improving these

key elements of service. These are then assessed and ranked according to factors such as cost of change, ease of change, etc. An example of such an assessment for one of these solution areas is shown in Table 3.3.

Table 3.3 Assessment of possible solutions to performance gaps

Possible solutions	Order picking accuracy			
	Importance	Timescale	Cost	Difficulty
Re-train operatives regarding the importance of picking accuracy	medium	short	low	low
Install voice picking and barcode system to verify pick locations and items picked	high	medium	medium	medium
Install pick-by-light system	high	medium	medium	medium
Use collaborative robots ('cobots') to guide pickers through process	high	long	high	high

NOTE See Chapter 21 for details of the possible solutions

- 5 Develop specific customer service packages.** This is the implementation phase and it will depend on the results obtained from the stages that have been described. Alternative packages for the different market segments need to be costed accordingly and the most suitable packages determined.
- 6 Determine monitoring and control procedures.** It is vital to ensure that any service policy that is implemented is also monitored. This requires an effective focus on the measurement of the service provided, involving a systematic and continuous concentration on monitoring and control. In practice, and perhaps surprisingly, adequate customer service monitoring is quite rare. This is often because companies do not have a recognized customer service policy to measure against, but it may also be because companies find it difficult to construct quantifiable standards that are capable of measurement.

The first task, then, is to identify the factors that need to be measured. These should be based on the major elements identified in the customer service packages that are developed. The second task is to produce a measure or series of measures. This can be undertaken in different ways for different elements, but must be fair and appropriate for the task in hand. The development of such measures, together with relevant examples, is described later in this chapter.

One final point concerns the need to ensure that any service measures are periodically reviewed. Businesses change fairly rapidly, with new products and new customers appearing continually. A regular updating of service measures is

relevant, so that old measures are discarded as they become redundant, and new measures are created as they become necessary. Some large companies carry out regular customer service studies designed to identify such changes in service requirements.

Levels of customer service

It has already been stressed that there is a need to balance the level of customer service with the cost of providing that service. This balance is not easy to define, although it can be described quite easily as the point where the additional revenue for each increment of service is equal to the extra cost of providing that increment.

It is seldom possible to devise a policy that is absolutely optimal in terms of the cost/service balance. Companies usually adopt one of two main approaches: 1) a cost minimization approach where specific service objectives are laid down and met at a minimum cost; 2) a service maximization approach where a distribution budget is fixed, and the 'best' service supplied within this cost constraint. The most appropriate approach to adopt will depend on particular product, business or market situations.

One factor that is clear, however, is the relationship between cost and service. This is shown in Figure 3.10. The cost of providing a given service is markedly higher the nearer it reaches the 'perfect service' – that is, the 100 per cent mark. Thus, an increase of 2 per cent in service levels will cost far more between 95 and 97 per cent than between 70 and 72 per cent. It should also be noted that a service increase from, say, 95 to 97 per cent may well have little, if any, noticeable impact on the customer's perception of the service being provided, even though it is a costly improvement.

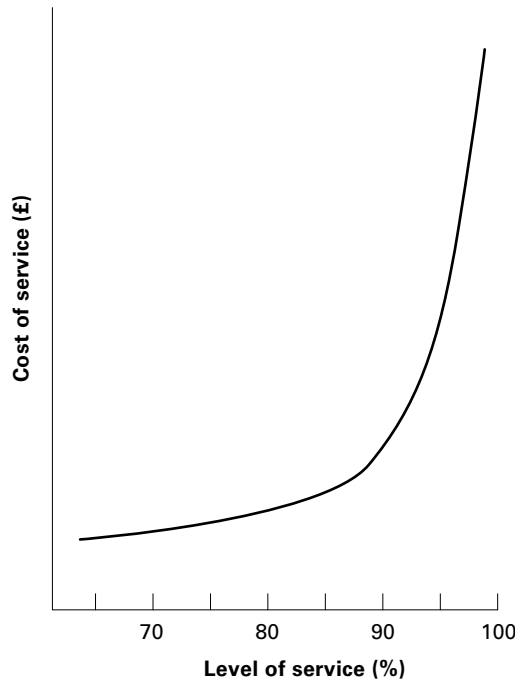
Measuring customer service

It is probably quite clear from reading this chapter that there are a number of different measures of customer service that might be used. The most important message is that, whatever measures are used, they must reflect the key service requirements for the customer in question. This is not always as obvious as it might seem.

Order fulfilment

One particular example is that of order fulfilment. It is possible to measure this in a number of different ways:

Figure 3.10 The relationship between the level of service and the cost of providing that service



- the number of orders completely satisfied, say 18 out of 20, over a period (90 per cent)
- the number of lines delivered from a single order, say 75 out of the 80 lines requested (94 per cent)
- the number of line items or cases delivered from a single order, perhaps 75 out of the 80 lines requested, but only 1,400 of the 1,800 total line items (78 per cent)
- the value of the order completed, say €750 of a €900 order (83 per cent)

Any or all of these might be used, and there is no right or wrong one. The most appropriate is the one that best suits the operation in question. As will be shown later, it may also be relevant to use a combination of these measures.

Order cycle time

There are other measures that can be made. These measures might, for example, be aimed at assessing the timeliness of delivery operations. Many express parcels companies set great store by the speed of their delivery operations, and calculate in detail

the time taken from receipt of order or parcel collection to final delivery. This idea is also used for conventional operations. Thus, order fulfilment can also be measured with respect to the order cycle time or the actual lead time from the receipt of the order to its final delivery to the customer. For a typical stock order this will be made up of the following discrete times:

- order receipt to order entry
- order entry to allocation for picking
- allocation to dispatch
- dispatch to delivery

The perfect order

Some companies now recognize what is called ‘the perfect order’. This is a measure that attempts to take into account all of the main attributes that go towards the completion of an order that absolutely satisfies customer requirements. The key components of the perfect order are generally:

- delivered complete to the quantities ordered
- delivered exactly to the customer’s requested date and time
- no delivery problems (damage, shortage, refusal)
- accurate and complete delivery documentation

There are also several variations of ‘the perfect order’. These may include elements such as accurate invoicing or whatever else is important to the customer. A simpler version that is often used is known as on-time-in-full (OTIF), which measures orders that are delivered both ‘on time’ and ‘in full’. Whatever is included, perfect order fulfilment can be measured as:

$$\text{perfect order fulfilment} = \frac{\text{number of perfect orders}}{\text{total number of orders}} \times 100\%$$

Organizations must therefore set clear, customer-service-driven measures of performance that reflect the real standards they are aiming to achieve. These, typically, ask severe questions of many logistics operations. For realistic measurement, any discrepancies should be assessed cumulatively. Thus, if they include:

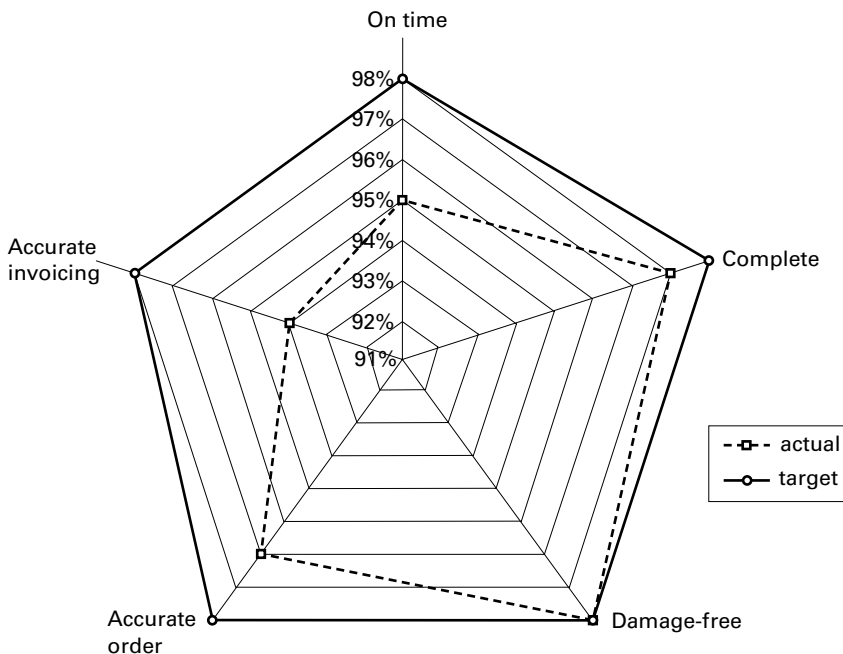
orders received on time	actual 95%	target 98%
orders received complete	actual 98%	target 99%
orders received damage-free	actual 99%	target 99%
orders filled accurately	actual 97%	target 99%
orders invoiced accurately	actual 94%	target 98%

then the actual customer service measure achieved is $(95 \times 98 \times 99 \times 97 \times 94) = 84$ per cent. This is not as good as it first looks when considering each measure individually.

Methods of presenting data

Clear and simple visual methods of presenting data are also important. Figure 3.11 shows a radar gram of these data such that the actual and target figures can be compared at a glance. Chapter 38 provides some additional comment on the development and presentation of key performance indicators.

Figure 3.11 Radar gram showing the perfect order targets and achievements



Service level agreements

Many customer/client relationships are defined by the use of a service level agreement (SLA). A service level agreement is a contract drawn up between a supplier or service provider and the end user or customer that defines the level of service agreed and expected. These are usually external – between one company and another – but may be internal in some large organizations where an internal service is being provided to another department. SLA requirements are generally output-based in that their purpose is specifically to define what the customer will receive. Some SLA

requirements may, however, be input-based, particularly internal ones, to ensure that both parties are providing appropriate resources to enable the supply or service to be provided effectively. Such resources might include, for example, timely information, physical availability of resources, etc.

Service level agreements are legal documents, usually separate from, but complementary to, a signed contract document, which governs the delivery of services between a provider and the client. An SLA is likely to include:

- a description of the products and services being provided
- the terms and conditions under which the products and services will be delivered
- a description of how the performance of the service will be measured – the monitoring and reporting service levels, including metrics and standards
- the procedure for reporting problems, including dispute resolution, remedies for breach of contract, penalties for sub-standard, late or non-delivery, etc
- the consequences if service obligations are not fulfilled – escape clauses or constraints; contract change and termination

SLAs detail the acceptable level of service achievable within the economic and logistical constraints of the provider/customer relationship. To be effective, the levels of expected performance have to be set realistically. If they are too low, this can result in poor service further up the supply chain. If they are too high, this can result in frustration and cost for the supplier. Both extremes are likely to lead to an adversarial relationship between supplier and customer. The level of service needs to be specific and measurable. This allows service performance to be benchmarked, and where necessary this can be rewarded or penalized accordingly.

The SLA is likely to include elements that can be categorized in two specific areas – services and management:

- Service elements include the specifics of the products and services provided (and what is excluded, if there is room for doubt), conditions of service availability, standards such as delivery time windows for each level of service, the agreed responsibilities of each party and escalation procedures.
- Management elements should include definitions of metrics, measurement standards and methods, a process for reporting and addressing service issues, a dispute resolution process for service-related disagreements and a set mechanism for reviewing and revising the agreement. This last item is important because service requirements and supplier capabilities can change over time. It is necessary to ensure that the SLA is updated at regular intervals to reflect the dynamic environment in which logistics operates.

The importance of customer service

The role of customer service as a critical success factor for most companies is very significant. Satisfying the customer is the key to achieving competitive success. Companies that fail to appreciate this do so at their peril because they may lose significant market share. Service is the key factor of differentiation in a customer's decision to buy one brand rather than another. In other words, good customer service can provide the distinctive difference between one company's offer and its competitors'. Thus, customer service strategy must play a major role in the determination of company strategy.

One key lesson that also comes through is the important role that logistics plays in providing good customer service. The ability to improve service levels and to maintain this improvement is a challenge that faces many companies. The major factors are:

- the growth in customer expectations – thus service fulfilment is a priority for any successful strategy
- the professionalism of buyers – buyers generally recognize the importance of service as well as price in the product offering
- markets are increasingly service-sensitive – there is often little else to differentiate between products
- the diminution of brand loyalty, particularly with respect to fast-moving consumer goods (FMCG), where immediate product availability is the vital factor
- the use of approaches, such as relationship marketing, where fulfilling service expectations is the key and customer retention is a priority
- the use of Big Data analytics that offers more accurate, more timely, more reliable and thus more effective measures of service to be used

Channels of distribution

04

Introduction

The alternative ways in which products can reach their market are discussed in this chapter. Different types of distribution channel are outlined, and an approach to channel selection is described. Finally, the key decision of whether to run an own-account distribution operation or whether to outsource to a third party is introduced.

Physical distribution channel types and structures

Terminology

‘Physical distribution channel’ is the term used to describe the method and means by which a product or a group of products are physically transferred, or distributed, from their point of production to the point at which they are made available to the final customer.

For consumer products the end point has been, historically, a retail outlet but, increasingly, it may also be the customer’s home, because some channels bypass the shop and go direct to the consumer. Indeed, for some products, such as music and films, the physical product can be transferred via the internet. This is broadly known as business-to-consumer (B2C).

For industrial products the physical channel is generally from a manufacturer/supplier to an end point, which is likely to be a factory. This is known as business-to-business (B2B).

In addition to the physical distribution channel, another type of channel exists. This is known as the ‘trading’ or ‘transaction channel’. The trading channel is also concerned with the product, and with the fact that it is being transferred from the point of production to the point of consumption. The trading channel, however, is concerned with the non-physical aspects of this transfer. These aspects concern the

sequence of negotiation, the buying and selling of the product, and the ownership of the goods as they are transferred through the various distribution systems.

One of the more fundamental issues of distribution planning involves the *choice and selection* of channels. The question that arises, for both physical and trading channels, is whether the producer should transfer the product directly to the consumer, or whether intermediaries should be used. These intermediaries are, at the final stage, very likely to be retailers, but for many of the other links in the supply chain it is now very usual to outsource to a third-party operator to undertake the operation.

Direct and indirect distribution channels

Physical distribution channels have, classically, been described as either direct or indirect channels of distribution. With the growth of internet shopping and home delivery, a number of additional channels have been developed so there is a less clear distinction between the two traditional alternatives of either direct or indirect.

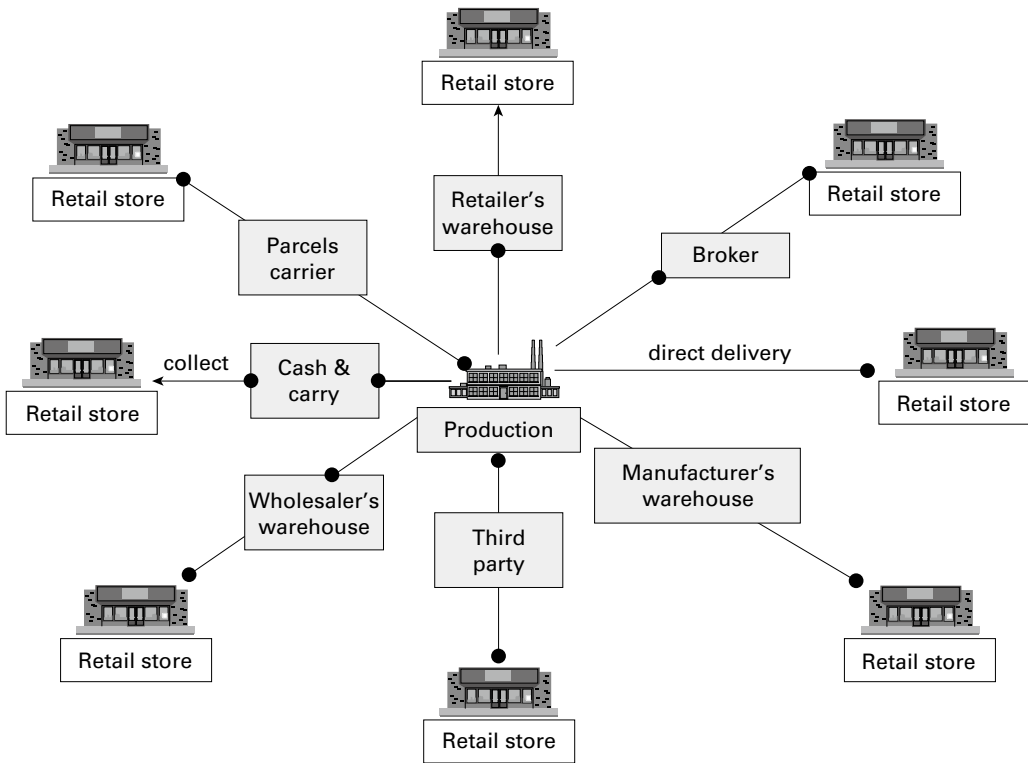
Generally, a distribution channel typically consists of a series of intermediaries through which goods proceed until they reach the final buyer or end consumer. These channels can include a variety of intermediaries, the most common of which are retailers, wholesalers and distributors. These types of channel have generally been known as indirect channels of distribution. A distribution channel where the consumer can obtain the goods straight from the manufacturer has been known as a direct distribution channel.

In order to take account of the more recent development of new (and re-visited) channels of distribution, channels are categorized here as manufacturer-to-retail or direct-to-consumer/user.

Channel alternatives: manufacturer-to-retail

There are several alternative physical channels of distribution that can be used, and a combination of these may be incorporated within a channel structure. The diagram in Figure 4.1 illustrates the main alternative channels for a single consumer product being transferred from a manufacturer's production point to a retail store. (Throughout this book, the term 'retail store' is used; this is the same as a 'retail shop', which is a term preferred in some parts of the world.) The black dots in the diagram indicate the points at which products are physically transferred from one channel member to another. It is useful to take note of these when interpreting the diagram while reading the descriptions of the channels below.

As previously mentioned, there are, of course, other important channels of distribution that are used – channels that go directly to the end user or consumer (whether

Figure 4.1 Alternative physical distribution channels for consumer products to retail stores

● = Point of physical transfer of product to next intermediary

industrial or home): these are the direct deliveries to the consumer/user discussed separately later in the chapter.

The alternative physical distribution channels in Figure 4.1 are:

- **Manufacturer direct to retail store.** The manufacturer or supplier delivers direct from the production point to the retail store, using its own vehicles. As a general rule, this channel is only used when full vehicle loads are being delivered, thus it is quite an unusual distribution channel.
- **Manufacturer via manufacturer's distribution operation to retail store.** This used to be one of the classic physical distribution channels and was the most common channel for many years. Here, the manufacturer or supplier holds its products in a finished goods warehouse, a central distribution centre (CDC) or a series of regional distribution centres (RDCs). The products are transported in large vehicles (known as primary distribution, line-haul or trunking vehicles) to the sites, where they are stored and then broken down into individual orders that are delivered to retail stores on the supplier's retail delivery vehicles. All of the logistics

resources are owned by the manufacturer. This type of physical distribution channel has decreased in importance due to the development of a number of alternative channels of physical distribution.

- Manufacturer via retailer distribution centre to retail store. This channel consists of manufacturers either supplying their products to retailers' national distribution centres (NDCs) or RDCs for final delivery to stores, or supplying them to consolidation centres, where goods from the various manufacturers and suppliers are generally consolidated into shelf-ready loads for dispatch direct to the stores. These centres are run by the retail organizations or, as is often the case, by their third-party contractors. The retailers then use third-party delivery vehicles to deliver full vehicle loads to their stores. This type of distribution channel has developed significantly as a direct result of the growth of the large multiple retail organizations that are a feature in high streets and large retail parks.
- Manufacturer to wholesaler to retail store. Wholesalers acted as the intermediaries in distribution chains for many years, providing the link between the manufacturer and the small retailers' shops. However, this physical distribution channel has altered with the development of wholesale organizations or voluntary chains (often known as 'symbol' groups in the grocery trade). They originated on the basis of securing a price advantage by buying in bulk from manufacturers or suppliers. One consequence of this has been the development of a distinctive physical distribution channel because the wholesalers use their own distribution centres and vehicle fleets.
- Manufacturer to cash-and-carry wholesaler to retail store. Another important development in wholesaling has been the introduction of cash-and-carry businesses. These are usually built around a wholesale organization and consist of small independent shops collecting their orders from regional wholesalers, rather than having them delivered. The increase in cash-and-carry facilities has arisen as many suppliers will not deliver direct to small retail stores because the order quantities are very small.
- Manufacturer via third-party distribution service to retail store. Third-party distribution, or the distribution service industry, is a significant alternative, mainly due to high distribution costs and the constantly changing and more restrictive legislation that has occurred. Thus, a number of companies have developed a particular expertise in logistics operations. These companies can offer general distribution services but may also provide a 'specialist' service for one type of product (e.g. china and glass, hanging garments) or for one client company. Developments in third-party distribution, or distribution outsourcing as it is also known, are considered in some detail in Part Six, Chapters 34 to 37.
- Manufacturer via small parcels carrier to retail store. This channel is very similar to the previous physical distribution channel, as these companies provide a

‘specialist’ distribution service where the ‘product’ is any small parcel and next-day delivery is generally available. Small parcels carriers now also specialize in making home deliveries, as discussed below. In addition, pallet distribution networks fulfil a similar role for single pallet deliveries.

- Manufacturer via broker to retail store. This is a relatively rare type of channel, and may sometimes be a trading channel and not a physical distribution channel. A broker is similar to a wholesaler in that it acts as intermediary between manufacturer and retailer. Its role is different, however, because it is often more concerned with the marketing of a series of products, and not necessarily with their physical distribution. Thus, a broker may use third-party distributors, or it may have its own warehouse and delivery system.

Channel alternatives: direct-to-consumer/user

The alternative physical distribution channels described in the previous section refer to those consumer products where the movement is from the manufacturer to the retail store. In this section, the channels going direct to the end consumer/user are outlined. These can be B2C (business-to-consumer) generally for deliveries to the home or B2B (business-to-business) for deliveries to industrial or business premises:

- Mail order (B2C). The use of mail order or catalogue shopping is very popular for certain types of goods, although internet shopping is now a popular alternative. For mail order, goods are ordered by catalogue, and delivered to the home by post or parcels carrier. The physical distribution channel is thus from manufacturer to mail order house as a conventional primary transport (line-haul) operation, and then to the consumer’s home by post or parcels carrier, bypassing the retail store.
- Factory direct to home (B2C). The direct factory-to-home channel is another alternative. It can result from direct selling methods, often as a result of newspaper or magazine advertising. It is also commonly used for one-off products that are specially made and are not stocked in a warehouse to provide a particular level of service to the customer.
- Internet shopping for home delivery. Shopping from home via the internet is a very common means of buying products. Initially, physical distribution channels were similar to those used by mail order operations – by post and parcels carrier. The move to internet shopping for grocery products has, however, led to the introduction of additional specialist home delivery distribution operations. These are almost all run by third-party companies. In the grocery industry, home delivery is usually undertaken on small specialist vehicles where orders are picked and packed in distribution centres or in retail supermarkets. (See Chapter 12 for a more detailed discussion on the implications for distribution channels that have resulted from developments in home delivery.)

- A completely new channel development is that of computer-to-computer, as some products, such as music, software, films and books are distributed directly online.
- Factory-to-factory/business-to-business (B2B). The factory-to-factory or business-to-business channel is an extremely important one, as it includes all of the movement of industrial products, of which there are many. This may cover raw materials, components, part-assembled products, etc. Options vary according to the type and size of product and order. This may range from full loads to small parcels, and may be undertaken by the manufacturers themselves or by a third party.

Different channel structures

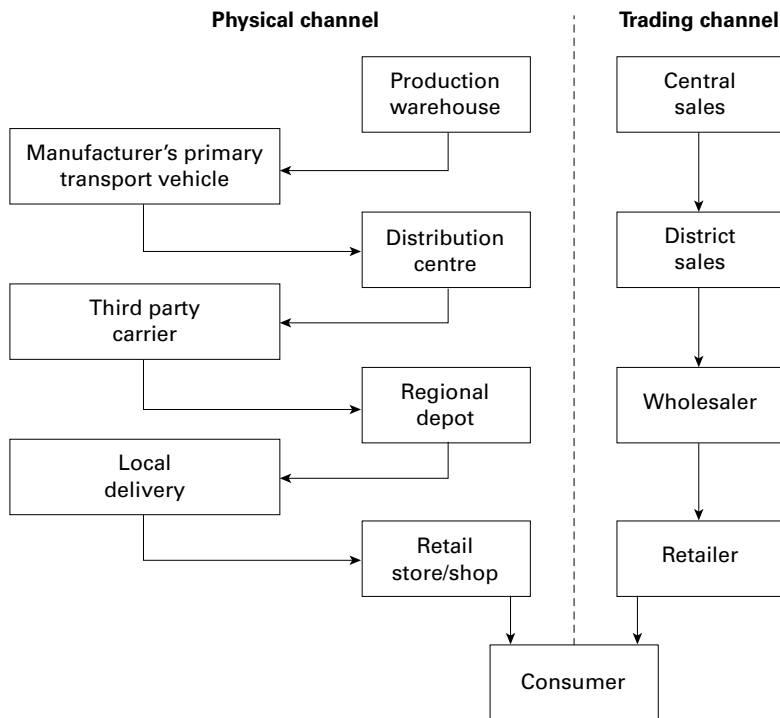
It can be seen from the list of alternative channels that channel structures can differ very markedly from one company to another. The main differences are:

- the types of intermediaries (as shown above)
- the number of levels of intermediaries (how many companies handle the product before it reaches the final customer)
- the intensity of distribution at each level (are all types of intermediary used at the different levels or just selective intermediaries?)

It should also be noted that a policy of disintermediation is being followed by some companies – this involves the planned elimination of channel members from certain supply chains. The aim is to cut out steps in the distribution process to eliminate costs and improve speed to market. For some companies, disintermediation is becoming a part of overall supply chain design.

Some small and medium-sized companies may have fairly simple channel structures. Many companies, however, have a number of different products and a number of different types of customer. Companies such as these will therefore use several different channels to get their products to market. This, together with the large number of variable factors and elements possible within any channel structure, makes it difficult to identify what might be called a ‘typical’ channel of distribution. Figure 4.2, however, provides a representation of a typical single-channel structure. The different physical and trading channels are also illustrated in this figure.

Figure 4.2 A typical channel of distribution, also showing the difference between the physical and the trading channel



Channel selection

Channel objectives

For successful channel selection, it is important for a company to identify the most suitable objectives that ensure that it can get its products to its customers in the most appropriate fashion. Channel objectives will necessarily differ from one company to another, but there are a number of general points that are likely to be relevant to most companies. These should normally be considered by a company in the course of its distribution planning process to ensure that the most appropriate channel structure is developed. The key points that should be addressed are as follows:

- *To make the product readily available to the market consumers at which it is aimed.* Perhaps the most important factor here is to ensure that the product is represented in the right buying environment for customers. For a consumer product this might be, for example, retail store and internet. Having identified the correct marketplace for the goods, the company must make certain that the appropriate physical distribution channels are selected to achieve this objective.

- *To enhance the prospect of sales being made.* This may be the responsibility of either the sales group or the logistics group or jointly as a team. It can be achieved in a number of ways. The most appropriate factors for each product or type of retail outlet will be reflected in the choice of channel. For example, the general aims of delivery to stores/shops might be to get good positions and displays in the store, and to gain the active support of the retail salesperson, if this is relevant. The product should be 'visible, accessible and attractively displayed'. In this instance, channel choice might be affected by the following requirements:
 - Does the deliverer arrange the merchandise in the retail store?
 - Are special displays used?
 - Does the product need to be installed, demonstrated or explained?
 - Is there a special promotion of the product?
 - Does the supplier pay for favourable shelf location for the product?
- *To achieve cooperation with regard to any relevant distribution factors.* These factors may be from the supplier's or the receiver's point of view, and include minimum order sizes, unit load types, product handling characteristics, shelf-ready upon delivery to store, materials handling aids, delivery access (e.g. vehicle size) and delivery time constraints, among others.
- *To achieve a given level of service.* Once again, from both the supplier's and the customer's viewpoints, a specified level of service should be established through a formal service level agreement which is then monitored, measured and maintained. The customer normally sees this as crucial. Relative performance in achieving service level requirements is often used to compare suppliers and may be the basis for subsequent buying decisions. This was discussed in detail in Chapter 3 and is covered in Chapter 14.
- *To minimize logistics and total costs.* As always, cost is very important, as it is reflected in the final price of the product. The selected channel will reflect a certain cost, and this cost must be assessed in relation to the type of product offered and the level of service required.
- *To receive fast and accurate feedback of information.* A good flow of relevant information is essential for the provision and maintenance of an efficient distribution service. It might include sales trends, inventory levels, damage reports, service levels, cost monitoring and EPOS information shared with suppliers.

Channel characteristics

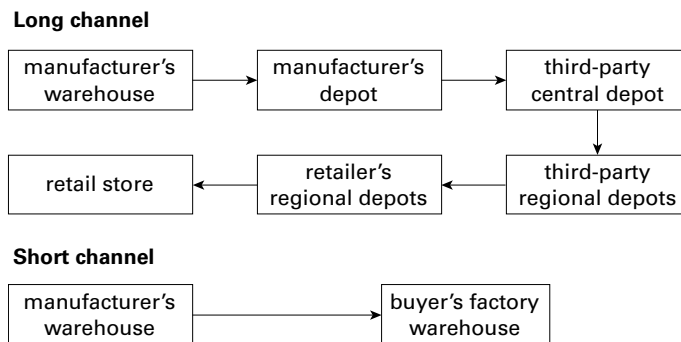
As well as identifying the relevant channel objectives, as described in the previous section, there are a number of channel characteristics that also need to be considered. These include market, product and competitive characteristics. These different fac-

tors will affect the decisions that need to be made when designing a channel to be used in a distribution system. They can be summarized as follows.

Market characteristics

The important consideration here is to use the channels that are the most appropriate to get the product to the eventual end user. The size, spread and density of the market is important. If a market is a very large one that is widely spread from a geographic point of view, then it is usual to use 'long' channels. A long channel is one where there are several different storage points and a number of different movements for the product as it is transferred from the point of production to the final customer. Where a market has only a very few buyers in a limited geographical area, then 'short' channels are used. A simple example of what are known as 'long' and 'short' channels is illustrated in Figure 4.3.

Figure 4.3 'Long' and 'short' distribution channels



Product characteristics

The importance of the product itself when determining channel choice should not be underestimated. This is because the product may well impose constraints on the number of channels that can be considered. For example:

- High-value items are more likely to be sold direct via a short channel, because the high gross profit margins can more easily cover the higher sales and distribution costs that are usual from short channels. In addition, the security aspects of highly priced items (e.g. jewellery, smartphones) make a short channel much more attractive because there is less opportunity for loss and theft than with a long channel. Short channels also reduce the requirement for carrying large inventories of high-value goods and thus help to avoid the associated issues of poor use of working capital and the cost of obsolescence.
- Complex products often require direct selling because any intermediary may not be able to explain how the product works to potential customers.

- New products may have to be distributed via a third-party channel because final demand is unknown and supply channels need to be very flexible to respond to both high and low demand levels. Existing own-account operations may find it difficult to deal effectively with the vagaries of new product demand.
- Time-sensitive products need a 'fast' or 'short' channel, for shelf-life reasons in the case of food products such as bread and cakes, and relevance in the case of newspapers and tender documents.
- Products with a handling constraint may require a specialist physical distribution channel, e.g. frozen food, china and glass, hanging garments and hazardous chemicals.

Competitive characteristics

Competitive characteristics that need to be considered concern the activities of any competitors selling a similar product. Typical decisions are whether to sell the product alongside these similar products, or whether to try for different, exclusive outlets for the product in order to avoid the competition and risk of substitution. It may well be that the consumer preference for a wide choice necessitates the same outlets being supplied. Good examples include confectionery and most grocery items.

Of particular significance is the service level being provided by the competition. It is essential that channel selection is undertaken with a view to ensuring that the level of service that can be given is as good as, or better than, that which is being provided by key competitors. This may well be the main area for competitive advantage, especially for those products where it is very difficult to differentiate on quality and price.

Company resources

In the final analysis, it is often the size and the financial strength of the company that is most important in determining channel strategy. Only a fairly large and cash-rich company can afford to set up a distribution structure that includes all of its own storage and transport facilities. A company may like to do this because it feels that it gives it greater control and that it can allow the company to provide more easily the service it thinks its customers require. However, smaller and less financially secure companies may have to use intermediaries or third-party organizations to perform their distribution function because they do not have the financial resources to allow them to run their own distribution operations.

Designing a channel structure

Many of the factors previously described in this chapter will need to be considered when designing a channel structure and selecting the appropriate channel members.

A formalized approach that might be adopted when undertaking the design of such a channel structure is outlined below:

- Identify key marketing and customer service requirements: this will be required in order to determine the basis for the channel structure. (See Chapter 3 for more detailed information on how this can be done.)
- Set and coordinate distribution objectives and specify distribution tasks: this is aimed at determining what the company requires with regard to the products that are sold and the customer requirements for these products. The ‘Channel selection’ section in this chapter covers many of the key aspects.
- Develop alternative appropriate channel structures: the preceding steps will have covered the collection of all of the necessary information and data. In this step, the different elements should be assessed to allow for suitable appropriate channel structures to be identified.
- Choose the best channel structure: at this stage the most appropriate channel structure from the feasible alternatives can be determined. This might be a single channel or a series of different channels that may be required to enable the effective distribution of different product types to different types of customer.
- Select channel members: the final task is to identify which channel members best fit into the chosen channel structure. (See Chapter 36 where the process for selecting third-party contractors is described.)

Outsourcing channels

Third party or own account?

It is probably true that the most important channel decision for those operating in distribution and logistics is whether to use an own-account (in-house) operation or whether to outsource to a third-party logistics (3PL) service. If the decision is to outsource then there are a number of associated factors that need to be considered concerning how much of the operation to outsource and which of the many third-party companies to choose to undertake the outsourced operation. These and other key questions related to outsourcing are addressed in detail later in the book: the different services offered (Chapter 34), the main decision criteria (Chapter 35), the selection process (Chapter 36) and the management of outsourced operations (Chapter 37) are all covered. In addition, the opportunity to move to the next phase of outsourcing – fourth-party logistics – is described in Chapter 5. Nevertheless, as outsourcing is such a key element when considering channels of distribution, two important questions regarding outsourcing are considered here: what are the reasons

for companies outsourcing their distribution operations, and what are the reasons for companies not outsourcing?

The reasons why companies outsource their distribution operations

Some of the key reasons why companies outsource their operations are:

- To reduce cost: this is generally the main reason that a company will give for outsourcing. It often arises after a company has compared or benchmarked (see Chapter 39) its operation against another similar operation and identified major cost differences. Outsourcing is a quick and relatively easy way to address this.
- To improve service: another major reason for outsourcing as there are scale benefits in warehousing and, particularly, reach and service frequency benefits in delivery.
- To concentrate on core competence: distribution is often seen as an ancillary activity and not a key part of a company's manufacturing or retailing speciality.
- To reduce assets: warehouses and vehicles can be transferred to the third-party contractor and thus they do not appear on the company's balance sheet.
- To employ capital more effectively: capital previously employed to purchase buildings or rapidly depreciating assets such as trucks may be more profitably employed elsewhere in the business.
- To facilitate access to new geographic markets: as a company wishes to expand its market area, it is often quicker and more effective to use an existing physical distribution operation (outsource) rather than have to set up a new own-account operation.

The reasons why companies do not outsource their distribution operations

Some of the key reasons why companies do not outsource their operations are:

- Logistics is seen as a core competency in the company: companies feel that service is key to their product offering and that distribution should not be outsourced because they may lose this as a competitive advantage.
- Costs will not be reduced: this is because the contractor will be paid a profit margin on top of the cost of the operation.
- Loss of control: companies feel that they will lose direct control of their own operation and this may impact customer service flexibility.

- Over-dependency risk: companies fear that they will become over-dependent on the contractor and that, over time, it would become impossible to reverse the decision.
- Loss of key skills: companies may be concerned that they would lose some of the key skills and key knowledge that is important to a key part of their business.

There are other reasons given that can influence this key decision of whether or not to outsource. For further discussion see the section in Chapter 35, 'Drivers and drawbacks of outsourcing logistics'.

Key issues and challenges for logistics and the supply chain

05

Introduction

In this chapter a number of key issues are raised and discussed with the aim of highlighting the most important challenges that are being addressed by logistics and supply chain professionals. There are constant changes and developments in the structure, organization and operation of logistics, notably in the interpretation of logistics within the broader supply chain. Although many of these are covered in greater detail in the appropriate chapters within this book, some are introduced in this chapter in order to provide a clearer picture of the broad areas of change that are occurring within logistics and the supply chain.

It is worth emphasizing that, aside from external issues and developments in technology, some changes in logistics are largely conceptual in nature whereby certain aspects of logistics and the supply chain are viewed with a new or different approach. Many people, especially experienced logistics practitioners, may feel that some of these concepts and approaches are very much like old ideas dressed in new clothing. To a certain extent this is true; for example, much of the new process-oriented approach to logistics (see Chapter 7) is an echo of what used to be called 'work study'. The use of flowcharts for analysing workflows in distribution and logistics has, in fact, been very common for many years.

What some of these new concepts and approaches are achieving, however, is to re-emphasize certain ideas, update their approach and content and rekindle the fires of enthusiasm for constant review and change. Logistics exists in a very dynamic and ever-changing environment, so this is undoubtedly a positive development. Another relevant point is that a number of these concepts are not applicable to all operations and organizations. This may be due to the size of the organization or to the extent

of the market; for example, small nationally oriented organizations are usually unaffected directly by globalization. Nevertheless, for large multinational companies these are very important questions that need to be addressed.

Initially, the broader context of the digital supply chain is described, followed by developments and influences from the external environment. These aspects generally have an impact across the supply chain as a whole. The remaining sections concern changes which are more specific to particular components of logistics. The broad categorizations of change refer to:

- the digital supply chain
- the external environment
- manufacturing and supply
- logistics and distribution
- retailing
- the consumer

The digital supply chain

There are several technological developments that have implications for the supply chain in its broadest context. In the opening section of this chapter, an overview of these elements and how they help create what might be called the digital supply chain is outlined. Many of the different technologies are discussed in more detail in Chapter 40 of this book.

As with many evolving ideas and concepts that are associated with the supply chain, the basis for these developments is strongly associated with changing customer expectations. Customers choose and select products across multiple platforms and demand service that is both personal and fast. They also may have concerns about both product and supply chain sustainability. These requirements must be met in changing and challenging circumstances, including elongated and complex supply chains, disruptive events such as global health crises and political insecurity. These, in turn, may result in severe or sporadic supply shortages.

Although it may appear as rather ambitious to try to accommodate all requirements such as these, there are existing and developing concepts that make this far more feasible. One key concept is the idea of the Fourth Industrial Revolution (4IR), also known as Industry 4.0, whereby developing digital technologies have begun to significantly alter the scope of what is achievable. These terms describe the way economies can develop through the integration of innovative technological, societal and business practices to encourage a fresh combined approach to commerce and industry. Evolving from this is Supply Chain 4.0 (SC:4), which incorporates the

combination of associated technologies that have enabled the introduction of an 'era of digital transformation in new real-time data gathering across the supply chain, smart analysis, and algorithms to better simulate and predict different supply chain scenarios and foster data-based decision-making' (PwC, 2020).

The remainder of this section considers these aspects of the digital supply chain. SC:4 is described, the various enabling technologies are listed and the associated resulting key outputs are briefly reviewed. As indicated earlier, the different technologies are discussed in more detail in Chapter 40.

Supply Chain 4.0 (SC:4)

As indicated above, the concept of Supply Chain 4:0 (SC:4) describes how developing digital technologies can significantly alter the scope of what is achievable and attainable within the supply chain.

The move towards SC:4 is enabled by many different approaches and developments. These might be informational, through digital services such as logistical control towers using Big Data and the Internet of Things (IoT), or the use of internet-connected devices that interact automatically. In addition, there are digitally-enabled logistics services that can improve cross-border movements in a single simplified process based on technology enhancements. Innovative delivery options significantly change operational opportunities for physical shipments, including the use of drones and autonomous vehicles or 3D printing which eliminates the need to hold finished inventory. The implications on traditional distribution are immense.

One aspect of SC:4 that is already commonly discussed is that of sustainability and the circular economy: an important consideration for many manufacturing and logistics operations, where a key facet of their planning is to ensure that environmental concerns are catered for through the elimination of waste material, recycling and reduced emissions. Finally, the concept of the shared economy is also very much reflected in developments in logistics. This not only includes shared warehousing and shared transport operations, already apparent in multi-user third-party logistics services, but also the increasing use of parcel collection from and delivery to the home and office – often enabled by smartphone technology.

Industry 4.0 and SC:4 encompass the age of smart machines, production facilities and storage systems that can autonomously exchange information, prompt actions and control operations without human intervention. This is enabled through the Internet of Things and other interconnected networks of machine devices and vehicles, but this 'revolution' is seen as a clear separation between humans and machine robots. Industry 5.0 and SC:5 anticipates the next stage in the cycle, as man and autonomous machine are reconciled to work together, producing the synergy of human intelligence and cognitive computing interacting harmoniously. Manufacturing and distribution are expected to reach new levels of speed and perfection while also

protecting the environment through the incorporation of renewable energy and minimal waste.

Innovative technologies

The key contributors to the digital supply chain are the innovative technologies that make the concept feasible. Many of these and others are described in Chapter 40, but a brief list and some implications for the supply chain are given here:

- **Big Data:** extremely large data sets that may be analysed by software designed to reveal patterns, trends and associations, especially relating to human behaviour and interactions (e.g. from sensors, etc). This leads to Big Data analytics.
- **Artificial intelligence (AI):** the ability of a computer or a robot controlled by a computer using machine learning to undertake tasks that are usually done by humans because they require human intelligence and discernment, e.g. home-based assistants (Amazon Echo) can link with home smart appliances, identify stockouts and automatically re-order (e.g. milk in fridge), warehouse pick routes etc.
- **Internet of Things (IoT):** describes the network of physical objects – ‘things’ – that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet, e.g. shelving, vehicle sensors and telematics.
- **Control towers:** the essence of the control tower concept is to provide supply chain visibility across divisions, countries and transport modes. The heart of the control tower is an information hub supported by a set of detailed decision-making rules and a trained team of operators, e.g. SC and logistics decisions will be made automatically (by AI) from Big Data systems to deliver customer service while minimizing inventory.
- **Blockchain:** a permanent digital record of transactions that is stored across a distributed or decentralized network of computers. The blockchain is not split across many computers, but copied to all computers in the link – a single source of information on which all stakeholders can rely.
- **Distributed order management:** DOM systems are designed to arrange orders across the multiple systems and processes utilized by those involved in replenishing an order. DOM can analyse every transaction and determine the most efficient shipping location considering multiple factors, including speed of delivery, the distance between the shipping point and the customer, as well as available stock levels. This clearly requires a unified view of stock across multiple channels in order to know exactly where the products are.
- **Digital marketplace:** a technology platform to improve/simplify buying logistics requirements – e.g. a freight exchange/marketplace, an e-forwarder, a tender platform (for outsourcing).

- Crowd-shipping: also known as crowd-logistics, ordinary citizens using social networking collaboratively to act as couriers, creating new informal logistics networks for local distribution of small items ordered online – small parcels.
- Robotics/automation: many warehouse and logistics jobs can be undertaken by robots, e.g. container stacking, warehouse put away, picking and packing.
- Autonomous vehicles: vehicles and drones (self-driving robots) used for delivery purposes.
- 3D printing, also known as ‘additive manufacturing’: enables the remote production of three-dimensional objects. This can eliminate large elements of an upstream supply chain.

Digital supply chain: key aspects

What does a digital supply chain look like? The use of an amalgam of the many innovative technologies outlined above implies the need for a very different structure and operational approach. Yet, in many ways, there is a natural progression that has occurred and is still occurring. It is the linking of these new ideas and techniques that is the key to any fundamental change. The digital supply chain can be characterized in several different ways but there are five major elements that can be considered as key to the formulation of an autonomous and self-optimizing supply chain:

- Supply chain transparency and sustainability: this involves multi-level data flow and seamless connection of all data across the supply chain for products, logistics, customers and finance, together with a completely transparent and sustainable supply chain that includes the reuse of materials and the integration of suppliers and other players.
- Closed-loop and integrated planning and execution: end-to-end planning from customers to sub-suppliers covering all planning time horizons. This to include integrating financial and capacity plans, demand and supply balancing, collaborative workflows and automated decision-making using advanced analytics.
- Smart logistics flows: includes inbound and outbound transportation considering all modes; automated warehouses transport management systems (TMS) and warehouse management systems (WMS); optimized and dynamic distribution; omnichannel order management.
- Dynamic supply chain segmentation: the use of segmentation strategies to support key business requirements, covering all realistic service, margin, cost and inventory parameters. The adoption of supply chains that are flexible and which can be further segmented for each customer order, as well as reshaped for alternative market conditions and product components.

- AI-driven supply chain management: data networks and AI connect along the supply chain to provide enhanced demand forecasts via demand sensing. Patterns and trends can evolve based on machine learning within the supply chain and trigger appropriate responses. This enables a fully autonomous supply chain making appropriate and effective optimization decisions.

The external environment

There are many ways in which external issues have an impact on logistics, and a number of the key aspects are considered in this section.

One factor that has a particular impact is the importance of *green* or *environmental issues*. This has occurred through an increasing public awareness of environmental issues, but also as a result of the activity of pressure groups and the recognition by governments that global environmental policies need to be initiated. It has led to the introduction of environmental legislation, which has had important consequences for logistics and the supply chain (see Chapter 42 for a detailed discussion on logistics and the environment). Some of the key policies and developments include:

- the banning of road freight movements at certain times and days of the week
- the promotion of rail over road transport
- the recycling of packaging
- the ‘greening’ of products
- the design of products to facilitate repair, reuse, recycling and the minimization of packaging

For many companies, the need for a sound environmental policy is seen to be essential and plays an important part in determining appropriate logistics and supply chain strategies and operations.

For most cities throughout the world, one very visible external impact on logistics is *road congestion*. Severe road traffic congestion can have a very negative effect on some of the key concepts in logistics – in particular just-in-time (JIT) and quick-response systems. It is likely that congestion will get worse as most forecasts predict a significant increase in vehicle numbers at a time when, in most countries, with the exception of China and India, there are very limited road-building programmes. Many Western countries try to reduce congestion through a combination of road tolls, truck bans, access restrictions, time restrictions and usage tax – all of which can have a significant impact on logistics costs and performance. There is no generally accepted solution. Companies try to alleviate the problem through strategies such as out-of-hours deliveries, stockless depots and the relocation of DCs closer to delivery points.

Changes and developments in logistics thinking and logistics systems have also contributed to another issue that has a significant impact on logistics operations – this is the problem of the *restricted availability of suitable management and labour*. The need for an understanding of the strategic elements of logistics and the need for an appreciation of the integrated nature of logistics are important for managers who are operating in today's supply chain-oriented networks. Some managers do not have the opportunity to obtain the relevant experience or knowledge that provides this. Some are also likely to have worked in functional silos rather than cross-functional teams and their focus has generally been in an operational rather than a planning context. This applies to managers from both in-house and third-party operations. Add to this the rapid introduction of new technology, and it is understandable why there is such a shortage of managers with suitably broad knowledge and experience.

This problem is also reflected in the nature of the labour available to work in the many different logistics and distribution functions. In particular, new technological developments in operational logistics have meant that the skill requirements have changed and that the necessary skill levels have become much higher for some logistics jobs. There are also significant labour shortages in some geographic areas and for some specific logistics jobs, such as transport drivers.

There are regular occurrences of unpredictable and unexpected events that can create serious disruptions to supply chain and logistics activities. These may happen for a variety of reasons, such as natural disasters, terrorism, corporate failures and industrial disputes. These events have highlighted the *vulnerability of many supply chains* (sometimes called *supply chain disruption*) and have shown that there are potential risks to many supply chain and logistics operations that may not have been adequately addressed (see Chapter 41).

One major example is, of course, the Covid-19 pandemic. Supply chains across the world have been severely disrupted, but in many ways the resilience and flexibility of supply chains have proved to be critical in helping to alleviate some of the major problems related to the provision of essential medical supplies, food and other key necessities. But it has not been easy. Basically, some of the fundamental elements of supply chain planning and design have been affected – consumer behaviour, supply sources, routes to market, order sizes – which have resulted in the need for flexibility and agility in responses.

In terms of the future, the pandemic has highlighted the need for resilience and flexibility in the design of supply chains and should lead to a greater inclination for change. This is likely to promote a move towards the digital supply chain including many of the technologies indicated at the beginning of this section. Another aspect that may be reconsidered is the globalization of supply, particularly the potential problems associated with single-source operations and long, inflexible supply routes.

At a more parochial level, Brexit – the departure of the UK from the EU – has shown how vulnerable supply chains can be as a result of change, in this case a re-enforcement of trade agreements, customs regulations and physical barriers, among others. Consequences involve the reassessment of sourcing, revised storage locations, inventory level changes and transport choices.

Globally, there are examples of companies moving to a single source for the supply of a key component, only to experience severe supply issues, resulting in production at the companies' plants being disrupted or halted. Reasons for the supply failure have been due to the supplier becoming insolvent or because of plant failure through fire or natural disaster. The Fukushima tsunami in Japan in 2011 caused Toyota's manufacturing to shut down all over the world because the factories of some of its suppliers were devastated. Renesas manufactured a key component – chip controllers – and it was unable to deliver these into the Toyota JIT supply chain.

Vulnerability has become recognized as a significant issue as the complexity and length of supply chains have increased and inventory levels have been significantly reduced. Appropriate risk assessment techniques and contingency plans have been developed to enable supply chains to be more resilient (see Chapter 36 for an example of a risk assessment methodology commonly used for outsourcing). Many companies have developed more resilient supply chain models that aim to allow for a greater volatility in supply.

Manufacturing and supply

Many developments in manufacturing and supply, or inbound logistics, have influenced and affected the supply chain. These have occurred through both technological and organizational change (see Chapter 13 for detailed discussion on some of these). Within the context of *raw material sourcing and production*, these include:

- *New manufacturing technology* (computer integrated manufacturing (CIM), 3D printing, nanotechnology) which can accommodate more complex production requirements and more product variations, thus creating more complicated logistics flows (see also Chapter 40).
- *New supplier relationships*, with the emphasis on single sourcing and lean supply, which involves suppliers and buyers working more closely together by sharing information and expertise to ensure that product supply is maintained.
- *Focused factories*, with a concentration on fewer or even a single source for a product, but resulting in longer transport journeys to the customer.
- *Global sourcing*, emphasizing the move away from local or national sourcing to sourcing from any location, again resulting in longer transport journeys to the customer.

- *Postponement*, where the final configuration of a product is delayed to enable reduced stockholding of finished goods in the supply chain. This also means that the final finish of products can become a logistics activity (see Chapter 13).
- *Co-makership* involving the development of partnerships between supplier and buyer to help take costs out of the supply chain through quality and information improvements. This represents a positive move away from the more traditional adversarial relationship that has been common between buyers and suppliers.
- *Co-location*, with the joint physical location of supplier operations on or next to customer production sites (see Chapter 14).

Increases in *product range* and other product characteristics have also affected logistics requirements. Examples include: product life cycles which have become shorter, bringing pressure on inventory systems as it becomes more difficult to minimize stock obsolescence; a wider product range, both expected by customers and provided by suppliers, which increases inventory requirements and costs; increases in demand for time-sensitive products – especially fresh and prepared foods – which can provide additional logistics problems with respect to the impact on stock levels and in particular the speed of delivery required.

The *lean manufacturing* concept was developed from a worldwide benchmarking programme in the automotive industry which was published in a book called *The Machine that Changed the World* (Womack, Ross and Jones) in 1990. It identified huge opportunities for closing the gap between the best in the world and other manufacturers. The approach that was developed became known as ‘lean manufacturing’, and is based on the Toyota system of production management (see Chapter 13). It is an approach that has been followed in recent years by many manufacturing companies from a variety of different industries. The five principles of lean thinking concentrate on the elimination of waste and are as follows:

- 1 Specify what does and does not create value from the customers’ perspective and not from the perspective of individual firms, functions and departments.
- 2 Identify all the steps necessary to design, order and produce the product across the whole value stream to highlight non-value-adding waste.
- 3 Make those actions that create value flow without interruption, detours, back-flows, waiting or scrap.
- 4 Only make what is ‘pulled’ by the customer order just-in-time.
- 5 Strive for perfection by continually removing successive layers of waste as they are uncovered.

These ideas are discussed further in Chapter 13. Lean thinking owes a lot to the philosophy of just-in-time and is an extension of this type of approach.

The concept of the *agile supply chain* is the development of a strategic structure and operation that allows for the rapid response to unpredictable changes in customer demand. The emphasis is on the need for companies to work together across the supply chain in order to fulfil customers' requirements, and to be flexible in the way that they are organized for production and distribution. This will allow them to be responsive to changes in customer requirements. The concept recognizes the key importance of the final customer and strives to set up a system and structure that can service customer requirements in the most effective way.

Two dictionary definitions serve to emphasize the difference between lean thinking and the agile supply chain: *lean* 'having no surplus flesh or bulk'; and *agile* 'quick in movement, nimble'. Some of the reasons for the need for agility in the supply chain include: shorter product life cycles (for example, desktop and laptop computers have about a six-month life cycle before they are superseded, and mobile phones and tablets can become outdated in even shorter time periods); an increase in the variety of final products (typically in colour and style refinements); the unnecessary build-up of stock, which can quickly become obsolete because demand requirements change so rapidly; developments in direct selling and buying – notably via internet and mobile shopping – which means that customers expect to acquire the most up-to-date products immediately.

The agile approach to supply chain management aims to create a responsive structure and process to service customer demand in a fast-changing marketplace. Key characteristics of an agile approach are:

- production is planned across functional boundaries and flexible fulfilment (postponement) is used
- inventory is held at as few levels as possible and much stock is held as work-in-progress awaiting final configuration, which will be based on actual customer requirements
- replenishment at the different levels in the supply chain is driven by actual sales data collected at the customer interface
- finished goods are sometimes delivered direct from factory to customer
- supply chain systems are highly integrated, giving clear visibility of inventory at all levels

Factory gate pricing (FGP) is another initiative that is intended to reduce logistics costs – in this case the inbound supplier's transport costs incurred while delivering to customers' manufacturing sites or distribution centres (DCs). Traditionally, many products, particularly industrial components and raw materials, have been delivered direct to customers via suppliers' own transport or a third-party contracted to the supplier. This approach disguises the real transport cost because it is included within the cost of the product. Now, some products are bought 'at the factory gate' (or 'ex works' in import/export Incoterms® terminology) without any transport cost

included, so that the product price is transparent. Buyers can then decide whether to ask the supplier to deliver, with the transport cost indicated separately, or to collect the product using their own company transport or by using a third-party resource that they can control.

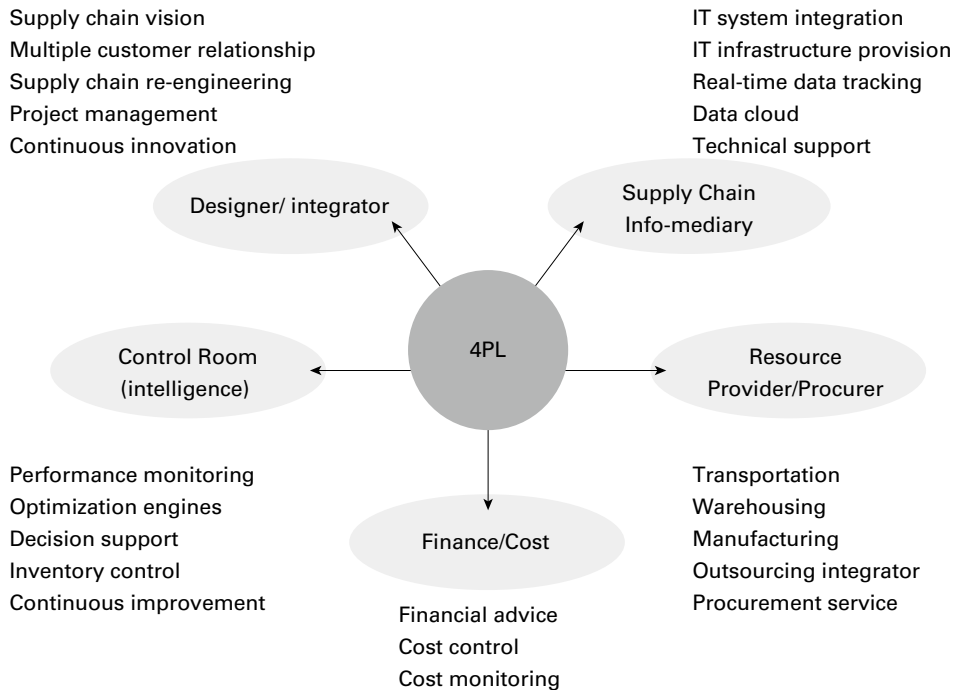
FGP provides an opportunity for buying companies to reduce transport costs by improving the utilization of their own, or their outsourced, transport operations because collections can be made using returning empty delivery vehicles. This alternative approach also gives the buyer much more control over when goods are received and how much is received. This can help them to avoid stockouts of essential products and also to ensure that they do not become unnecessarily overstocked with any products. Many companies that have adopted a broad FGP policy have done so by using third-party logistics service provider (3PL) companies to plan and undertake all the collections of the products that they buy.

Some large consumer goods companies have also recognized the advantages of more structured and controlled inbound supply chain management, and are taking this in-house. Thus, they are organizing and controlling their own inbound shipments rather than leaving this to their suppliers. Both Walmart and PepsiCo in the United States have taken this route (see also Chapter 14).

An associated development is that of *inbound to manufacturing* (I2M). This is a service used in support of a manufacturer's need to ensure that materials and components are purchased in the best way in support of their customers' variable manufacturing demands. Global manufacturers are seeking to reduce their overall supply chain costs by improving the inbound control of the supply of raw materials and components and thus reducing the inventory that they consume in their manufacturing process, reducing operational costs and using expensive factory space more productively. I2M is the supply chain management of the inbound flow of materials from collection points at component suppliers' facilities to the consumption point in manufacturers' production lines, which are usually situated in developing countries. Usually a vendor-managed inventory (VMI) programme is established in support of this service.

Logistics and distribution

There are constant changes and developments in logistics and distribution, and the majority of these are included in the appropriate chapters within this book. Some of the more topical ones are, however, noted in this section. As well as the extent of change, the speed of change is also relevant as new concepts and ideas can very quickly become standard practice. The take-up of new ideas can vary from one company to another. Thus, an idea or concept may be standard practice for one company but totally new for another. It may be vital for one company, but completely irrelevant for another.

Figure 5.1 Fourth-party logistics, showing the main areas of service that could be provided

One major area with constant change and development is third-party logistics (3PL) or outsourcing. This is a logistics expertise that has existed for many years and is discussed in great detail in Part Six. *Fourth-party logistics* (4PL) is a development from 3PL that is hailed as the future for supply chain management outsourcing. 4PL is where an external organization is able to provide a user with an overall supply chain-wide solution by incorporating the resources and expertise of any number of third parties to best effect. The fourth-party provider will be involved in both the design and the management of a client's logistics system and will act as a coordinator for many different types of service, which may include distribution, information systems, financial services, etc. Figure 5.1 summarizes the key elements.

A fourth-party service provider or co-venturer can offer a number of enhanced services, which can provide a total supply chain perspective. This can include visibility and cost/performance measurement along the supply chain as well as tailored structures and systems offering open systems and technical vision. Accenture have defined a fourth-party logistics service provider as 'an integrator that assembles the resources, capabilities and technology of its own organization and other organizations to design, build and run comprehensive supply chain solutions'. The main impetus is for the overall planning to be outsourced and that the complete supply chain operation should be included within the remit of the 4PL. Note that a fourth-

party logistics service provider is a different concept from a lead logistics provider (LLP) because the LLP uses a degree of its own physical assets and resources together with the assets of other 3PLs. LLPs and 3PLs deliver solutions across well-defined parts of the supply chain, usually in specific elements of logistics activity. The remit of the 4PL is a much wider one.

There are a number of different ways in which fourth-party logistics may be able to solve some of the key problems that users of third-party logistics companies have experienced. The major drawbacks are likely to be the cost of using a 4PL and the loss of control over the supply chain function within the company. The main advantages are likely to be:

- *Strategic*: minimizing the time and effort spent on logistics by the user; having a single point of contact for all aspects of logistics; the management of multiple logistics providers within a single organization; easier provision of broader supply chain services (IT, integration strategy, etc); a fourth-party specialist can source expertise with best-in-class credentials.
- *Operational*: a new entity should mean it is easier to eradicate outdated logistics practices; overcome old industrial relations issues and transfer selective personnel; establish a new and more flexible working environment and create a new company culture.
- *Service and cost*: the user company's capital can be freed up for core/mainstream use by selling assets; continuous monitoring and improvement of supply chain processes, performance and costs can be coordinated; different supply chain processes can be benchmarked against world-class companies; continuous monitoring and reassessment of service level achievements can be more easily undertaken.
- *Additional benefits*: provision of 'knowledge management' – the bringing together and effective sharing of knowledge among the identified stakeholders; provision of supply chain accountability for achieving desired performance; the provider assumes risk on behalf of the user – generally in return for a share of the profit.

There is a view that 4PL is merely a refinement of 3PL; in fact there is a very significant difference between the two:

- A 4PL is non-asset-based, unlike a 3PL, which is generally seeking to fill its asset capacity of distribution centres, vehicles and freight.
- Historically, 3PLs have operated vertically in the supply chain, providing specific services in warehousing, transportation and other logistics activities. In contrast, 4PLs work horizontally across the whole supply chain and use the services of a variety of 3PLs to help provide end-to-end solutions for customers.
- 4PLs essentially act as managers of the client's supply chain whereas 3PLs execute supply chain functions.

- Typically, the 4PL only owns IT systems and intellectual capital and is therefore asset light. This allows the 4PL to be neutral in terms of asset allocation and utilization, with the ability to manage the supply chain process, irrespective of which carriers, forwarders or warehouses are used. Thus, the 4PL does not have to consider using its own assets, but can take the shipper's perspective, using the best operators for the different logistics requirements.
- The 4PL focuses on satisfying and retaining its customers by understanding the complexity of the customer's requirements and providing end-to-end solutions based on sound processes, which address their customers overall supply chain needs.

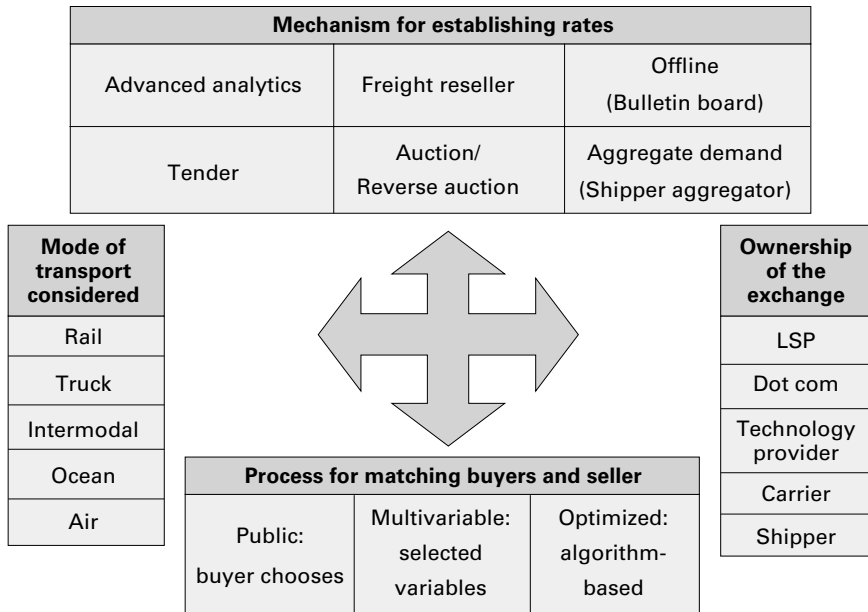
It has been argued that 4PLs have stepped into the vacuum created by 3PLs, due to the 3PLs' disinclination to develop beyond their traditional warehousing and transportation role. Indeed, 3PLs usually focus on servicing functions such as warehousing, transport or freight management, whereas the 4PL targets the logistics or supply chain process as it impacts the customer's entire business. So far, however, the adoption of the fourth-party concept has been limited, being restricted to some new ventures and to some large global organizations. It would seem that the outsourcing of complete supply chain strategies and operations is perhaps a step too far for many organizations as they appreciate more and more the importance of their supply chain to their own business success and therefore wish to maintain control in this key area. However, this may be changing. Accenture have, for example collaborated with Shell to set up a number of 4PL logistics solutions for various parts of their business. This includes supply and delivery to Shell forecourt shops in several European countries, as well as logistics operations for their North American oil and gas business, and freight operations in the United States (*The Chain Magazine*, 2018).

One important information-based development in logistics is the *digital freight exchange or digital platform*. These are online transaction systems for shippers and carriers that enable online freight purchasing. Basically, they are internet-based trading mechanisms that facilitate the matching of shipper demand with carrier availability. They range in complexity from simple electronic bulletin boards (these allow shippers and carriers to post their needs, manually compare the two lists and then contact each other) to sophisticated algorithm-based systems (these identify suitable matches through the filtering and comparison of rates, carrier performance, service offering and equipment types).

Figure 5.2 provides a summary of some of the major differences between alternative freight exchanges. As indicated, these are: the various mechanisms that are used for establishing rates (bulletin boards, auctions, aggregation, etc), the different modes considered, the different types of owner and the matching processes.

Initially, it was thought that freight exchanges might take the place of the contract agreements that are made between many shippers and carriers, but it is apparent that

Figure 5.2 The different characteristics that distinguish digital freight exchanges from each other



contracts need to be negotiated face-to-face and that internet contact alone is insufficient because of the extent of detail required in a contract. There is possibly some scope for the use of freight exchanges in the early stages of the outsourcing selection process, specifically when putting together a request for information (RFI) (see Chapter 36) in order to develop a shortlist of suitable 3PLs to take to the final tendering stage. Also, where a company prefers some form of consultancy support to undertake the selection process, some freight exchanges can offer useful advice and suitable processes to help accomplish this successfully. It must also be remembered, of course, that freight exchanges work with a limited number of transport contractors (those that have signed up to the site) so this will pose an immediate restriction on the number of contractors that will get the opportunity to be considered for the shortlist. Thus, freight exchanges are ideal for organizing non-contract ('spot') or occasional transport requirements but are limited in their ability to cater for complicated long-term service contracts.

One very major trend that continues to be of great significance is the idea of the *networked economy*. This is linked very closely to a number of different concepts that have already been discussed, including the digital supply chain, the agile supply chain and the development of 4PLs as described above. The networked economy recognizes the difficulty for a company to act totally independently because the success of most enterprises is inextricably linked to many other companies – whether suppliers, manufacturers, service providers or retailers. Globalization has increased

the complexity of supply chains, so associated issues are multiplied making this interdependence even more important. To facilitate the development of successful networks it is necessary for enterprises to improve cooperation, increase trust and create positive collaborative environments – not an easy task within the context of traditional business relationships.

So how has the world of logistics reacted to the requirements of a networked economy? Well, in many ways it has taken the lead and developed a major role. What we have seen has been the significant move within logistics towards the integration of the many different elements of logistics into what is known as the ‘total logistics concept’ as described in Chapter 2. From this has arisen the recognition of the need to evolve this integration across the external boundaries of supply and demand. Thus, the concept of ‘supply chain management’ has come to reflect this need. This is, in many ways, the forerunner of the idea of the networked economy. For very practical reasons, supply chain management has developed because it is the logical means of supplying and moving product efficiently through to the final customer – by disregarding (or at least minimizing) the effects of the boundaries that have grown up between the different companies involved. It has thus been both a forerunner and also an enabler of the networked economy (see Chapter 2 for further discussion).

Linked very closely with the idea of the networked economy, *horizontal collaboration* is a concept where competitive companies in the same industry share logistics operations where these operations are regarded as a commodity and therefore not a basis for competition. This enables companies to gain through a reduction in logistics costs as well as the potential for an improvement in service levels. With shared delivery transport there are also environmental benefits from improved fuel and energy savings. Early users of horizontal collaboration have included Henkel, Procter & Gamble, PepsiCo, HJ Heinz, GlaxoSmithKline, Sara Lee and Colgate-Palmolive.

Collaboration has occurred between semi-direct and direct competitors, and as opportunities have increased a number of 3PLs have begun to offer collaborative services to their clients. Manufacturers Kimberly-Clark and Unilever identified that they shared well over 60 per cent of their delivery addresses and were able to benefit from significant cost savings and service improvements by combining deliveries to retail outlets. Subsequently they have been able to collaborate in the development of a manufacturing consolidating centre, which has further enhanced mutual benefits.

Many companies remain very reluctant to allow their products to be stored and distributed alongside those of their competitors because they fear the loss of important competitive information. Many 3PL users will stipulate in their contract arrangements that the 3PL cannot also undertake logistics operations for any key competitors. This attitude is now changing as the benefits of horizontal collaboration have been recognized. Some of the key issues in proceeding with a collaboration

project are: finding the right partner (both in terms of company ethos and product, distribution and customer compatibility); establishing levels of trust and cooperation; complying with legal requirements concerning competition; and the protection of competitive information.

Aftermarket or service-parts logistics is now recognized as a key aspect for many businesses, particularly high technology ones. There has been an important after-market requirement for many years, but it has rarely been viewed as important. An effective operation is one that is based on ensuring the rapid fulfilment of post-sales high-value or critical parts in support of customers worldwide. These services typically include: parts logistics; returns management; field technical support; field stocking network, usually enabling between one- and four-hour response times; centralized DCs; depot and field repairs; parts planning; asset recovery and recycling management.

Post-sales service can differentiate a company's offering and provide growth opportunities. However, the complexities associated with managing a global or pan-regional service-parts supply chain stop many manufacturers from achieving this. Suppliers often struggle with the visibility and control required to deliver the right parts or services to the right place, at the right time and at an acceptable cost. Traditional outbound logistics operations can rarely provide the service levels required, nor the return flow of items that is key (see Chapter 42 for a discussion on reverse logistics). Many businesses, especially technology and electronics companies, now outsource these activities to service providers who can offer an integrated closed-loop supply chain that is specifically designed to be a responsive outbound service combined with a reverse material flow. Third-party providers have developed skills in this area that involve the development of advanced IT and visibility systems to support the logistics offering.

Retailing

There are several trends in the retail sector that have had, and continue to have, an impact on developments in logistics and the supply chain. Many of these logistics-related changes have emanated from the grocery multiple retail sector, which continues to play a major role in introducing innovative ideas.

Overall, in many countries, the number of retail outlets has been in decline, but the average size of outlets has increased considerably. Although many town and city shopping areas have experienced a distinct fall in the number of shops, there has been a significant growth of large out-of-town 'one-stop' superstores and hypermarkets, as well as the construction of large retail parks where many multiple chain stores and shops are located. There has been a steady decrease in the number of small independent shops, although in recent years many of the large grocery multiples

have moved into this space. Of increasing significance has been the introduction and use of home and mobile internet shopping and delivery which has been magnified because of the coronavirus pandemic. These changes have all had an influence on logistics retail strategies and operations.

One far-reaching implication has been that of *inventory reduction* within the retail supply chain, which has evolved from a number of different inventory-reduction policies and which can affect many elements of a supply chain. These policies include:

- The maximization of retail selling space: an important retailing policy has been the move to maximize selling space in retail stores in order to increase sales opportunities. This has usually been achieved at the expense of shop stockrooms, leaving nowhere for stock to be held in a retail outlet except on the shop floor, thus leading to vastly reduced stockholding at the retail outlet. This can have significant implications for customer service and retail delivery operations, as it is essential to have extremely fast and effective replenishment of store inventory to avoid stockouts.
- A reduction in DC stockholding: this has been undertaken in order to promote cost saving through reduced inventory levels in the supply chain. A direct consequence has been to put additional pressure on the accuracy and speed of inventory-replenishment systems.
- A reduction in the number of stockholding DCs: many companies have reduced the number of stockholding depots in their logistics structure as a result of cost-saving exercises that involve depot rationalization and a move to stockless depots.
- JIT philosophies and concepts: some manufacturing concepts such as just-in-time have been applied to the retail sector. This has been achieved through a number of developments in information technology, particularly electronic point-of-sale (EPOS) systems, which provide a much more accurate and timely indication of stock replenishment requirements at retail store level (see Chapter 40).
- Vendor-managed inventory policies: in the United States and elsewhere, a number of companies have adopted vendor-managed inventory policies whereby the supplier rather than the retailer is responsible for shop stock replenishment (see Chapter 14).
- The streamlining of some of the activities within the retail environment through the movement of activities back into the DC (labelling, unpacking, etc): this has been augmented by the introduction of consolidation centres where goods are received from many suppliers and are consolidated into loads for individual shops. Goods are unloaded, unpacked and marked with price tags, ready to be put straight onto the retail shelves. These store-ready items are then consolidated into loads and delivered to shops.

The consequences are that stocks and buffers in retail stores have been reduced or eliminated in favour of the continuous flow of products into the stores. This necessitates more responsive delivery systems, more accurate information and more timely information. Thus, logistics operations must perform with greater efficiency but with fewer safeguards.

The out-of-stock problems created by inventory reduction at retail outlets have highlighted a number of other related issues. These are classified under the title of *on-shelf availability* or *the last 50 metres*. In its simplest definition, this refers to the ability to provide the desired product in a saleable condition when and where the customer wants it. This definition describes the effect of the problem but, in fact, there are many interrelated causes throughout the supply chain that can create the problem. Product availability tends to reduce as the product moves through the supply chain. Institute of Grocery Distribution (2005) research indicated that manufacturers achieve about 98 per cent availability, which reduces to 95 per cent in retailers' DCs and to about 90 per cent by the time the product reaches the shelves in the retail outlet.

Poor in-store execution can create shortages, due to the lack of replenishment staff in shops, insufficient shelf space or ineffective stock management at the shop. It is estimated that loss of sales can be quite significant because, although some shoppers will delay purchase or purchase a substitute, most are likely to buy the product online or from another store.

Seven areas for improvement in supply have been identified; the two most important are fairly obvious, being the accurate measurement of on-shelf availability and the greater attention of management to address the issue. The others are to improve replenishment systems, merchandising, inventory accuracy, promotional management and ordering systems. More sophisticated real-time data systems can provide stock information about every SKU in the store. Thus, it should enable suitable alerts before an out-of-stock event occurs.

Competitive strategy in retailing continues to develop, a key development being the concept of *time-based competition*. This concept has evolved from the idea that the supply chain can be broken down into a number of closely linked stages: inbound logistics, manufacturing, branding, packaging, outbound logistics, display, etc. At each stage of the process value is added to the product in terms of its physical development and availability, but, additionally, this comes at a certain cost. This 'pipeline' flow has to be managed to best effect to create the highest value for the customer but at the lowest cost. As well as the normal cost minimization approach, one way of achieving this is by reducing the time within the pipeline, which can reduce cost and also give a competitive advantage to the product compared to the competitors' products. There are three major areas benefiting from effectively managed time-based competition:

- time to market: the speed at which it is possible to bring a product from its design stage to the marketplace
- time to serve: the speed of meeting a customer's orders
- time to react: the speed it takes to adjust manufacturing output to unexpected or extreme changes in demand

Strategies for lead time management can be constructed using a pipeline 'map' drawn up to identify value-adding time and wasted time. Plans can then be developed to help eliminate wasted time and the cost associated with it. This type of approach was initially adopted in the retail sector – particularly fashion and clothing products.

The principles and methods of achieving time-based competition are discussed in various sections of this book, including value/time analysis (Chapter 7), supply chain mapping (Chapter 16), time compression, quick response (QR) and efficient consumer response (ECR) (all in Chapter 17).

E-commerce (electronic commerce or EC) is the buying and selling of goods and services, or the transmitting of funds or data, over an electronic network, primarily the internet. This is a particularly important development for the retail sector, but as well as business-to-consumer (B2C) these types of business transaction can also be business-to-business (B2B), consumer-to-consumer or consumer-to-business.

As well as a large year-on-year increase in e-commerce transactions, there is also a major challenge to most logistics operations due to the extreme seasonality of much of the demand created via or moving to e-commerce. In Western countries this is seen in the run-up to Christmas with major peaks in demand, which are exacerbated by one-day special offers that are a feature of internet selling. The logistics structures and operations of some retailers are not sufficiently robust to respond to these demands.

More detailed discussion of the issues surrounding e-commerce, particularly home/mobile shopping and e-fulfilment, can be found in the next section of this chapter, 'The consumer' and in Chapter 40.

One final comment concerning e-commerce is to note that the internet is now playing a part in the 'physical' distribution of products themselves – as a mode of transport for digital products. Digital products are sold commercially and distributed to the satisfaction of customers – although there are no official figures that indicate how much is actually distributed in this way. The further development of concepts such as 3D printing could, one day, have an important impact on the future of logistics and supply chain principles and practice.

Retailing has changed significantly in recent years, having developed from local shops and stores to one-stop-shop, large-scale, out-of-town multiple stores and now to e-tailers fulfilling individualized and personalized internet-based demand. The existence of these different channels to market can lead to some confusion for the consumer because the different channels do not offer similar product price and

availability for the same product. *Omnichannel fulfilment* and marketing is aimed at a seamless approach to the consumer experience through all available shopping channels, such as mobile internet devices, computers, brick-and-mortar shops, television, etc.

An omnichannel approach should use software to track customers across all channels, not just one or two. All shopping channels should work from the same database of products, prices and promotions so that merchandise and promotions are not channel specific, but are consistent across all retail channels. There are major implications for the supply chain with this approach and that involves developing integration across the different channels – this has become known as omnichannel retailing, fulfilment or marketing. Thus, the provision of an integrated physical distribution channel needs to be established that comprises the supply of products to the end consumer using any or all of the available channels.

The key consideration, from a logistics perspective, is how to fulfil the final delivery/collection of the goods to/from the consumer in a seamless way, whether this is in-store, in the home or via a suitable collection point – and to develop a suitable and cost-effective supply chain that achieves this. Omnichannel fulfilment is discussed in detail in Chapter 12.

The consumer

Non-store shopping, both *home and mobile shopping*, continues to increase and has direct implications for retailing operations. This phenomenon was initially introduced through the use of direct selling and mail order catalogues where products could be ordered by post or phone. In several countries, home shopping has now achieved ‘breakthrough’ levels in the grocery sector and made significant inroads into more conventional retail shopping. The enablers for such a change were the widespread use of home computing, the internet with broadband and online banking. Mobile shopping (m-commerce) is the buying and selling of goods and services through wireless handheld devices such as mobile phones and tablets. The Covid-19 pandemic accelerated the use of home and mobile shopping. All of these developments have had a fundamental impact on logistics. The very nature of the final delivery operation has, for home delivery, altered dramatically, with wide implications for the whole of the supply chain.

This major move to non-store or home shopping was, for many years, always ‘just around the corner’ but it is now reasonable to say that its time has arrived. The main consequence for logistics is the parallel increase in home delivery. In some sectors (e.g. white goods, brown goods), home delivery has been common practice for many years, but the advent of home shopping has substantially increased the demand for the home delivery of many other types of goods. The rapid growth in online selling

companies, such as Amazon, and the fact that all major grocery companies have wholly embraced the concept means that home shopping is now very common, with all the implications for logistics that home delivery brings.

It is important to differentiate between home shopping and *home delivery* – also known as *e-fulfilment* and *the final mile*. ‘Home shopping’ refers to the different ways of shopping for and ordering products from home. ‘Home delivery’ refers to the physical delivery of the product to the home (strictly speaking, e-fulfilment is the delivering of orders made via the internet but these terms are used interchangeably). ‘The final mile’ is an expression used to accentuate the particular problems, and solutions, of delivery to the final consumer. The growth of home delivery has led to the need for some fundamental rethinking in logistics operations that wish to serve the home market. The very nature of the final delivery operation to the home is noticeably different from a standard delivery operation, and home delivery requirements also affect other elements in the supply chain. Typical implications are:

- the customer may not be available to take and sign for goods
- there may not be anywhere safe to leave the goods if there is no one at home
- there may be restricted delivery time windows, often during the evening and this can have an impact on delivery vehicle and driver utilization
- new distribution systems need to be set up (small deliveries on small vehicles into residential areas, community depots, etc)
- there are increased opportunities for existing delivery systems (postal service, parcels delivery operations)
- customer ordering systems can be linked directly to manufacturers’ reordering systems, and goods ordered can flow directly from manufacture to the customer
- there is a high rate of returns – reverse logistics and outside the grocery sector, returns levels can vary between 30 and 50 per cent
- some shops become more like showrooms where stock replenishment is no longer an issue

Those companies involved in grocery home delivery have had to develop specialist small vehicles that allow them to deliver different types of grocery products together: ambient, fresh, chilled and frozen. A number of different logistics solutions are still used for the storage and picking elements. Most operations either stock and pick within designated areas of existing DCs or pick from the large retail hypermarkets. The use of specialist home delivery (e-fulfilment) depots is limited (see Chapter 12).

Internet orders tend to be small, with few order lines, few items per line and are generally for individual items rather than whole cases. Thus, the picking workload and cost of operation is much greater for a given throughput of goods, compared to a standard operation. Picking solutions vary. For low throughput operations picking

is likely to be undertaken using multiple order picking on compartmentalized picking trolleys. Thus, up to 20 orders may be picked at a time by the picker. In high throughput operations, zone picking can be used whereby a tote bin representing a single order is transferred via a conveyor to the different picking zones until the order is completed. In some instances, batch picking may be used via a conveyor to an automated high-speed sortation system that sorts the final orders. Other types of technology may also be used, such as pick-to-light and dynamic pick faces for slow-moving lines (see Chapter 21).

Some storage and handling problems have been identified, such as the number of picking errors that can occur in this type of single-item picking operation, damage to the product and the less-than-perfect quality of some fresh food items. As companies have become more familiar with and practised in these operations, these problems have reduced.

There are several different types of company that provide home delivery services. They include internet companies, such as Amazon, that undertake delivery themselves; existing 3PLs that have their own local delivery operations; parcel delivery companies that already have intricate home delivery operations; legacy postal companies that already deliver to the home; and courier services that have developed specific home delivery operations. Final mile delivery is seldom a dilemma if there is a householder to receive the goods that are sent. However, there are many occasions when this is an issue. Several alternative solutions have been considered to overcome this, and other, home delivery problems. They include:

- Urban or city warehouses which are located closer to high-density housing areas to enable fast same-day and two-hour delivery availability.
- The concept of purpose-built semi-trailers for use as mobile parcels sortation hubs, linked to electrically assisted delivery bikes. This latter concept is specifically suited to city/town centre deliveries.
- The provision of secure boxes outside or attached to a property. The average grocery delivery is likely to contain some chilled and some frozen goods, so this approach poses problems for the grocery sector. It is an option, however, that does circumvent the issue of restricted delivery times and so could become attractive for some types of home delivery – although there is a significant set-up cost for supplying the secure boxes.
- Alternative points of delivery, such as a place of work or a petrol station, are used as an alternative to home delivery. Picked and packed goods are delivered to await customer collection. Also, parcel towers, parcel vending machines and coded lockers are available, either in-store or in building forecourts. These types of operation allow for returns to be facilitated.
- To cater for busy lifestyles, grocery companies are offering ‘in-home delivery’ whereby smart lock technology is used. Temporary access is granted to a delivery

driver through a code issued via a smart app. The code is deleted once the delivery is completed. The driver can enter a house and put away frozen and chilled food and leave ambient products as instructed. The delivery is captured on a chest-cam which can subsequently be referred to, as necessary.

- Concepts such as the gig economy and crowd-sourcing have been applied to home delivery, as the personalized delivery of freight or internet orders. This is known as crowd-shipping or crowd-logistics which lend themselves towards opportunities in final mile delivery. Using app technology, those with a car (or even a bike) can offer local delivery services when they have the time available. Such services have a limited geographic reach.
- Various autonomous customer delivery options are under trial. These include the use of autonomous drones (under consideration by companies such as Amazon) and autonomous vehicles that can operate on existing roads and walkways. Potential savings are high as these types of delivery eliminate the high-cost labour element, but safety and reliability are problematic.

The key topic of *customer service* has been previously discussed (see Chapter 3). It should be re-emphasized that customer service issues continue to be of significant importance and to have a major impact on logistics, such that the logistics function has become the key element in customer service strategy. Issues include:

- the development of ‘customer-facing’ organizations and operations – designed and aimed specifically to satisfy customer demands and expectations (rather than the more traditional sales-oriented approach of aiming just to sell what is manufactured)
- a move towards service policies based on market segmentation – thus recognizing that customers and markets can have different requirements and may need to be supplied in different ways (see Chapter 8)
- JIT and quick-response systems requiring markedly more frequent and reliable delivery
- ‘brand image’ becoming less strong – the dominant differentiator being the availability of the product
- the service implications of increased home delivery operations

One example of the ever-changing importance of customer service has been the move to develop an alternative approach to the supply chain by creating what is called *demand chain management* (DCM). Here the intention is to move the emphasis away from the supply of products and towards the demand for products – to reflect the importance of what the customer requires rather than what the supplier wants to provide. Ultimately this is linking the two concepts of supply chain management

(SCM) with customer relationship management (CRM), or linking logistics directly with marketing.

Big Data analytics allow for the manipulation and use of extreme amounts of very detailed data (see also Chapter 40). Thus, the two concepts, SCM and CRM, can be integrated to eradicate any isolation between producer and consumer, and to do this by moving from supplier-facing systems and activities to customer-facing systems and activities. Perhaps this is only a subtle change in thinking – another new consultancy concept? – but it does have the good intention of emphasizing the need to concentrate on the customer rather than the supplier.

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PART TWO
**Planning for
logistics**

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Logistics planning 06 overview

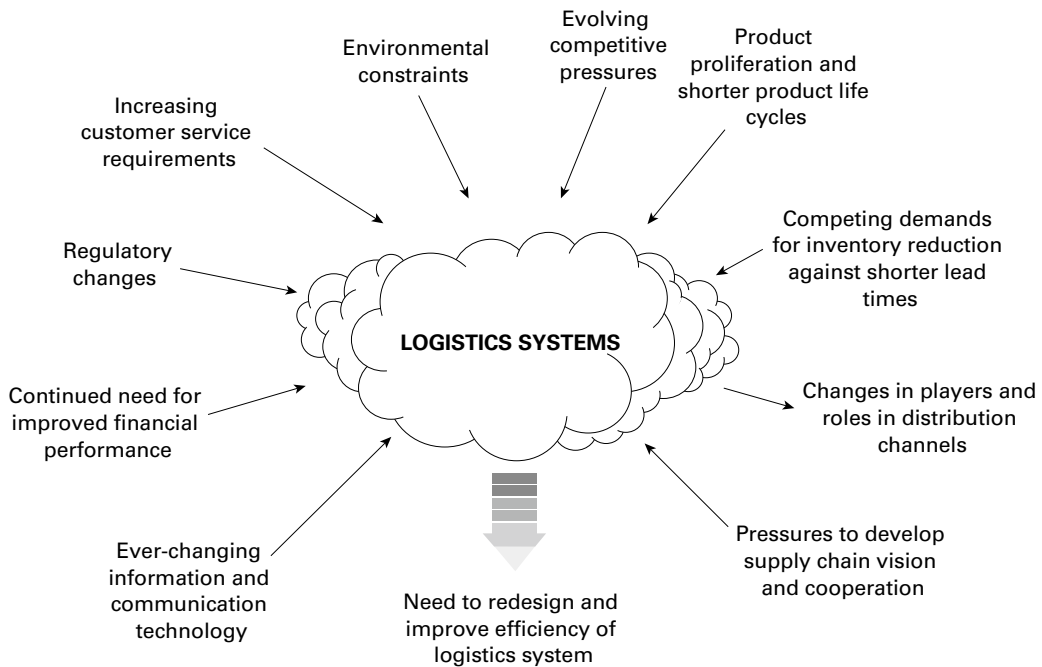
Introduction

The need for a positive approach to planning was discussed in Chapter 2, together with the concept of a logistics planning hierarchy. In this chapter a generalized approach to corporate strategic planning is outlined, and this is linked to a specific logistics design strategy. The main elements of this design strategy are described. Finally, some of the fundamental influences on logistics network planning and design are detailed, in particular, product characteristics, the product life cycle, packaging and unit loads.

Pressures for change

Many organizations adopt a piecemeal and incomplete approach to their strategic planning. This is particularly true in the context of logistics, where individual functions within logistics or the supply chain have often been sub-optimized to the detriment of the logistics chain as a whole. One of the reasons for this incomplete approach is the pressure for change exerted on companies from a wide variety of sources. Figure 6.1 provides an illustration of some of these pressures. They include:

- significant changes in communications systems and information technology, including such developments as the use of Big Data analytics, real-time information and artificial intelligence, as well as the internet, satellite and mobile phone technology
- the need for improved financial performance at a time when companies and economies are under severe pressure
- regulatory changes, such as the development and revision of economic unions, of which the Single European Market (SEM) is one example among many
- increasing customer service requirements, especially where the levels of service that logistics can provide are often seen as a major competitive edge between different companies and their products

Figure 6.1 Pressures influencing logistics systems

- recognition of the importance of various environmental and green issues such as the need to reduce greenhouse gas emissions
- increased competition from global as well as national companies to new breed technology disruptors
- a shortening of product life cycles, particularly for high-technology and fashion products, together with an explosion of product choice
- competing demands for inventory reduction and depot rationalization against shorter lead times and supply chain disruption
- the development of new players with new roles in channels of distribution – this includes the continued growth of third-party service providers and their move to offer global and pan-European operations and to develop supply partnerships
- the need to adopt a wider supply chain perspective when planning, redesigning and operating logistics systems

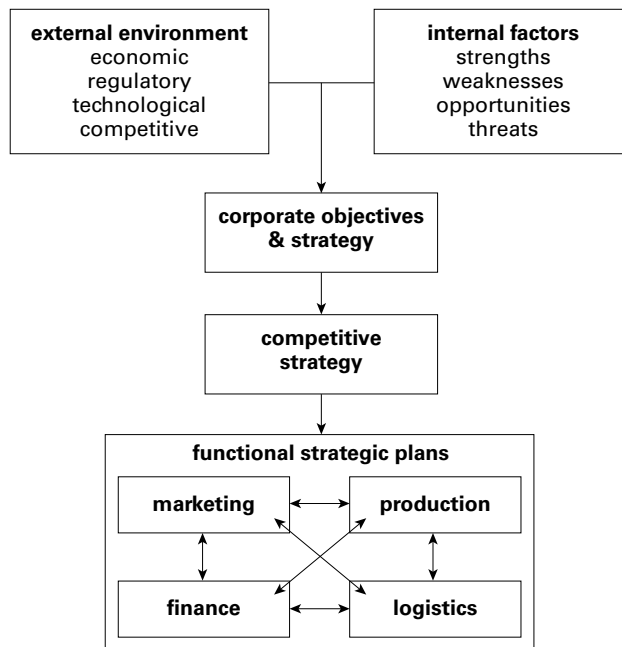
The danger for any organization is to overreact to this need for change. Thus, a measured response is required that enables distribution and logistics systems and structures to be developed as a whole in the context of company strategic plans. In this way, the likelihood of the sub-optimization of logistics activities can be avoided. The quantitative modelling of logistics requirements as a second stage of strategic

business planning is an important aspect of this. This chapter thus focuses on the development and use of a framework and approach that take into account broad organizational and business issues as well as more detailed logistics issues.

Corporate strategic planning overview

A generalized approach to corporate strategic planning is depicted in Figure 6.2. This is in many ways a classic strategic planning approach, but one important point is that it does clearly identify the logistics function as a key part of strategic planning. This is not always the case in some corporate planning processes.

Figure 6.2 Corporate strategic planning overview



The initial phase of a strategic study is very much a data collection exercise to enable key external influences on the company and its operations to be assessed and to allow for the major internal factors that help measure and describe a company to be identified.

This review of the *external environment* within which a company operates is likely to include such factors as the economic climate, current regulations and potential regulatory changes, and any relevant technological developments. Also of importance for most companies would be some sort of evaluation of major competitors – particularly, in this context, any information regarding service and

logistics strategies. One recognized approach to reviewing and evaluating the impact of the external environment is to undertake political, economic, socio-cultural, technological, environmental and legal (PESTEL) analysis. A very broad view of external factors is taken and an assessment is made of the effects of these and how they might influence the strategy of the company. Typical factors to be assessed using PESTEL analysis are shown in Table 6.1.

Table 6.1 PESTEL analysis: external influences

Political Taxation policy Foreign trade policy Trade restrictions and tariffs Government stability Political stability	Technological Government spending on research Government/industry focus on technology New discoveries/development Speed of technology transfer Rates of obsolescence
Economic Business cycles Interest rates Money supply Inflation Unemployment Disposable income Energy availability and cost	Environmental Environmental protection laws Weather, climate, and climate change Carbon footprint targets Business ethics Sustainability
Socio-cultural Population demographics Income distribution Social mobility Lifestyle changes Attitude to work and leisure Consumerism Levels of education	Legal Employment law Consumer rights and laws Health and safety law Monopolies legislation Discrimination law and equal opportunities Advertising standards Product labelling and product safety

An analysis of relevant *internal factors* should also be undertaken. A typical approach is strengths, weaknesses, opportunities and threats (SWOT) analysis. This allows a company to review its position within the marketplace with respect to its products, the demand for its products, the service it offers its customers and the position of its competitors. This type of analysis can and should also be undertaken with respect to identifying a company's key logistical variables.

Approaches such as these enable a company to identify what its overall *corporate strategy* should be. One of the key points that must be addressed is to define what business the company is in. Many companies can be classified as 'retailers' or 'manufacturers', but often a further definition is important because it will have an influence

on how the overall business is organized and structured. Beer provides a useful example. Typically, the brewing of beer has been seen as the key feature of the industry, and the brewing industry has a strong tradition that endorses this. Thus, the brewing of beer is seen as the key activity. However, there are many different aspects that need to be considered when determining how best to get the beer to the customer and many different types of customer. Different elements of a supply chain can be more or less influential dependent on the nature of the product output and the customer type. These requirements can necessitate the development of a variety of very different business and logistics environments. For example:

- *Brewing the beer*: this is the traditional role concerned with production and packaging. Beer production is often seen as a magician's art. Varieties of beer are produced, and they can be packaged in a number of different ways – barrels, kegs, cans, bottles, etc.
- *Environments in which to drink beer*: traditionally these have been pubs, clubs and bars. For the brewing industry a key question is whether or not to own these outlets (and thus have an assured sales outlet) or whether to concentrate solely on the production of the beer. A linked logistics issue is how best to get the beer to the outlets.
- *Environments in which to eat food and drink beer*: these are often known as leisure or lifestyle experiences. Typical are restaurants or 'theme' restaurants where the family might go to eat, drink and play. A major issue for these establishments is the supply and preparation of food as well as drink. For a brewer, this significantly changes the basic business objectives – there are other aspects to consider apart from brewing. Again, there are some obvious and extremely important implications for logistics.
- *Drinking beer at home*: another important aspect is the home consumption of beer and the fact that beer for home consumption is primarily bought from supermarkets, specialist shops, wholesalers or corner shops. The brewer is unlikely to have the option to own these outlets (although, of course, beer can also be bought from pubs and bars for home consumption), but there are very different business, marketing, packaging and logistics implications in competing in this environment.

These represent an overview of some of the alternative business choices a brewer might have. Before attempting to design a competitive strategy and identify possible functional strategies, a company must be clear about which business it is in and what it wants to achieve within this business – a strategy based on set objectives.

In addition to a company's corporate or business strategy, the other element that is crucial is the *competitive strategy* that the company plans to adopt. Competitive strategy has a major influence on the development of logistics strategy and in the

way the physical structure of the operation may be configured. There are a number of influencing factors, but some of the key ones include the extent of globalization – the size and spread of the business, the type of competitive positioning adopted and the degree to which the supply chain is an integrated one. These factors were discussed in Chapter 2, and some of the major implications for logistics were explored.

As indicated in Chapter 2, a company should adopt a competitive strategy by competing as a service or cost leader, or where relevant (and if feasible!) as both of these. A service leader is a company that is trying to gain an advantage over its competitors by providing a number of key added-value service elements that differentiate it from its competitors in terms of what it is offering to its customers. A cost leader is a company that is trying to utilize its resources by offering the product at the lowest possible cost, thus gaining a productivity advantage.

Either of these extremes, or a combination of both, will necessitate a very specific logistics structure. A more service-oriented approach will involve investment in service-enhancing features such as next-day delivery, time-guaranteed delivery, tracking systems, or information support systems (all of which will increase costs). A more cost-oriented approach will aim to reduce costs through methods such as full load deliveries, minimum order sizes, 48- or 72-hour delivery (all of which will limit service possibilities).

Logistics design strategy

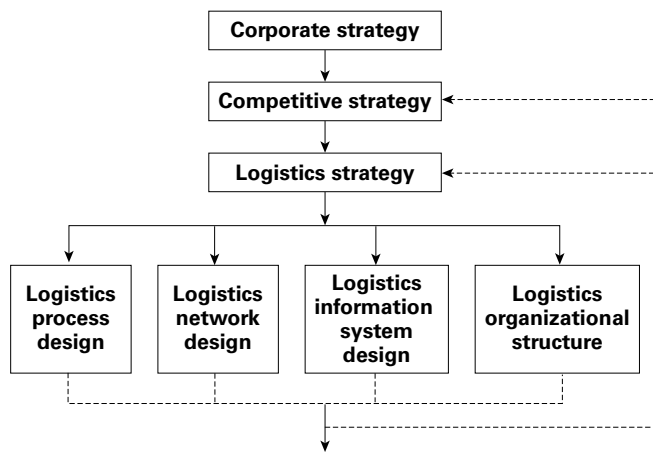
On completion of this initial phase of the business planning process it should be possible to identify corporate strategy and objectives, and to determine a specific competitive strategy. The next task is to prepare appropriate functional strategic plans. Figure 6.2 indicates that such plans can be developed for finance, marketing, production and logistics. For some companies there will be other functions that require specific plans such as research and development (R&D). The remainder of this chapter will concentrate on the functional strategy for logistics.

There are several important issues concerning the development of a suitable logistics strategy. The first is the need to link the logistics or distribution plan directly with the corporate plan. This is best achieved by ensuring that logistics is an integral part of the corporate plan and that factors related to these functions are used as inputs in the overall planning process.

The second point concerns the extent or coverage of the logistics strategic plan. This will clearly vary from one company to another. It may well just be a 'distribution' functional plan, but it is most likely that it will be necessary to incorporate elements from other functions (marketing, production, etc) to represent the fully integrated nature of logistics or the supply chain.

The third, and in many ways most important, issue is whether or not a company has a structured logistics plan at all. Many still don't, so a first and major step may be to ensure that such a plan is developed, based of course on the company's business and competitive strategic plans. To achieve this, a logistics planning framework, as outlined in Figure 6.3, can be used.

Figure 6.3 A framework for logistics network design



As can be seen from Figure 6.3, there are four key logistics design elements that need to be considered. Traditionally, logistics planning and design have evolved around the structure of the logistics network, such as depot numbers and location, but it is now recognized that, as well as these physical logistics elements, there are other factors that also need to be considered. These are the design of logistics processes, logistics information systems and logistics organizational structure.

Logistics *process design* is concerned with ensuring that business methods are aligned and organized so that they operate across the traditional company functions and become supply chain-oriented. Thus, they should be streamlined and should not be affected or delayed because they cross functional boundaries. A typical logistics process is order fulfilment, designed to ensure that customers' order requirements are satisfied with the minimum of time and the maximum of accuracy. The process should be designed as a seamless operation from the receipt of the order to the delivery of the goods and not as a series of different operations that occur each time a different internal function is involved – sales department, credit control, stock control, warehouse, transport, systems design. As well as order fulfilment, other logistics processes that might be considered are information management, new product introduction, returns or spare part provision. Processes might also need to be further developed to take account of different customer types, customer service requirements, product groups, etc. Logistics process design is considered in more detail in Chapter 7.

Logistics *network design* refers to the more traditional elements of logistics strategy. These include aspects related to the physical flow of the product through a company's operation, such as the manufacturing location from which a product should be sourced, the inventory that should be held, the number and location of depots, the use of stockless depots and final product delivery. One key to the determination of an appropriate physical design is the use of trade-offs between logistics components and between the different company functions. Some typical trade-offs were described at the beginning of Chapter 2. A detailed approach to physical design is provided in Chapter 10.

Logistics *information system design* should include all of those information-related factors that are vital to support the processes and the physical structure of the operation. As well as these, however, it is important to recognize that there are also enterprise-wide information systems (enterprise resource planning or ERP systems), which may directly influence logistics process and network design. Typical information systems that may support logistics process and network design include electronic point-of-sale (EPOS), electronic data interchange (EDI) between companies, warehouse management systems and vehicle routing and scheduling, as well as the use of Big Data analytics, real-time information and artificial intelligence (outlined in Chapter 40).

The final design element is that of the logistics *organizational structure*. It is the experience of many companies that an inadequate organizational structure can lead to substantial problems. These include issues such as sub-optimization whereby functions tend to concentrate on their own operation in isolation from the rest of the company, or even worse examples where different functions and their managers compete against one another and develop antagonistic attitudes, often styled as a 'blame culture'. These types of attitude work against the company but are also detrimental to customers and customer service. Organizational issues are further discussed in Chapter 11.

Each one of these different logistics design factors needs to be planned in association with the others. It is inappropriate to concentrate on any one without understanding and taking into account the influence of the others. Although Figure 6.3 has process design as the first logistics design factor, this does not mean that it is necessarily the first one that should be considered when a strategic study is undertaken. For different companies it may be any one of the other design factors that plays the most dominant role. For example, a company that has introduced an enterprise-wide information system may find that this has a primary influence on how logistics strategy is formulated, because it has a set structure that needs to be accommodated with the various processes that are to be developed. Equally, a company may feel that it is necessary to put a workable logistics organizational structure in place before it attempts to redesign its logistics processes and physical operations – so that those

who are to manage and operate the system will also plan it and thus have a vested interest and responsibility in its success.

Note that Figure 6.3 emphasizes the need for constant reappraisal within the planning process (the arrows that refer back to previous steps in the planning process). Logistics and supply chain operations are dynamic by their very nature and require regular and ongoing reappraisal as many elements (customer demand, customer types, products, technology, etc) continue to adapt and change over time.

The different tools and techniques for undertaking logistics design are described in the next few chapters. Before considering these, the remainder of this chapter looks at some key logistics factors that also have an influence on how a logistics operation is designed.

Key logistics design factors

Product characteristics

One of the major factors to be considered when planning for logistics is, perhaps not surprisingly, the product itself. The product is, in fact, perceived to be an amalgam of its physical nature, its price, its package and the way in which it is supplied. For the logistics planner, the physical characteristics of the product and package are seen to be of great significance. This is because, in distribution and logistics, we are directly concerned with physical flow – movement and storage. The physical characteristics of a product, any specific packaging requirements and the type of unit load are all-important factors in the trade-off with other elements of distribution when seeking least-cost systems at given service levels. This potential for trade-off should continually be borne in mind.

There is a variety of product characteristics that have a direct, and often important, impact on the development and operation of a distribution system. This impact can affect both the structure of the system and the cost of the system. There are four main categories: volume-to-weight ratio; value-to-weight ratio; substitutability; and high-risk products.

Volume-to-weight ratio

Volume and weight characteristics are commonly associated, and their influence on logistics costs can be significant. A low ratio of volume to weight in a product (such as sheet steel, books, etc) generally means an efficient utilization of the main components of distribution. Thus, a low-volume/high-weight product will fully utilize the weight-constrained capacity of a road transport vehicle.

The converse, a high volume-to-weight ratio, tends to be less efficient for distribution. Typical products include paper tissues, crisps, disposable nappies, etc. These products use up a lot of space, and are costly for both transportation and storage, because many companies measure their logistics costs on a weight basis (cost per tonne) rather than a volume basis (cost per cubic metre). In Europe, for example, draw-bar trailer outfits are often used to increase vehicle capacity and so decrease the transportation costs of moving high-volume products.

Companies need to recognize the extent to which both weight and volume drive their distribution costs.

Value-to-weight ratio

Product value is also important to the planning of a logistics strategy. High-value products are more able to absorb the associated distribution costs because the distribution element is a relatively low proportion of the overall product cost. Low-value products need to have an inexpensive distribution system because the cost is a large proportion of the overall product cost – and if too high the effect on the total cost of the product might make it non-viable in terms of its price in the marketplace.

Once again, it is useful to assess the value effect in terms of a weight ratio: this is called the value-to-weight ratio. Low value-to-weight ratio products (e.g. ore, sand, etc) incur relatively high transport unit costs compared with high value-to-weight products (e.g. computers, mobile phones, etc). Inventory holding unit costs of low value-to-weight ratio products tend to be low in comparison with high-value products because the capital tied up in inventory is much lower for the low-value products.

Substitutability

The degree to which a product can be substituted by another will also affect the choice of distribution system. When customers readily substitute a product with a different brand or type of goods, then it is important that the distribution system is designed to avoid stockouts or to react to replenish stocks in a timely fashion. Typical examples are many food products, where the customer is likely to choose an alternative brand if the need is immediate and the first-choice name is not available.

In a distribution system, this can be catered for either through high stock levels, additional local distribution centres or through a high-performance transport mode. All of these options are high cost. High stock levels will decrease the likelihood of a stockout, but will raise average stock levels and, thus, costs. Additional depots would be costly. The provision of a faster and more dependable transport function will reduce acquisition time and length of stockout, but this increase in service will be at a higher transport cost.

High-risk products

The characteristics of some products present a degree of risk associated with their distribution. Typical examples include: perishability, fragility, hazard/danger, contamination potential and extreme value. The need to minimize this risk (sometimes a legal obligation) means that a special distribution system design must be used. As with any form of specialization, there will be a cost incurred. Examples of this effect are as follows:

- Hazardous goods may require special packaging, a limited unit load size, special labelling and isolation from other products. Regulations for the movement of hazardous goods differ between the different modes of transport.
- Fragile products require special packaging to take account of handling and transport shocks. Specialist distribution service providers exist for some types of fragile goods.
- Perishable goods in many instances require special conditions and equipment for their distribution (e.g. refrigerated storage and transport facilities for frozen and chilled food).
- Time-constrained products – almost all foods are time-constrained, especially those with ‘best before’ or ‘use by’ dates – have implications for distribution information and control systems (e.g. first in/first out). Some products have fixed time or seasonal deadlines: daily newspapers have a very limited lifespan, which requires early morning delivery and allows for no delivery delays; fashion goods often have a fixed season; agrochemicals such as fertilizers and insecticides have fixed time periods for usage; there are the classic seasonal examples of Easter eggs and Christmas crackers, which are time-constrained. There are significant implications for the choice of distribution system for many products such as these.
- Very high-value products – cigarettes, mobile phones, computer tablets, etc – are attractive products that require especially secure means of distribution.

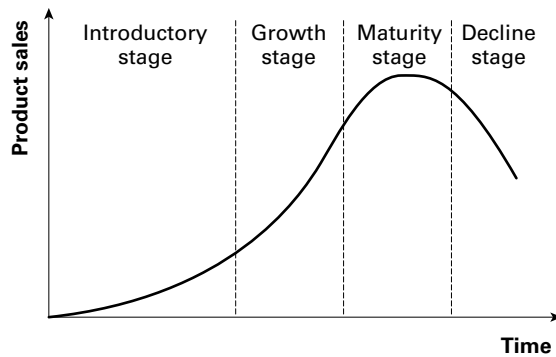
There are many and varied product characteristics that can impose important requirements and constraints on all manner of logistics operations. They also affect the interrelationships between the different logistics functions, providing quite complex alternatives that need to be carefully assessed according to the implications on service and on cost.

The product life cycle

One marketing concept that concerns the product and is also very relevant to distribution and logistics is that of the product life cycle (PLC). The principle behind

the PLC is that of the staged development of a product. This starts with the introduction of the product into the market and follows (for successful products) with the steady growth of the product as it becomes established. The life cycle continues with the accelerated growth of the product as competitors introduce similar products at competitive prices, which reduces the demand for the company's product, and ends as the demand for the product runs into acute decline. The PLC concept is illustrated in Figure 6.4.

Figure 6.4 Standard product life cycle curve showing growth, maturity and decline



It is important that the performance of a logistics operation is able to reflect and respond to the developing life cycle of a product. This can be differentiated as follows:

- *Introductory stage:* here, there is usually a requirement for an operation that can provide a high response to demand with a logistics structure that gives stock availability and quick replenishment, and can react to sudden demand increases. Initial retail stockholdings are likely to be low, to avoid the overstocking of products that might not fulfil their expected demand. Thus, there is a need for speedy information and physical logistics systems, probably from a centralized stockholding base and using a fast mode of transport.
- *Growth stage:* here, sales are more predictable. The requirements for distribution are now for a better-balanced, more cost-effective system. The trade-off between service and cost can be realized.
- *Maturity stage:* this is where the introduction of competitive products and substitutes are likely to increase price and service competition. Thus, an effective logistics operation becomes vital in order to maintain market share, especially for key customers.
- *Decline stage:* here, the product is becoming obsolete. The logistics system needs to support the existing business but at minimum risk and cost.

There is a clear requirement to take account of the product life cycle when planning for logistics. A different emphasis needs to be placed on certain aspects of the logistics system according to the stage of a product's life. For operations where there are many products at varying stages of their product life cycle, the effect on the overall system may not be apparent. In many instances, however, there will be a need to plan a logistics operation that is suitably dynamic and flexible to reflect the changing characteristics of a product (see Chapter 8, 'Supply chain segmentation').

Packaging

As a part of considering the product and its logistics requirements, it is important to be aware of other relevant physical characteristics that can influence any decisions regarding the choice of logistics operation. In terms of the physical nature of a product, it is not generally presented to the logistics function in its primary form, but in the form of a package or as a unit load. These two elements are thus relevant to any discussion concerned with the relationship of the product and logistics.

The packaging of a product is broadly determined for product promotion and product protection, the latter being the function that is particularly pertinent to logistics. There are also some other factors that need to be considered when designing packaging for logistics purposes. In addition to product protection, packages should be easy to handle, convenient to store, readily identifiable, secure and of a shape that makes best use of space – usually cubic rather than cylindrical.

Once again, there are trade-offs that exist between these factors. These trade-offs will concern the product and the logistics operation itself. It is important to appreciate that, for those involved in logistics, the package is the product that is stored and moved and so, where possible, should be given the characteristics that help rather than hinder the logistics process.

Packaging is very much a part of the total logistics function, and the design and use of packaging has implications for other functions such as production, marketing and quality control, as well as for overall logistics costs and performance.

Unit loads

The idea of using a unit load for logistics was developed from the realization of the high costs involved in the storage and movement of products – particularly in the inefficient manual handling of many small packages. The result of this has been the unit load concept, where the use of a unit load enables goods and packages to be grouped together and then handled and moved more effectively using mechanical equipment. Two familiar examples are the wooden pallet and the large shipping

container, both of which, in their different ways, have revolutionized physical distribution and logistics. From the product point of view, it is possible to introduce unit load systems to alter the characteristics of a product and thus make more effective logistics possible. One classic example has been the development of the roll-cage pallet that is in common use in the grocery industry to aid the movement of products from depots into store stockholding areas and onto the shop floor. Although the cages are expensive units, the trade-off, in terms of time saving and security, is such that overall distribution costs decrease significantly.

Much of distribution and logistics is structured around the concept of load unitization, and the choice of unit load – type and size – is fundamental to the effectiveness and economics of a logistics operation. Choosing the most appropriate type and size of unit load minimizes the frequency of material movement, enables standard storage and handling equipment to be used with optimum equipment utilization, minimizes vehicle load/unload times, and improves product protection, security and stocktaking.

Logistics processes

07

Introduction

As discussed in Chapter 6, one of the key elements of planning for logistics is the design of appropriate logistics processes. These processes are the methods that are used to ensure that the business operates effectively so that all major objectives are achieved. The aim is for a streamlined operation that works across the various functional boundaries that exist within any company. Thus, processes need to be supply-chain-oriented. One of the main problems with many logistics processes is that although they are very often the responsibility of one particular function, they are spread across the boundaries of several different ones, making effective planning and operations more difficult. The consequences of this are usually inefficiencies, which show up as additional costs within the logistics system or lower levels of customer service. In many companies, both of these effects occur.

In this chapter logistics processes are considered and the need to move away from functional and towards cross-functional process development is explained. The main reasons for adopting more streamlined processes are discussed. Some of the key logistics processes are described, and the ‘process triangle’ is introduced as a means of categorizing the different processes. A broad approach to process design is outlined, and the main steps in this approach are discussed. Finally, some key tools and techniques are described. These can be used for logistics process redesign.

The importance of logistics processes

The reason that logistics processes are highlighted is because there is a recognition that a broader, holistic view of logistics is more appropriate than the traditional functional approach. Although functional excellence is important – if you are running a fleet of vehicles, it is still important to ensure that it operates cost-effectively and fulfils all the necessary requirements – the concept of trade-offs within logistics is now an accepted aspect of sound logistics planning (see Chapter 2). An individual element may be sub-optimized to the greater good of the operation as a whole.

Following on from this is the broader supply chain perspective that the logistics function is viewed not just across internal company functions but also across the expanse of different companies. The chief beneficiary of this has been the final customer. The aim of any supply-chain-oriented approach is to ensure that cross-company and cross-supply-chain activities are directed at achieving customer satisfaction for the end user. Thus, processes need to be developed to make this happen. They need to be able to span across internal functions and company boundaries to provide the type and level of customer service required. Unfortunately, this does not happen in a number of companies.

Functional process problems

Processes were traditionally derived to enable each separate function within an organization to undertake its particular role, so they were not streamlined to act across all company functions as a united whole. An effective process should be designed as a seamless operation rather than as a series of different elements.

The order fulfilment process provides a good example of a typical logistics process. The aim of order fulfilment should be to ensure that a customer's order is received, checked, selected and delivered according to the customer's requirements, with no disruption and with complete accuracy. The process within many companies does not always work like this! As well as the possibility of error or delay within functions, there is also the possibility of error and delay between the different functions. Typical functional errors might be:

- incorrect transcription of the original order requirements
- incorrect notification of availability
- incorrect selection or picking of the order
- damage to the goods
- late delivery
- delivery to an incorrect address
- invoicing to the incorrect address

Cross-functional process problems

In addition, there might also be errors and delays associated across the functional boundaries. Examples might include:

- website not designed to show real-time out-of-stock situation at time of order, resulting in customer not being advised of delayed delivery date until much later
- stock may appear to be available but is actually pre-allocated to another customer

- order details may be incorrectly transcribed because there is no automated link between one information system and another
- credit control may delay the progress of the order – but the customer may not be informed
- different goods may be picked because the original requirement is out of stock so the ‘next best’ is selected, and the customer may not be informed of this
- goods may not be delivered as part orders due to some product unavailability, when partial delivery may be better than no delivery
- goods may be physically delivered via an incorrect channel – to the customer’s cost (next-day rather than the normal three-day service)

It is usually quite easy to identify problems that occur within individual functions and then put into place control measures to overcome these problems. It can be much more difficult to identify problems that occur between functions. First, there may be an unclear line of demarcation between functions, which makes it no easy matter to determine that there is a problem, let alone what the problem is. Second, it may be very difficult to determine what the cause of the problem is – not least because of the associated ‘blame’ culture that may exist between functions, so that one will traditionally blame the other regardless of the true issues.

To avoid issues such as these, some companies now seek to redesign their key logistics processes. There are three essential elements to achieving a successful redesign. Properly designed processes should be customer-facing, that is, they should aim specifically to satisfy customer demands and expectations. They should also be cross-functional, or indeed where possible they should be supply-chain-oriented in that they cross not just company functions but also the boundaries between several companies. For most companies, the aim of achieving cross-functional processes is a big and daunting challenge. Finally, they should be time-based in that they need to reflect the importance of time as a key element in the logistics offering.

Before considering the methods by which processes can be redesigned, the different process types and categories are outlined.

Logistics process types and categories

Key logistics processes

What then are the key logistics processes? Some are very common to many businesses, but others, as may be expected, vary between different organizations, different sectors and different industries. Typical examples are:

- *Order fulfilment*: probably the most common logistics process that is quoted, order fulfilment is concerned with the ability to turn a customer's requirements into an actual delivered order. Thus, it embraces many of the traditional functions usually recognized as being a part of the logistics operation. Order fulfilment will involve the information elements of receiving and specifying an order through to the physical means of selecting and delivering the goods. For some 'make-to-order' manufacturing operations, this will also have an impact on the production process itself. Some companies maintain the divide between the order-taking component (which is information-based) and the order-delivery component (which is both information-based and physical). This is a reasonable first step in process redesign, but ultimately there should be a seamless process for the operation as a whole.
- *New product introduction*: this is an area where many companies find they have problems. There are many logistics issues related to the introduction of new products into the marketplace. Very often existing, standard logistics structures and processes can be inappropriate to enable a satisfactory launch of a new product. One of the main problems is the inability to respond with sufficient speed. Standard processes are designed to deal with known products. There are two likely consequences of introducing new products using existing processes. The first is that the product takes off very quickly and very well but there is insufficient flexibility in the supply chain to ratchet up supply to the required levels. The second is that demand is lower than initially expected and so there is an oversupply of stock, which eventually leads to products being sold off at discount rates or becoming obsolete.
- *New product development*: for new product development, the idea is to design the product so that it can reach the market as quickly as possible from the initial design plan through to availability to the customer. The aim is to link the development of the product with the logistical requirements so that all secondary developments (of which there are normally many) can be identified and re-engineered in the shortest possible time.
- *Product returns*: there is a growing requirement in many businesses to provide an effective process for the return of products. This may be for returns that come back through the existing distribution network or through a new one that is specifically set up. The process may be required to include movements for a variety of reasons: it may be for product returns that will be reworked or repackaged to go into stock; product returns for subsequent disposal; or packaging returns that may be reused or scrapped. In the light of developments in environmental legislation, this is a very important area for process design or redesign.
- *Aftermarket or service-parts logistics*: for a significant number of companies, the supply of a product or series of products is inextricably linked to the subsequent

provision of service-parts to support the continuous use of the initial products. For many logistics operations, neither the physical structure nor the associated processes for the original equipment are capable of also providing a suitable support mechanism for the spare parts. This is another example of the need for the development of processes specifically designed to undertake a particular task.

- *Information management*: advances in information technology have enabled a vast amount of detailed data and information to be available and manipulated very effectively. This has led some companies to recognize the need to devise suitable processes to ensure that data is collected, collated and used in a positive and organized way. For logistics, this means detailed information can be made available for individual customers, concerning not just their product preferences but also any customer service requirements that are distribution-specific (delivery time preference, order size preference, real-time delivery tracking). This enables a much more positive, proactive approach to be adopted when considering particular customer relationships.

There are other associated processes that could also be relevant, such as supplier integration, quality, strategic management, maintenance, human resource management and environmental management.

Process categorization

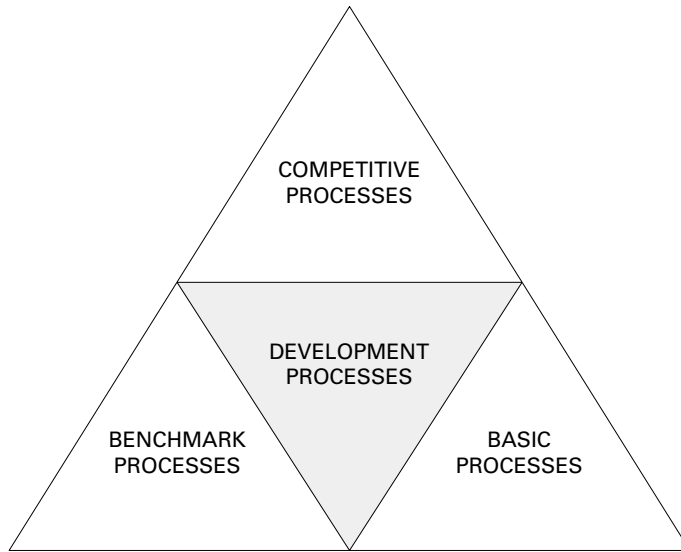
Several different concepts have been proposed to try to help differentiate the type and importance of the various processes that might be relevant to any given company as it tries to position itself with its customers. Perhaps the most useful of these is known as the process triangle. This is shown in Figure 7.1. The process triangle is based around three different process categories. These can be used to help identify those particular processes that need to be highlighted for specific development. The key process categories are as follows:

- **Basic processes**: those processes that are essential to a business and are therefore a prerequisite.
- **Benchmark processes**: those processes that are seen to be important to the customer and must be of at least an acceptable standard to begin to compete satisfactorily in a given market.
- **Competitive processes**: those processes that are of direct significance to the competitive arena. Good practice and excellence in these processes are likely to provide a competitive edge and ensure that the company is active and successful through its logistics operations.

An assessment of what is required in these three areas and then the identification of what is missing – the ‘gap’ – will enable the development processes to be identified

(the central element in the diagram shown in Figure 7.1). This will include all of the process areas on which further work is necessary to ensure that the company will achieve or maintain a suitable competitive position.

Figure 7.1 The process triangle: used to help differentiate the type and importance of the various processes within a company, and to identify which processes need to be redeveloped



It would be difficult for any company to develop a suitable process to cover all possible contingencies. Thus, it is useful to understand some of the main methods of differentiating between the various factors that are fundamental to most logistics operations. Processes can then be developed to suit different requirements. Typical differentiating factors will include:

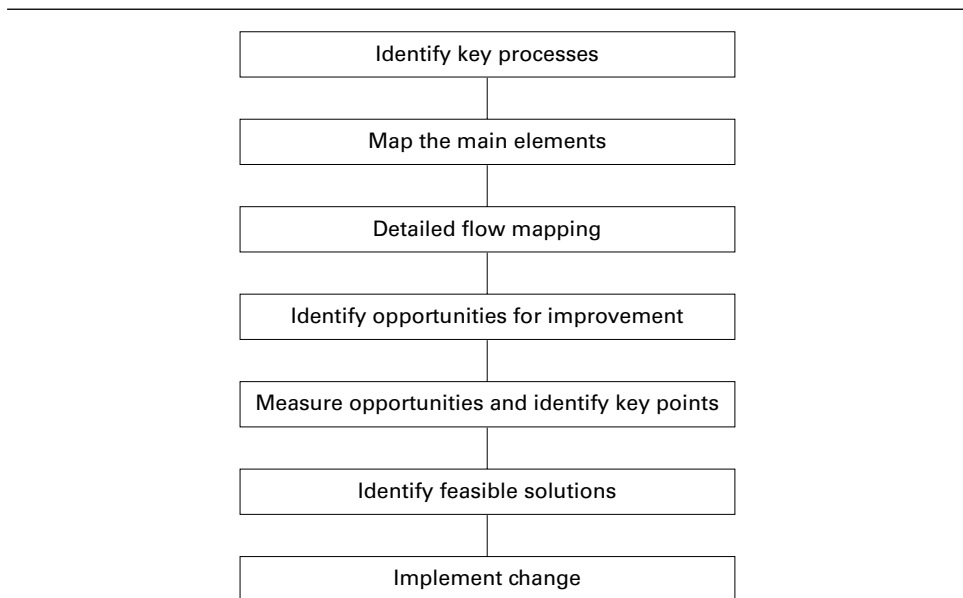
- market segmentation: there may be different requirements for different sectors – engineering, automotive, chemicals, etc
- customer types: these may vary between, for example, industrial and consumer, or international, national and local
- product groups: these may be broken down according to a variety of categories, dependent on the industry – household, industrial, consumer, or hardware, software, spares, etc
- customer service requirements: these may vary between same day, next day, normal, special, etc
- order type: these could be made to order, off the shelf, postponement (partial production)
- channel type: these could be direct, via depot, via wholesaler

An approach to process design and redesign

In this section an approach to process design and redesign is provided and then the final section of the chapter describes a number of different tools and techniques that can be used to support the approach. The idea of redesign is introduced here to emphasize the point that it is often the redesign of existing processes that is the major concern and opportunity in most logistics operations rather than the setting up of new processes.

The approach to process design is outlined in Figure 7.2. The first step is to *identify the key processes for design or redesign*. This can be undertaken in a variety of different ways, but it is important that representatives of all the main functions from within the company are included in the team that identifies these key processes. Typically, some type of brainstorming exercise will provide the initial ideas, linked closely with a customer service study similar to that described in Chapter 3. As usual, it is imperative to get a clear view of customer service requirements, and these can only be truly identified through close contact with the customer. Any opportunity to benchmark against key competitors will also be advantageous.

Figure 7.2 Approach to process design or redesign



The next stage is to *map out the main elements* of each process that is to be redesigned. The objective is to identify the key steps in each process and clarify which departments and people are involved. Key outcomes are to provide an understanding of what the process is all about, what it is trying to achieve, what some of

the main problems are and perhaps to provide an indication of some of the potential improvements that might be introduced.

After the initial mapping stage is completed, the next step is to undertake a much more *detailed flow mapping exercise*. Here, the work flow is identified in detail as it progresses through each relevant department. Each crucial part of the process is identified, together with the specified amount of time taken to complete each of these parts. Any problems are identified and noted. The complicated nature of processes such as order fulfilment means that the mapping exercise itself is likely to take a lot of time and effort. In general, the specific opportunities that should be identified are those with a high potential for positive change, and those that are either very high in cost or very high in terms of the time taken to complete that respective part of the process, or of course all of these. Additionally, it may be possible to identify some parts of the process that are entirely superfluous. This is not uncommon with many processes that have been allowed to develop over time without any specific replanning.

Once the detailed flow mapping has been completed any *opportunities for improvement* can be identified. It is useful to set up a specific team to undertake this and the remaining stages of the process redevelopment. This team should be one that has the full backing of senior management and should also be representative of the main departments to be affected by the redesign. The team should be in a position to complete any additional or more detailed mapping or *measurement* as necessary, and from this identify any key points that arise. It should *identify any feasible solutions* and then get overall agreement for any changes that it is felt should be put into practice.

The final stage, once agreement for change has been reached, is to *implement any change*. This may be undertaken on a pilot basis at first to test the effectiveness of the redesigned process. Subsequently, measures should be put in place to monitor the process continually into the future.

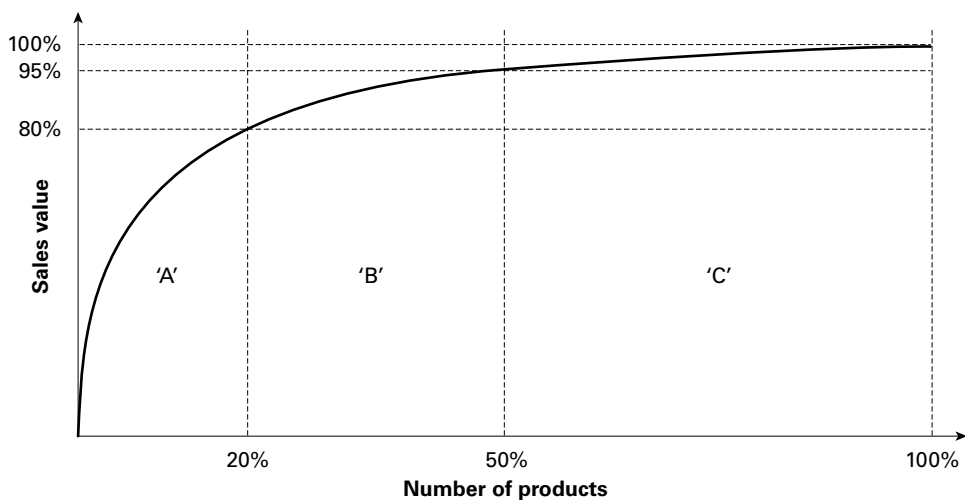
Tools and techniques

There are a number of different tools and techniques that can be used to help with logistics process redesign. These range from those that provide assistance with the initial categorization of key process objectives to those that offer a detailed assessment of the processes themselves and thus can be used to identify opportunities for improvement. Some of these techniques have been adopted in manufacturing under the umbrella known as ‘Six Sigma’ (see Chapter 13). Some of the main alternatives are:

- *Pareto analysis*: this is sometimes known as ABC analysis or the 80/20 rule and it is an important method used in logistics for identifying the major elements of any business or operation. By identifying these main elements, it is possible to ensure

that any analytical assessment is concentrated specifically on key aspects and is not taken up with the peripheral less consequential detail. A typical Pareto curve is shown in Figure 7.3. In this example, 20 per cent of the product lines or SKUs (stock-keeping units) are responsible for 80 per cent of the sales in value of the company's products and this shape of curve is common to most companies. This type of relationship holds true for many aspects of logistics and distribution – the most important customers, the most important suppliers, etc. Thus, it is possible to identify a limited number of key elements that are representative of the main business and to concentrate any major analysis on this important 20 per cent. Another useful result of Pareto analysis is to identify the items (customers, products or whatever) that make up the final 50 per cent of the 'tail' of the curve. These are often uneconomic to the company and should be considered for rationalization or elimination, depending on their actual profitability and their support to the overall product portfolio. In Figure 7.3, 'A' class products represent 20 per cent of the range of products, but account for 80 per cent of sales; 'B' class products represent 30 per cent of the range of products, but account for 15 per cent of sales; and 'C' class products represent 50 per cent of the range of products, but account for just 5 per cent of sales.

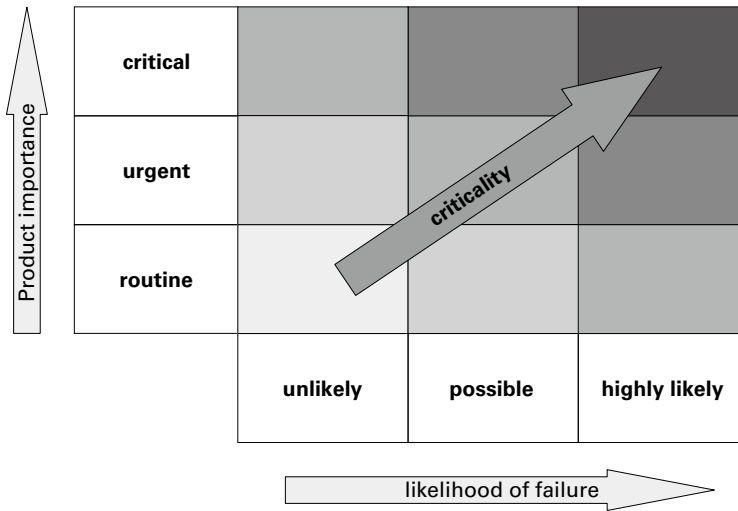
Figure 7.3 A typical Pareto curve showing that 20 per cent of products represent 80 per cent of sales value



- *Criticality analysis*: this can be used to rank products according to their importance and to differentiate the way in which they may be considered in a variety of circumstances. For example, it can be used for spare parts in order to identify how critical they are to a given machine. Critical parts may then be given a high service

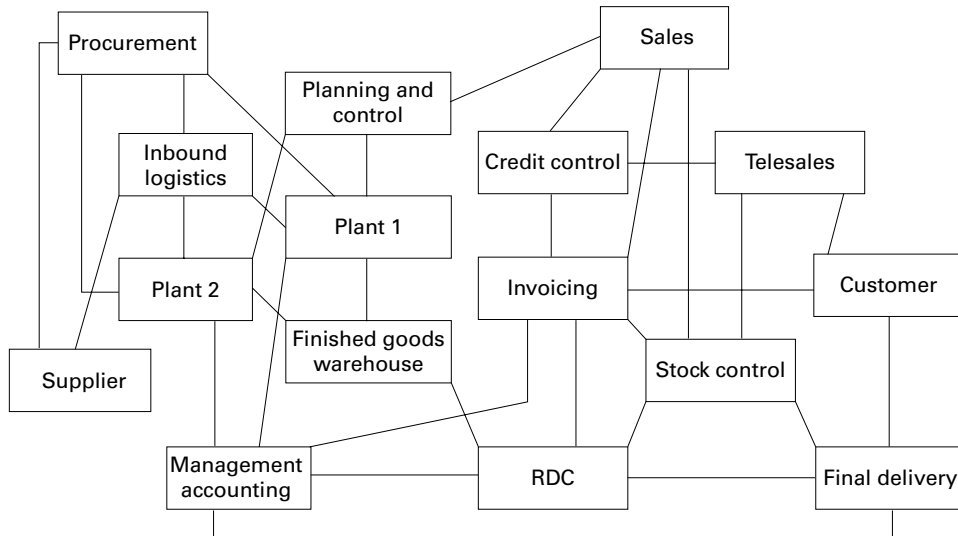
level, and non-critical parts a lower service level. This procedure can be conducted as a quantitative analysis or, where data is limited, as a qualitative (subjective) analysis. A criticality matrix can be developed, which is a graphical or visual means of identifying and comparing the criticality or service level requirements of all products within a given system or subsystem and their probability of occurring with respect to severity. The matrix can be used to prioritize products according to their service requirements. An example of a 3×3 criticality matrix is given in Figure 7.4.

Figure 7.4 An example of a criticality matrix



- *Market or customer segmentation*: one of the main objectives of the design of suitable logistics processes is to ensure that they are ‘customer-facing’ and to align them in such a way that all customers’ needs are met. Clearly, not all customers are the same and therefore not all customer requirements are the same. It is important to be able to identify different types of customers and different types of market and to adopt the appropriate service requirements to take account of these differences. Through the use of suitable customer service studies (as described in Chapter 3) it should be possible to categorize companies according to different types of service requirement. Suitable processes can then be based around the different categories of customer or segments of the market.
- *Customer service studies*: as already described in Chapter 3, a customer service study should be used as the basis for identifying key service requirements on which to design suitable logistics processes.
- *Relationship mapping*: this is used at an early stage of logistics process design to identify the main departments within a company (or across the broader supply

Figure 7.5 Relationship mapping: used to identify key departments and their interrelationships



chain if this is possible) that are specifically involved in a particular process. An example is given in Figure 7.5. As well as identifying these key departments, so that they can be brought into the design process, this will help to pinpoint the major relationships and will highlight the complexity within any particular process, thus indicating its need for redesign.

- *Process charts:* processes can be represented using a variety of different methods, whether by straightforward flowcharts or by a matrix, as shown in Figure 7.6. The flowchart approach can be based on traditional flowcharting techniques. This is useful because standard shapes are used to represent different types of activity (storage, movement, action, etc), and the importance of flows can be highlighted in terms of the number of movements along a flow. The matrix chart of Figure 7.6 provides a more systematic way of representation and can be beneficial where time is to be represented.
- *Value/time analysis:* this type of analysis can be used to identify the points in a process where cost is incurred and value is added to the product. The aim is to highlight, and subsequently eliminate, those parts of the operation that provide a cost but add no value. Traditionally, for most manufactured products, value is added when a process changes the nature of the product (such as production, which alters the physical attributes; or transport, which alters the physical location). Value is not added, but waste occurs through the passing of time, for example, when a product is stored as work-in-progress between operations. Figure 7.7 provides an example of a value/time analysis. This is not an easy type

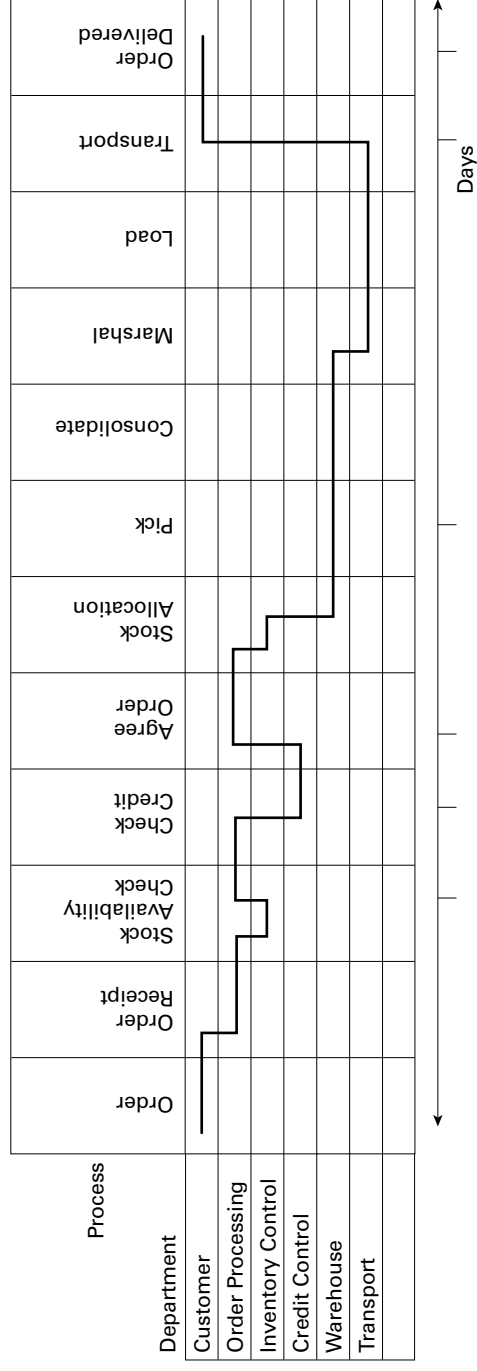
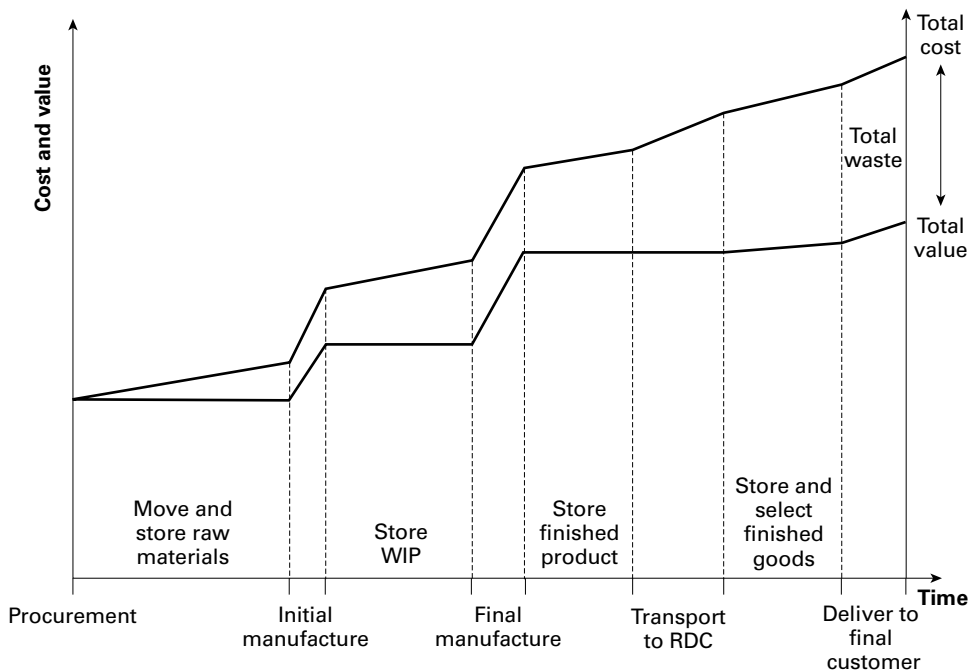


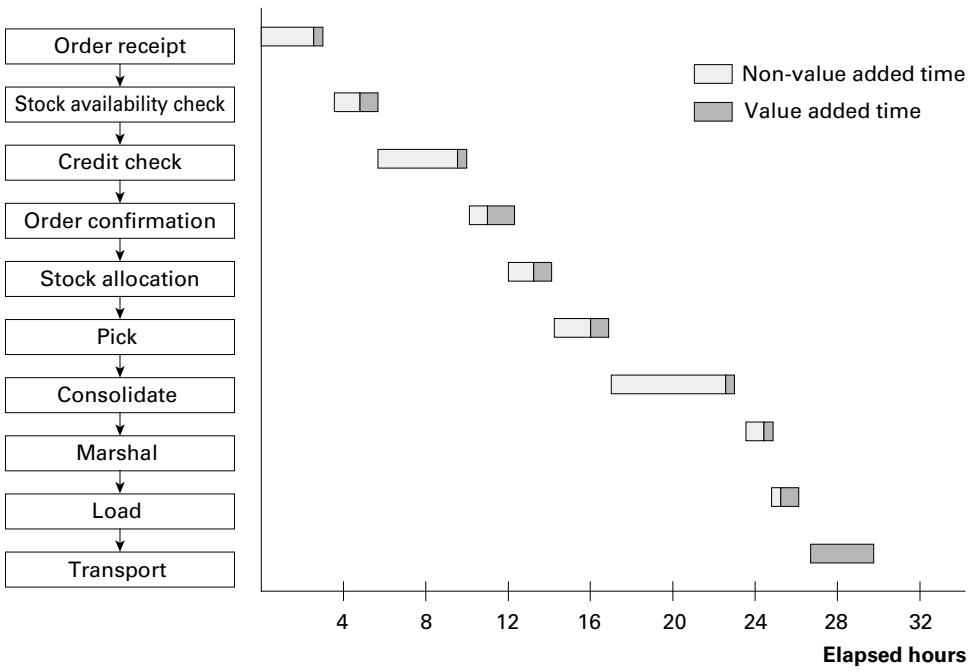
Figure 7.7 Value/time analysis

of analysis to undertake, especially for the early downstream activities when it becomes difficult to isolate the true time and costs attributable to partially manufactured products.

- *Time-based process mapping*: this is another method of identifying and eliminating wasted time in a process. The idea is to understand and record a process in detail and to be able to identify what is active or useful time and what is wasted time. The output from such an exercise is the opportunity to engineer the wasted time out of the process so that service is improved and cost is reduced through a reduction in the overall time taken to complete the process. The simple steps are:
 - a** Map the process by ‘walking’ through the actual operation and recording the key steps and the associated time taken.
 - b** Identify and differentiate between what is value-adding (e.g. necessary) and what is non-value-adding (e.g. unnecessary) and record this.
 - c** Calculate the relative time spent on the different activities and identify the most appropriate for improvement.
 - d** Analyse the causes of the problem and assess any opportunities for change.
 - e** Develop solutions and implement.

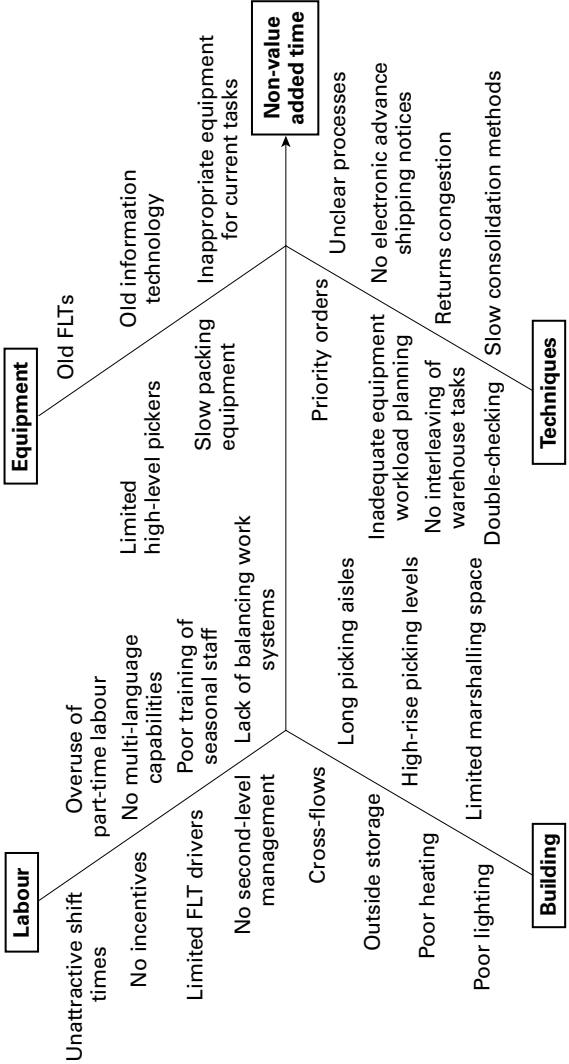
An example of a time-based process map is given in Figure 7.8.

Figure 7.8 A time-based map illustrating the order to dispatch process broken down into value-added and non-value-added time



- *Root cause analysis*: this is a method that can be used to help to identify the causes of non-value-added time. The example here is based on an Ishikawa diagram and is shown in Figure 7.9.

Figure 7.9 Root cause analysis: finding the cause of non-value-added time in a depot using an Ishikawa diagram



Supply chain segmentation

08

Introduction

As noted in Chapter 2, a ‘one-size-fits-all’ approach to logistics is not appropriate in most instances. Some form of supply chain segmentation is therefore necessary for a company to satisfy the different service and cost needs of its customers. In addition to the channel options discussed in Chapter 4, this raises the question of exactly how a company’s own supply chain should be segmented. For example, one type of supply chain may be appropriate for large bulky items and another for small parcels. Similarly, a supply chain may be necessary for highly demanding customers separate to that generally available to the market. There are many different ways in which supply chains may be segmented and this chapter explores some of the more common segmentation approaches that are available.

Product segmentation

It may be necessary to have different supply chains because of the very nature of the products. For example, when delivering to petrol stations the fuel may be delivered in large road tankers whereas the food and other items for the petrol forecourt shop would need to be delivered in clean, enclosed vans or trucks. Some key product characteristics were described in Chapter 6. Such product characteristics are often an important basis for supply chain segmentation. Examples include:

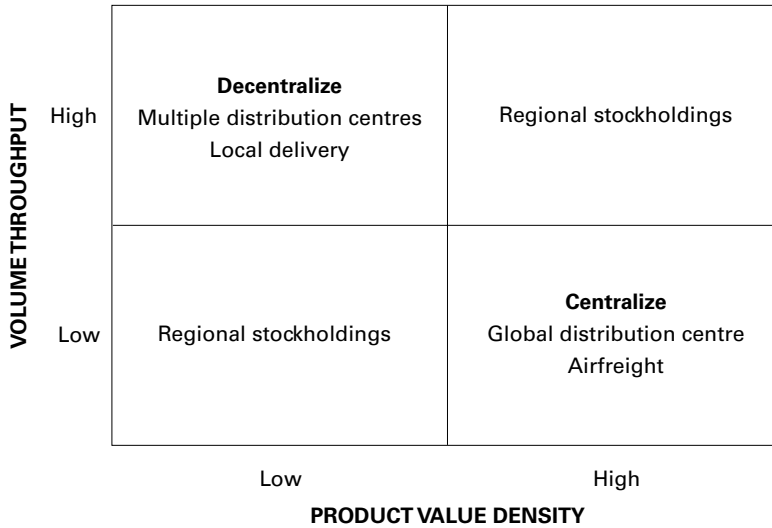
- **Size:** the size of the product (or the total order) may determine whether it is best suited to be delivered via a palletized delivery network or by parcel carrier or by post. Another example is where large items, such as beds or sofas, require two people to unload and, in such instances, it is often found more cost-effective to set up a separate network just for large bulky items, rather than having two people in a vehicle for all deliveries.
- **Temperature regime:** there are three main temperature regimes for food products, namely frozen (about -18°C to -25°C), chilled (about $+2^{\circ}\text{C}$ to $+5^{\circ}\text{C}$) and ambient

(normal outside) temperatures, although some fresh foods, for example, may need temperatures slightly different to these. The three main temperature regimes often form the basis for segmented supply chains, although it is quite common to find chilled and ambient goods combined. In fact, it is possible to combine all three in a single supply chain that comprises multi-temperature warehouses and compartmentalized vehicles.

- Bulk: some products are well suited to bulk handling (e.g. liquids, powders and granules) and therefore require specialist storage, handling and transport facilities.
- Hazard: hazardous goods may require a separate supply chain so that all the necessary safety measures can be implemented.
- Contamination: even where goods are not hazardous, they may be able to contaminate other products (e.g. by their smell).
- Pilferable goods: certain goods may be the target of opportunistic or planned robberies and therefore require greater security. An obvious example of this is where armoured vehicles are used for bank note and bullion deliveries.
- Value: the value of goods may be important for segmentation purposes as this affects how costly it is to hold inventory in the supply chain. For example, goods that are low in value may be held at multiple locations close to the customers, whereas high-value goods may be centralized so as to reduce safety stocks (as explained in Chapter 15). This concept can give rise to a segmentation basis as shown in Figure 8.1, whereby high throughput but low value-density products (i.e. a low value compared to their weight or cube) may be dispersed geographically, while a low throughput but high value-density product may be held at a single global distribution centre and air freighted from there around the world. A typical example of the former product type is photocopy paper; a typical example of the latter is high-value electronic parts.
- Variety: some goods by their nature are sold in a wide variety of forms. For example, a single shirt 'product line' may have many different collar sizes, colours and sleeve lengths. Each combination of these is significant to the customer and therefore many individual stock-keeping units (SKUs) need to be made available for sale. It is very difficult to forecast demand at the SKU level for every geographic region and therefore, as with high-value goods, the stockholding of these may be centralized so as to minimize safety stocks.

Demand and supply segmentation

In addition to the physical characteristics of the goods, there may be a distinction between whether the demand for the goods is predictable or unpredictable in nature.

Figure 8.1 Segmentation by throughput and value-density

SOURCE Adapted from Lovell et al, 2005

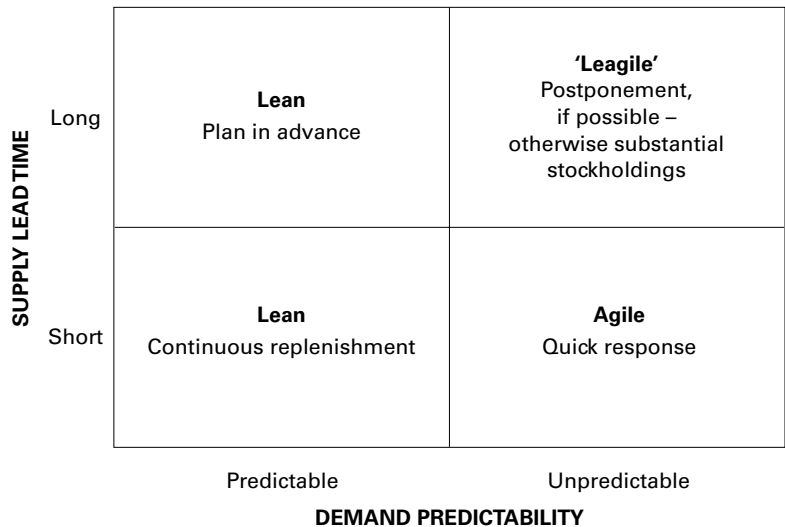
Goods with a predictable demand pattern may be best suited to a cost-efficient supply chain whereas goods with unpredictable demand may require a much more responsive supply chain. This type of distinction is often associated with lean and agile concepts respectively, as explained in Chapter 5.

Demand is, however, only one side of the supply chain. The nature of supply also needs to be taken into account. An important factor on the supply side is the length of the supplier lead time – from the time of placing orders on the supplier up to the time of physically receiving the goods. A segmentation framework using a combination of demand and supply factors is shown in Figure 8.2.

Under this segmentation framework, lean supply chain principles can be applied where there is predictable demand. In the case of long lead times, the sourcing, production, storage and movement of goods can be planned in advance in the most cost-effective manner. Where lead times are short, then quick response and continuous replenishment policies can be adopted so that goods are supplied on a ‘just-in-time’ basis at the last possible moment, again keeping inventories and waste to a minimum.

However, if demand is unpredictable, agile policies can only be fully adopted where supplier lead times are short. In this circumstance, supply can flex to meet the rapidly changing demands of the marketplace, and again inventories can be kept low. However, where supplier lead times are long, then this is likely to lead to either an oversupply of goods (leading to high inventories) or an undersupply (leading to lost sales). Other approaches therefore need to be explored to combat this, such as production postponement, whereby goods are configured to the actual specification

Figure 8.2 Segmentation by demand and supply characteristics



SOURCE Adapted from Christopher et al, 2006

of the customer at the last possible moment. Goods are therefore held in a generic form, which can be more easily forecast than at a more detailed level. An example of this would be the holding of personal computer components ready to be assembled once an order is received, rather than manufacturing computers to exact specifications of memory size etc and holding a multitude of finished goods SKUs in stock (see Chapter 13 for further details on postponement). Policies such as postponement that combine elements of lean and agile approaches are sometimes referred to as 'leagile'. However, particular circumstances will dictate whether such approaches are possible, as a combination of long supplier lead times and unpredictable demand tends to result in the need for high safety stocks. This has been found to be the case in many industries that are served by global supply chains.

The geographic location of supply is obviously a very important factor in supply chain design. Separate supply chains will be needed, for example, to bring goods from the Far East to European markets, rather than from local European suppliers. In fact, the decision as to where to source is often part of the supply chain design process. For example, goods with predictable demand may be sourced from low-cost suppliers in distant parts of the world (i.e. part of a 'lean' approach) whereas goods with unpredictable demand may be sourced locally where lead times are generally much shorter and therefore supply can easily be changed to meet fluctuating levels of demand (i.e. part of an 'agile' approach). Understanding factors such as these is key to the development of an effective logistics operation and is integral to the logistics network planning process described in the next two chapters.

However, it may be rather simplistic to categorize the demand for goods as being either predictable or unpredictable. Another approach is to examine whether there is a 'base' demand that can be identified separately from any unpredictable 'surge' demand. In this circumstance, it may be advantageous to segment the supply chain accordingly, with a lean supply chain for the base demand (e.g. by sourcing in low-cost countries) and an agile supply chain for the surge demand (e.g. by sourcing locally).

A similar approach could be taken by segmenting in accordance with the Pareto classification of the goods. Thus, fast-moving goods normally have more predictable demand than slow-moving goods, as the latter tend to be demanded only occasionally and in small quantities. A lean approach could therefore be adopted for the fast-moving goods and an agile approach for the slow-moving goods.

Marketing segmentation

Segmentation has been adopted in marketing for many decades. It is used for demand creation purposes and it has long been recognized that different classifications of customer require different marketing approaches. As it is the customer that supply chains are trying to satisfy, it would be sensible to examine whether marketing segmentation frameworks are relevant to supply chain design.

There are many categorizations of marketing segments but one such classification that can fit particularly well for the supply chain is as follows:

- **geographic:** the location of the customer, e.g. by continent, country, region or urban/rural
- **demographic:** populations are often broken down into categories according to such factors as age, gender, income, home/car ownership, employment and ethnic origin
- **psychographic:** this form of segmentation is concerned with the interests, activities and opinions of consumers, and is often related to lifestyles
- **behaviouristic:** this relates to how consumers behave, in terms of, for example, how frequently they buy certain products and whether they remain loyal to particular brands
- **firmographic:** in the case of industrial customers, a common form of segmentation is by such factors as turnover, number of employees and industry sector

The geographic location of the customer is obviously relevant to supply chain, as well as marketing segmentation. For example, export orders are often segregated within warehouses for specialist packing and are frequently dispatched using different logistics companies than is the case with home orders. Similarly, some companies deliver to the main urban conurbations using their own vehicles, while they may

use third-party logistics providers for more distant locations (as such providers can combine deliveries with goods from other companies in order to improve their load factors and routing efficiency).

It may also be argued that the other marketing segmentation frameworks are highly relevant to the supply chain in that each segment may represent a different demand characteristic that needs to be supplied in a different way. For example, psychographic factors, such as lifestyle, are important in the fashion industry. Customers who require standard commodity garments (e.g. low-price jeans) can probably be supplied using lean principles as demand tends to be fairly stable. However, the demands of fashion-conscious buyers (i.e. who seek the latest fashions as seen on the catwalks or fashion blogs) need to be satisfied in a much more agile way – for example, using rapid design and manufacturing techniques, local suppliers and cross-docking through the distribution network immediately to the stores. Of course, it must also be remembered that individual customers may fit into both of these categories depending on the nature of a particular purchase (e.g. for everyday wear or for special occasions).

Behaviouristic segments may also be very important for supply chain design. For example, Gattorna (2006) used personality types to investigate buying behaviours, particularly of commercial customers, and identified four common categories:

- Collaborative: this is where customers are seeking a close working relationship whereby both parties may benefit. It is a common behaviour when dealing with mature products where demand is fairly predictable and is often associated with a supply chain design using continuous replenishment principles.
- Efficient: this is commodity-type buying where price tends to be the ‘order winner’. A lean supply chain at minimum cost is therefore suited to this segment.
- Demanding: in this segment, a rapid response is needed, often to cope with unpredictable supply and demand situations. An agile type of supply chain is therefore required.
- Innovative: this tends to be where the customer is continually seeking new developments and ideas from suppliers. The latter therefore need to be innovative in terms of supply chain solutions and fully flexible in their response.

Each of these categories of buying behaviour may therefore require a different supply chain design.

Combined segmentation frameworks

Most segmentation policies involve some combinations of the various frameworks described above. For example, one that has been proposed (by Childerhouse et al, 2002) has been named ‘dvw³’ with the key factors being as follows:

- duration: this refers to the stage in the product life cycle and its duration
- window: this is the time window for delivery or the delivery lead time that is required
- volume: this relates to the Pareto volume classification, i.e. whether the products are fast or slow-moving
- variety: this relates to the product range, particularly in terms of the number of individual SKUs (e.g. colours, forms, sizes, etc)
- variability: this relates to demand variability and unpredictability

This framework was applied successfully to the supply chains of a lighting manufacturer. However, some later investigations have found that additional factors may need to be incorporated, such as order line value and weight, and the number of customers buying each product, as well as, of course, the numerous other factors mentioned throughout this chapter.

Two-tier supply chains

The above segmentation frameworks assume that a company is selling directly to the end consumer. However, this is not always the case. For example, manufacturers in industrial markets may sell through distributors while manufacturers in consumer markets may sell through retailers. In such instances, the question often arises as to who is the real customer – the end consumer or the intermediary? One approach to this segmentation problem is to associate categories of end consumer to categories of intermediary – for example, in sports footwear, marathon runners may tend to purchase their running shoes from specialist retail stores. One framework for developing a supply chain segmentation strategy in such circumstances is described by Roscoe and Baker (2014):

- Step 1: define behavioural segments for end consumers by category (e.g. marathon runner or casual weekend runner).
- Step 2: determine where the end consumer in each behavioural segment is likely to make a purchase (e.g. by type of retailer).
- Step 3: decide upon the order winning criteria (e.g. price, service, customization) for each retailer type, taking into account the consumer category served.
- Step 4: identify the value proposition to be offered to each retailer type (e.g. innovation and responsiveness for the customizable and specialist running channels).
- Step 5: define which product at which price points would suit each retailer type.

- Step 6: describe the demand attributes of each article sold (e.g. predictability, growth trends).
- Step 7: define the demand pattern of the product type for that specific retailer (e.g. seasonal, erratic).
- Step 8: establish which supply chain type would suit that demand pattern (e.g. lean, continuous replenishment, agile – responsive, agile – customized).
- Step 9: configure the supply chain accordingly.

In this way, a segmented supply chain strategy can be developed so that each category of intermediary is serviced in accordance with the requirements of the end user categories that purchase through that type of intermediary. This may involve decisions on, for example, sourcing, manufacturing batch run size, customization, location of decoupling point, inventory levels and transport modes, so as to construct the appropriate supply chains in terms of cost and responsiveness.

Implementation

Supply chain segmentation can therefore be very complex as there is a wide range of factors that could be used as a basis for segmentation. Obviously, if a company decided to use all of these possible segmentation bases then it would find itself with a multitude of different supply chains that would be impossible to manage. It is therefore important to choose the segmentation frameworks that are most relevant to the particular product, supply, demand and buying characteristics experienced. Many of the different segments that could be identified will in fact require the same or similar supply chain designs and therefore these can be grouped together. The objective is to have a manageable number of cost-effective supply chain networks that adequately meet the different demands of the market.

It should be noted that there are a number of different elements involved in designing a supply chain, such as:

- sourcing (e.g. local supply, ‘near-shoring’, or ‘off-shoring’)
- manufacturing
- distribution network (e.g. the number, location and role of warehouses)
- transport modes (e.g. road, rail, sea or air freight)

The implementation of segmented supply chains requires decisions on all these elements. For example, a ‘lean’ supply chain may involve ‘off-shore’ sourcing (e.g. from a distant low-cost supplier), cross-docking through warehouses to meet a predictable demand and transport by sea freight, which is relatively low cost. An ‘agile’ supply chain, on the other hand, may require local suppliers that can

react quickly, a network of local depots holding small buffer stocks to service the immediate needs of customers and the use of road freight, which tends to be relatively fast and flexible in nature. There may be synergies that can be gained by merging certain aspects of segmented supply chains – for example, the use of the same warehouses for holding buffer stocks and for cross-docking.

The design of segmented supply chains is an important business decision and requires the involvement of various departments across a company, including marketing, manufacturing, procurement and logistics. The various elements of supply chain design are described further in Chapters 9 and 10.

Logistics costs and trade-off analysis 09

Introduction

In the next chapter, an approach to logistics network planning is developed and described, but before attempting this, it is essential to be fully aware of the key factors that underpin a distribution and logistics operation. This is the basis for this current chapter of the book.

The main elements of a logistics network planning study revolve around the location and use of the distribution centres (DCs) that are generally the distinctive part of any logistics operation. The way in which these DCs coexist with the other key elements, such as inventory and transport, needs to be understood. This involves both the cost- and the service-related aspects that are so important to any successful operation. It is this that is at the heart of this chapter.

The chapter begins with a discussion of the role of distribution centres and warehouses. The major part of the chapter is then concerned with identifying and representing the various costs of the key logistics elements together with a view as to how they can be considered with respect to the overall assessment of logistics costs as a whole. The final step is to understand the concept of logistics trade-off analysis, which is the focal point of logistics network planning and analysis.

The role of distribution centres and warehouses

There are a number of reasons why DCs and warehouses are required. These vary in importance depending on the nature of a company's business. In general, the main reasons are:

- To hold the inventory that is produced from long production runs. Long production runs reduce production costs by minimizing the time spent for machine set-up and changeover.
- To hold inventory and decouple demand requirements from production capabilities. This helps to smooth the flow of products in the supply chain and assists in operational efficiency, enabling an 'agile' response to customer demands.

Note that many supply chains have strategic inventory located at several different points, whereas this buffer only needs to be held at what is known as the decoupling point: the point at which discrete product orders are received.

- To hold inventory to enable large seasonal demands to be catered for more economically.
- To hold inventory to help provide good customer service.
- To enable cost trade-offs with the transport system by allowing full vehicle loads to be used.
- To facilitate order assembly.

These reasons emphasize the importance of getting the facilities location decision right, and also give an indication of the complex nature of that decision. It is possible to summarize the main reason for developing a logistics network as 'the need to provide an effective service to the customer, while minimizing the cost of that service'. Service and cost factors are thus of paramount importance when determining the number, size and location of facilities.

For the best possible customer service, a DC would have to be provided right next to the customer, and it would have to hold adequate stocks of all the goods the customer might require. This would obviously be a very expensive solution. At the other extreme, the cheapest solution would be to have just one DC (or central depot) and to send out a large truck to each customer whenever his or her orders were sufficient to fill the vehicle so that an economic full load could be delivered. This would be a cheap alternative for the supplier, but as deliveries might then only be made to a customer once or maybe twice a year, the supplier might soon lose the customer's business.

There is obviously a suitable compromise somewhere between these extremes. This will usually consist of the provision of a number of DCs on a regional or area basis, and the use of large primary (line-haul) vehicles to service these, with smaller vehicles delivering the orders to several customers on each trip that they make. For certain operations, of course, even these simple relationships will vary because of the need for very high levels of customer service or the very high value of products.

In addition, it should be noted that there are a number of different types of DC, each of which might be considered in the planning of a suitable physical distribution structure. These might include:

- finished goods DCs/warehouses – these hold the stock from factories
- distribution centres, which might be central, regional (RDC), national (NDC) or local DCs – all of these will hold stock to a greater or lesser extent
- trans-shipment sites or stockless, transit or cross-docking DCs – by and large, these do not hold stock, but act as intermediate points in the distribution operation for the transfer of goods and picked orders to customers

- seasonal stockholding sites
- overflow sites

Logistics network and DC location strategies are aimed at establishing the most appropriate blend of storage and transport at a given customer service level. The interrelationship of the different distribution elements and their associated costs thus provides the basis for decision-making.

Cost relationships

To plan an efficient logistics structure, it is necessary to be aware of the interaction between the different distribution costs, specifically as to how they vary with respect to the different site alternatives (number, size, type and location), and what the overall logistics cost will be. This is best undertaken by comparative analysis of the major alternative configurations. Before this can be achieved, the detailed make-up of the individual distribution cost elements must be understood.

Many companies have cost information based on their conventional accounting systems, but almost always these costs are too general to allow for any detailed breakdown into the integral parts that reflect the company's distribution structure. (See Chapters 38 and 39 for alternative methods of collecting and measuring logistics costs.) Without this cost information, and the understanding that goes with it, it is impossible to measure the effectiveness or otherwise of the existing operation. It is also impossible to gain the necessary insight into the distribution operation to allow for successful planning and management. The component parts of a distribution system necessarily interact with one another to form the system as a whole. Within this system, it is possible to trade off one element with another, and so gain an overall improvement in the cost-effectiveness of the total system. An appreciation of the make-up and relationship of these key costs is thus a vital link to successful distribution planning and operations. These major cost relationships are outlined in the following sections of this chapter. (Also see Chapter 30 for more detailed information concerning road freight transport costs.)

Storage and warehousing costs

The major cost breakdown for storage and warehousing is between building, building services, labour, equipment and management/supervision. The relationship of these costs will, of course, vary under different circumstances – industry, product type, volume throughput, regional location, age of building, handling system, service level agreements (SLAs), etc. In conventional DCs, the direct labour cost is likely to be the greatest element, with the building cost likely to fluctuate from very high (new

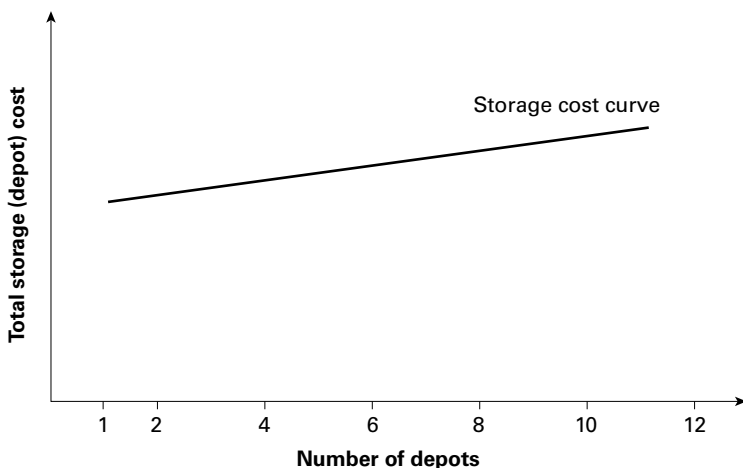
building, prime location) to very low (old building, peppercorn (low) rent, low rates or local taxes). (See Chapter 18 for more detailed discussion.)

With respect to the cost relationship of warehousing with other parts of the distribution system, the importance of storage and warehousing costs will be dependent on such factors as the size of the DC and the number of DCs within the distribution network as a whole.

The effect of site size is illustrated by the economies of scale experienced if larger DCs are operated. It has been established that the cost of operation of a site and the amount of stock required to support a DC tend to be higher (per unit) for a small site than for a large one. This is because larger DCs can often achieve better space and equipment utilization and can benefit from spreading overhead costs over the higher throughput. It should be noted that, eventually, diseconomies of scale can occur, because very large DCs can be adversely affected by such conditions as excessive internal travel distances, problems of management, etc.

The effect of a different number of warehouses or DCs in a given distribution network can be seen by developing the 'economies of scale' argument. If a distribution network is changed from one site to two sites, then the overall DC/storage costs will increase. The change is likely to be from a single large site to two medium-sized sites. This will not, therefore, double the costs, because the change is not to two large DCs. It will certainly increase costs, however, because there will be a need for more stock coverage, more storage space, more management, etc. In simple terms, this can be described by a graph, illustrated in Figure 9.1. Thus, as the number of DCs in a distribution network increases, then the total storage (DC) cost will also increase.

Figure 9.1 Relationship between number of depots (i.e. storage capacity) and total storage cost



One point that should be appreciated is that some care must be taken over any generalization of this nature. In practice, it will be found that each individual site

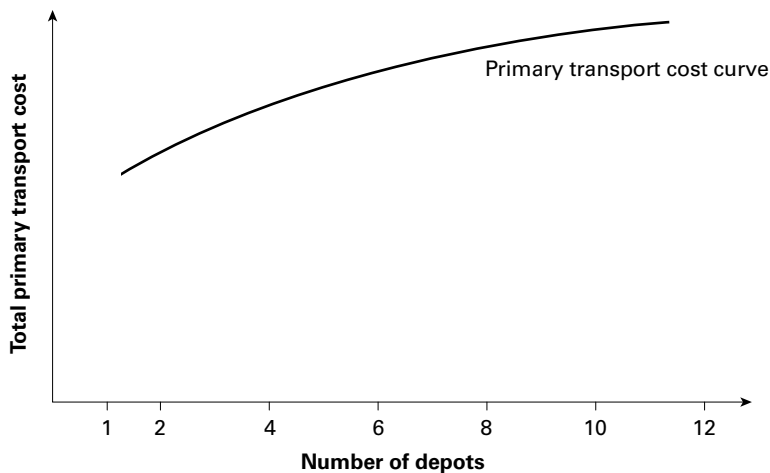
may differ in its cost structure from the other sites in a system for a variety of practical reasons. These may include, for example, high (or low) rent and rates according to the location of the DC (e.g. very high in cities) or high (or low) labour costs.

Road transport costs

The two most important categories of transport costs are: primary transport (sometimes called trunking or line-haul); and delivery transport (sometimes called final or secondary distribution). The requirements and costs for these two types of transport vary according to the number of DCs in a distribution network.

The *primary transport* element is the supply of products in bulk (i.e. in full loads) to the DCs from the central finished goods warehouse or production point. This element is generally undertaken using road freight transport, but of course for some bulk products other modes of transport are used. The number of sites affects the overall cost of this type of transport. In this instance, the effect is not a particularly large one, but it does result in an increase in primary transport costs as the number of DCs increases. The effect is greatest where there are a smaller number of sites, as the graph of Figure 9.2 indicates.

Figure 9.2 Primary transport costs in relation to the number of depots



The second of these two types of transport, *delivery transport*, is concerned with the delivering of orders from the DC to the customer. This can be carried out by a company using its own fleet of vehicles or by a third-party carrier. Whichever alternative is used, the cost of delivery is essentially dependent on the distance that has to be travelled.

The distance travelled by delivery transport can be divided into two different elements:

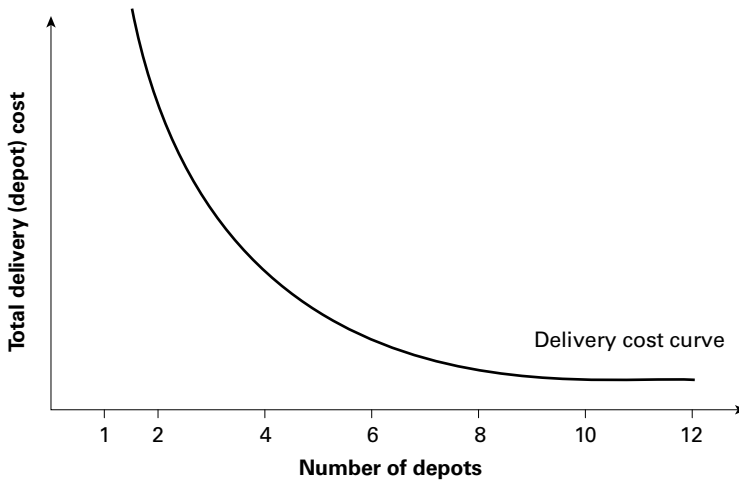
- 1 'Stem' distance, which is the distance to and from a delivery zone (from the DC outwards to the first 'drop' point and return from the final 'drop' point back to the DC).
- 2 'Drop' distance, which is the distance travelled once a drop or delivery zone has been reached (starting from the first 'drop' point and finishing at the final 'drop' point).

Stem distance to any particular delivery zone will depend on the location of the DC. If the DC is changed (because of a decision to reduce the number of DCs in the system) then the stem distance will also change (it will increase if there are fewer DCs and will decrease if there are more DCs).

Drop distance will not change if the number of DCs change because the delivery zone(s) will remain the same.

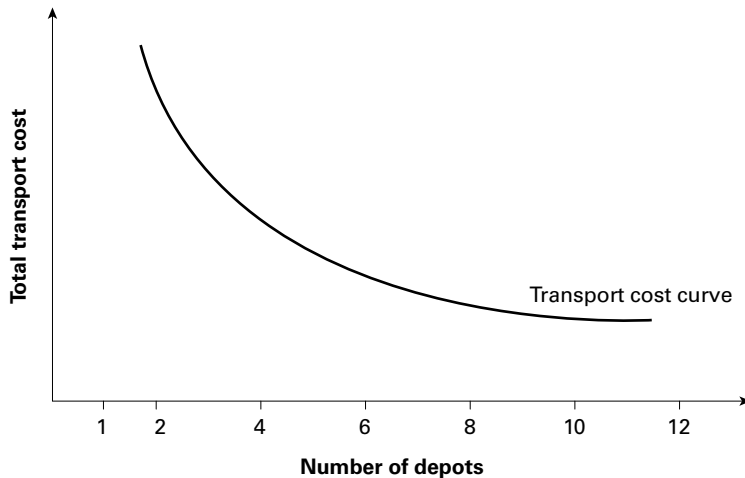
Thus, while the drop distance remains the same whatever the distance from the supplying DCs, the stem distance varies according to the number of DCs in the system. The greater the number of DCs, the less the stem distance. This can be described by a graph, as shown in Figure 9.3.

Figure 9.3 Delivery transport costs in relation to the number of depots



If the costs for both primary and delivery transport are taken as a combined transport cost then these total transport costs can be related to the different number of DCs in a distribution network. The overall effect of combining the two transport costs is that total transport costs will reduce, the greater the number of sites that there are in the system. The effect can be seen in the graph of Figure 9.4.

Figure 9.4 Combined/total transport costs (primary and delivery) in relation to the number of depots



Inventory-holding costs

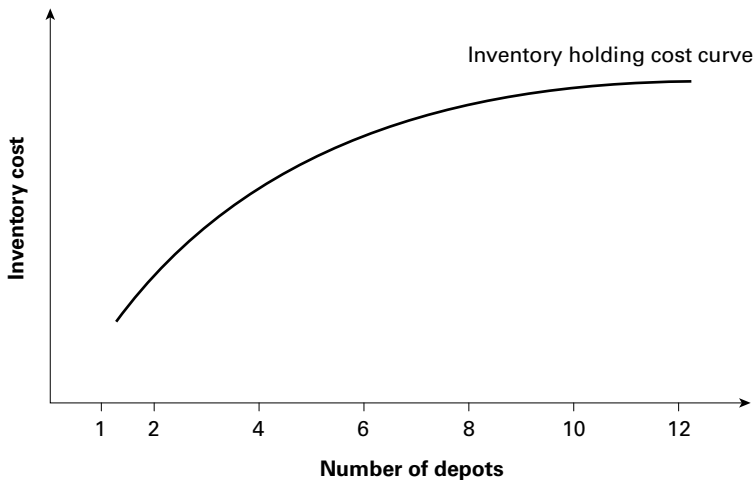
Another important cost that needs to be included is the cost of holding inventory. The main elements of inventory holding are considered in a little more detail in Chapter 15. The key costs can be broken down into three main areas:

- 1** Capital cost: the cost of the physical stock. This is the financing charge, which is either the current cost of capital to a company or the opportunity cost of tying up capital that might otherwise be producing a return if invested elsewhere.
- 2** Service cost: that is, stock management and insurance cost (the cost of servicing the inventory – not to be confused with customer service which is a very different cost).
- 3** Risk costs: which occur through pilferage, deterioration of stock, damage and stock obsolescence.

These costs, when taken together and measured against the number of DCs in a system, can be represented as shown in Figure 9.5.

Information system costs

The final cost element for consideration is that of information system costs. These costs may represent a variety of information or communication requirements ranging from order processing to load assembly lists. Usually, some type of computerized

Figure 9.5 Inventory-holding costs in relation to the number of depots

information system is used to provide these requirements. These costs are less easy to represent graphically because of the fast rate of change of information systems and because costs can vary considerably, dependent on the level of technology introduced. The higher the number of depots in a logistics operation, the higher information system costs are likely to be. This relationship can be broadly represented as shown in the graph of Figure 9.6.

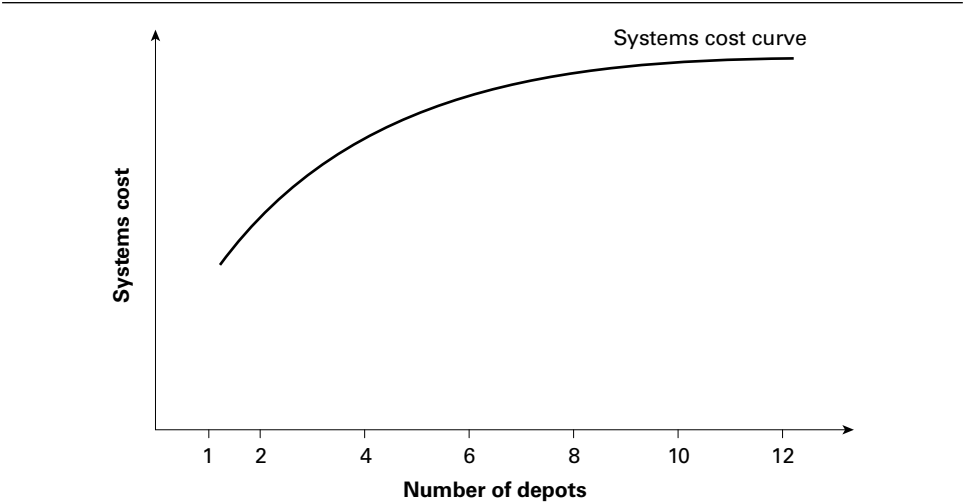
Total logistics costs

By its very nature logistics operates in a dynamic and ever-changing environment. This makes the planning of a logistics structure a difficult process. It is also not an easy matter to appreciate how any changes to one of the major elements within such a structure will affect the system as a whole. One way of overcoming this problem is to adopt a 'total' view of the system, to try to understand and measure the system as a whole as well as in relation to the constituent parts of the system.

Total logistics cost analysis allows this approach to be developed on a practical basis. The various costs of the different elements within the system can be built together. This provides a fair representation, not just of the total logistics cost, but also of the ways in which any change to the system will affect both the total system and the elements within the system.

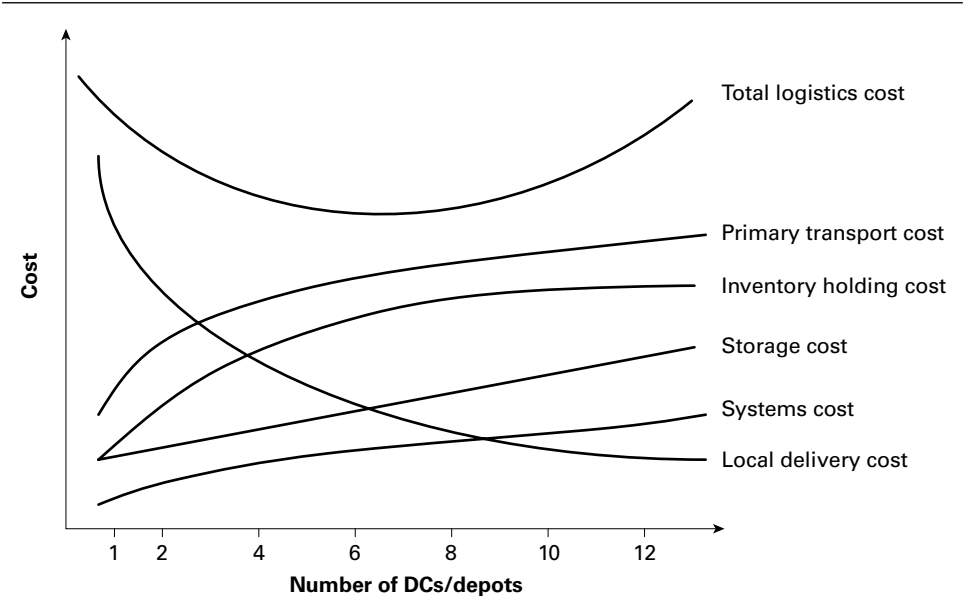
The total cost approach can be represented in a graphical format by building up a picture from the graphs used to illustrate the cost elements in the earlier section of

Figure 9.6 Information system costs in relation to the number of depots



this chapter. This is illustrated in Figure 9.7 and demonstrates how the individual distribution and logistics cost elements can be added together to give the total logistics cost. It shows, in this example, the individual functional costs and the total logistics cost for an operation as the number of depots in a given network changes.

Figure 9.7 The relationship between total and functional logistics costs as the number of depots in a given network changes



The overall cost effect of using a different number of sites can be explained by such a graph and can be used for facilities location planning. The top line on the graph shows the overall logistics cost in relation to the different number of DCs in the network. It is obtained by adding together the individual cost curves of the key distribution elements that correspond to each number of sites. For just a single DC, for example, there is a large local delivery cost to add to the much smaller costs of primary transport, inventory, storage and system costs.

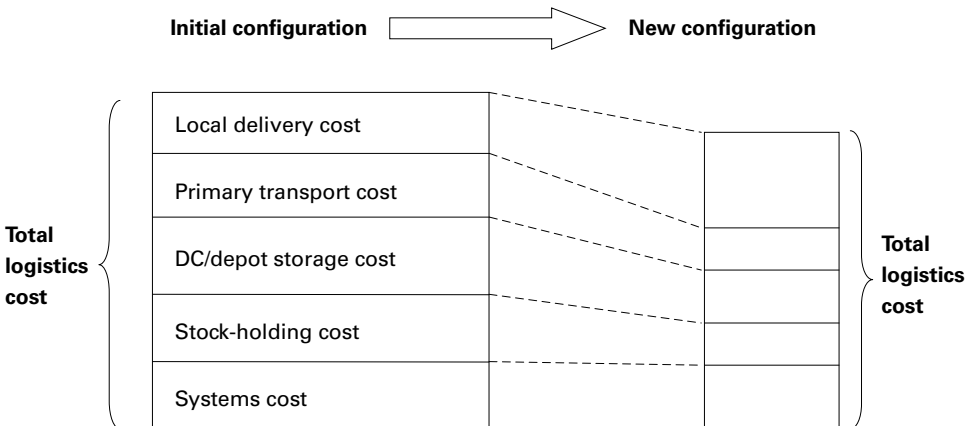
It can be seen from the graph that the least expensive overall logistics cost for this particular demand area occurs at around the 5–7 DC number. The minimum point on the overall logistics cost curve represents this lowest-cost solution. The results, in practice, will depend on a number of factors: product type, geographic area of demand, demographics and population density, service level required, availability of suitable buildings.

These relationships are the key to the planning of logistics strategy and structures. As will be discussed in Chapter 10, computer models have been developed that allow this type of detailed quantitative analysis to be carried out so that least-cost solutions can be identified and implemented.

Trade-off analysis

The concept of trade-off analysis is a key feature of this total cost approach to logistics planning. It has been shown that any change in one of the major elements within a logistics system is likely to have a significant effect on the costs of both the total system and the other elements. Indeed, it is often possible to create total cost savings by making savings in one element, which creates additional costs in another but produces an overall cost benefit. This can be seen in Figure 9.8.

Figure 9.8 Trade-off analysis showing that a change in configuration can lead to a reduction in total logistics cost while some cost elements increase and others reduce



In this example, a DC rationalization policy has been adopted whereby the number of sites in a logistics system has been reduced. Although this has led to an increase in local delivery costs (because vehicles must travel further to deliver products), savings in some of the other main elements of distribution have produced overall cost benefits.

The cost and service trade-offs within any logistics structure will, of course, vary from one company to another depending on the role the company plays within the supply chain as a whole. In the main, however, the following major costs and their associated trade-offs may need to be considered and assessed:

- **Production costs:** these will vary according to the type of production process or system used and the type of product manufactured. Make-to-stock or make-to-order will also be relevant. Factories may be 'focused' on one or two specific types of product or may make a large range of different products. Different distribution structures may be required to support different types of product. The effect on primary transport costs will be very relevant.
- **Packaging costs:** these are mainly concerned with the trade-off between the type of packaging and the handling and transport costs, although the influence of packaging costs will become more influential as environmental concerns increase. The type of load unitization will also be important.
- **Information systems costs:** these cover a wide area from order receipt to management information systems. The type of DC network will affect many of these costs.
- **Lost sales costs:** these might occur because of inadequate customer service, and are very relevant in the context of the proximity of the DC to the customer, together with the reliability and speed of service.
- **Inventory costs:** these include the cost of capital tied up in inventory as well as the cost of obsolescence, etc. They have a fundamental relationship with the DC network in terms of the number of stockholding points and the hierarchy of stockholding according to DC type.
- **Transport costs:** the number and location of sites within the distribution structure, and the associated throughputs significantly affect transport costs. Both primary transport and final delivery costs are affected by DC numbers and location.
- **Warehousing costs:** these costs vary according to the type of storage and handling systems used, product characteristics and the volume and throughput at the site. The size and type of site will thus be important, as will the location.

Logistics network planning 10

Introduction

In this chapter a particular approach to logistics network planning is described and developed. The main content follows on from, and links very closely with, the planning framework that was proposed in Chapter 6 as well as the key flows and cost relationships that were introduced in Chapter 9.

The question of determining the number, size and location of facilities in a company's distribution system is a complex one to answer. There are many different elements that go to make up the distribution mix, and it is necessary to take into account all of these when considering network structure and facilities location. Prior to the DC location decision, a lot of work must be undertaken. This is necessary to help to understand the key requirements of the company and to collect and collate a large amount of data. This enables a numerical picture of the distribution structure to be constructed so that appropriate analysis can be carried out to test potential options for improvement.

Before trying to determine the most appropriate number and location of DCs, it is also necessary to ensure that there is an efficient flow of products from source to final destination. This assessment of the different patterns of product flows is known as 'sourcing analysis'.

The complexity of sourcing and location decisions has led to the development of some quite sophisticated mathematical models that attempt to find the optimum flows and the optimum number of DCs to serve a system. The detailed mathematical principles used as the basis for these models will not be covered here, but consideration will be given to the relationships involved, and the approaches that can be undertaken when making location decisions.

It is important to recognize that the vast majority of location studies are undertaken when a company already has an established logistics network – a number of DCs and their associated delivery areas. Thus, location studies are rarely based upon the premise that the 'best' results can be applied across the board. Generally, it is necessary for a compromise to be reached between what is 'best' and what is currently in existence. The very high cost of DCs and vehicle fleets is the main reason

for this – there is a high cost and great disruption involved in making changes to existing structures and systems as well as the likely impact on customer service. Despite this, it is very important for companies to know how their distribution networks might be improved and to move towards this improvement.

Although networks are often planned at the beginning of a company's operation, the majority of existing systems have just evolved, with limited if any planning, based very much on the way that the company has developed over time. This may be a steady growth (or decline), or may be in short steps or large leaps as mergers and takeovers occur. Often these business changes are not adequately reflected in the logistics operation that has developed. Probably the most common reason why logistics networks are out of balance is that of inertia, because of the great amount of work and effort required to make changes.

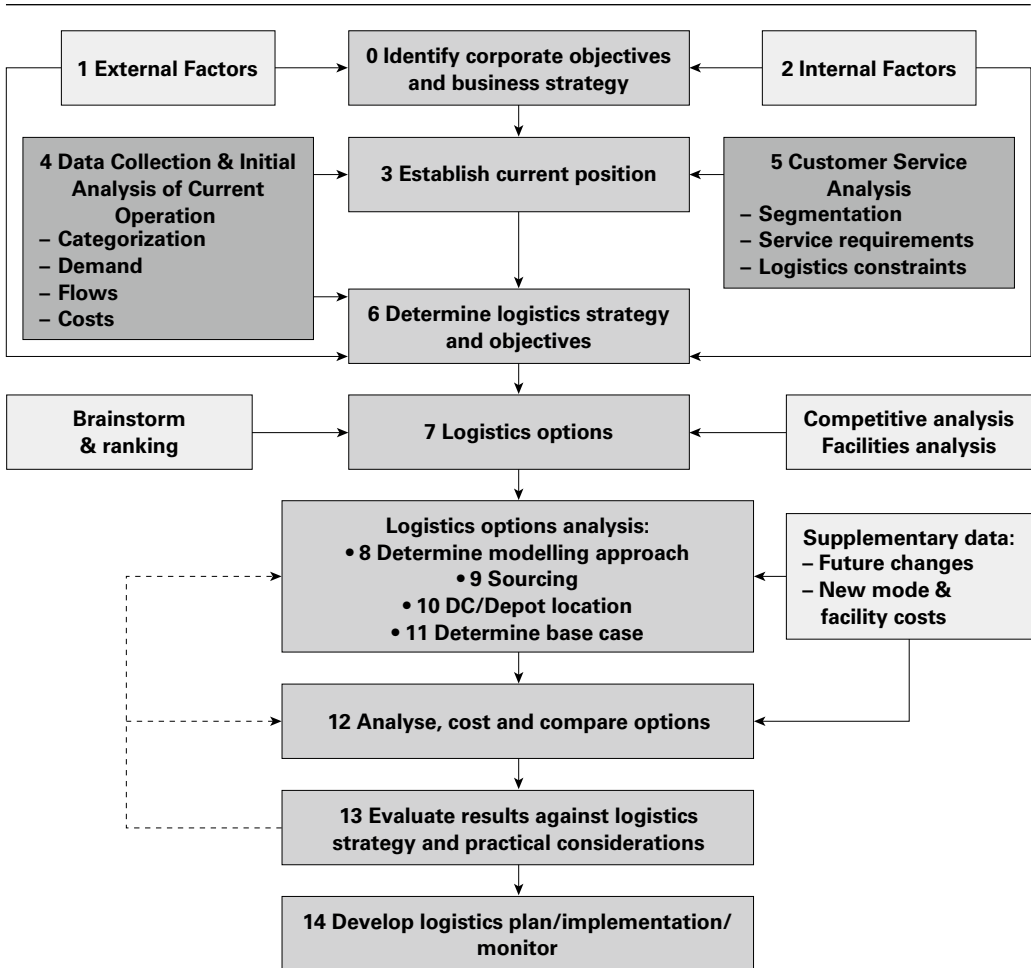
It needs a forward-looking management or a particularly significant change for a company to undertake a large-scale study of this nature. The understanding of the importance of logistics to most companies, and the need to cut costs and improve efficiency, now often provides sufficient impetus for companies to review their logistics and distribution structure with a particular emphasis on the use and location of DCs and warehouses.

A planned approach or methodology

An approach to logistics and distribution strategy planning is outlined in Figure 10.1. This approach describes the practical steps that need to be taken to derive a logistics strategy from a corporate business plan, as described in Chapter 6. This type of approach requires the collection, collation and analysis of a great deal of data. It is thus quantitative, although a degree of qualitative assessment may also be necessary.

This type of analysis is a very time-consuming task! Each key step is described in the remainder of this chapter, but a few general points are worth appreciating prior to contemplating such a study:

- Great care should be taken to define the precise overall problem. It is likely to be concerned with the use and location of DCs within a distribution network, but certain elements may or may not be included. For example, are production facilities included in the mix and if so, must some be retained? Can products be sourced at different production sites? Are there existing DCs that cannot be closed down?
- The planning horizon must be agreed. How far into the future is the strategy to be determined?
- Customer service requirements provide a key input to any logistics network planning study. It is essential to understand what customer service levels need to

Figure 10.1 An approach to logistics and distribution strategy planning

be achieved because these will have a vital impact on the type of logistics structure that should be developed.

- Both cost and service elements are vital inputs to the logistics planning process.
- All relevant logistics cost relationships need to be identified and understood. This is no small task, but it is crucial to the success of the entire strategic review.
- The relevant product flows for different patterns of demand and supply need to be established. Important aspects will include the identification of different types of product, the origin of these products (factories etc), the destination of products (shops, hospitals, factories, etc) and the amount of each product type going through the system (throughputs etc).

- The identification of all relevant data and information requires consideration. There are always problems in finding and obtaining the data and information required. It may be necessary to make compromises over the data that is available. Data collection is always the largest part of a study. Data should be collected in the format in which it will be finally used in the analysis.
- A sourcing or 'flow' model is likely to be an important link in the process of moving from a corporate to a logistics plan.
- Essential to the development of a suitable logistics plan is the need to carry out some fairly detailed quantitative analysis.
- Additional planning tools and models may also be used as add-ons to this planning process, but they are normally used as a second stage. They include, for example, inventory models (to determine stock levels, mix and location) and vehicle routing and scheduling models (to determine fleet size and vehicle mix).
- Once a suitable logistics strategy has been identified, it is essential to undertake the dual process of evaluating this strategy against the preferred business strategy and ensuring that due account has been taken of any practical considerations.

The following sections of the chapter involve a discussion of the key steps outlined in Figure 10.1, where the numbers in the text refer to the box numbers in the diagram. Step 0 has already been described in Chapter 6.

Initial analysis and option definition

1. *External factors*

Any number of external factors may be relevant in a logistics-based study and they must be factored into any planning or review process. These will, of course, vary according to the industry, the company, the marketplace, etc. Some of the factors that may be relevant will include:

- transport mode availability
- infrastructure changes (e.g. new roads, rail links, etc)
- regulatory changes (transport legislation, customs regulations, etc)
- information technology (EDI, EPOS, etc)
- technology changes (new vehicle design, unit load technology, etc)
- environmental impacts
- industry trends

Examples of these factors were described in Chapter 6.

2. Internal factors

The importance of the many internal factors will certainly vary from industry to industry. It is generally possible to categorize these in two ways: first, qualitative or descriptive factors that relate directly to the operation under review; and second, quantitative facts and figures. Both qualitative and quantitative information is used to help 'describe' the business in an operational context. These factors need to be developed in great detail to represent the inputs into the modelling process for costs, product flows and customer service requirements.

3. Establish the current 'as-is' position

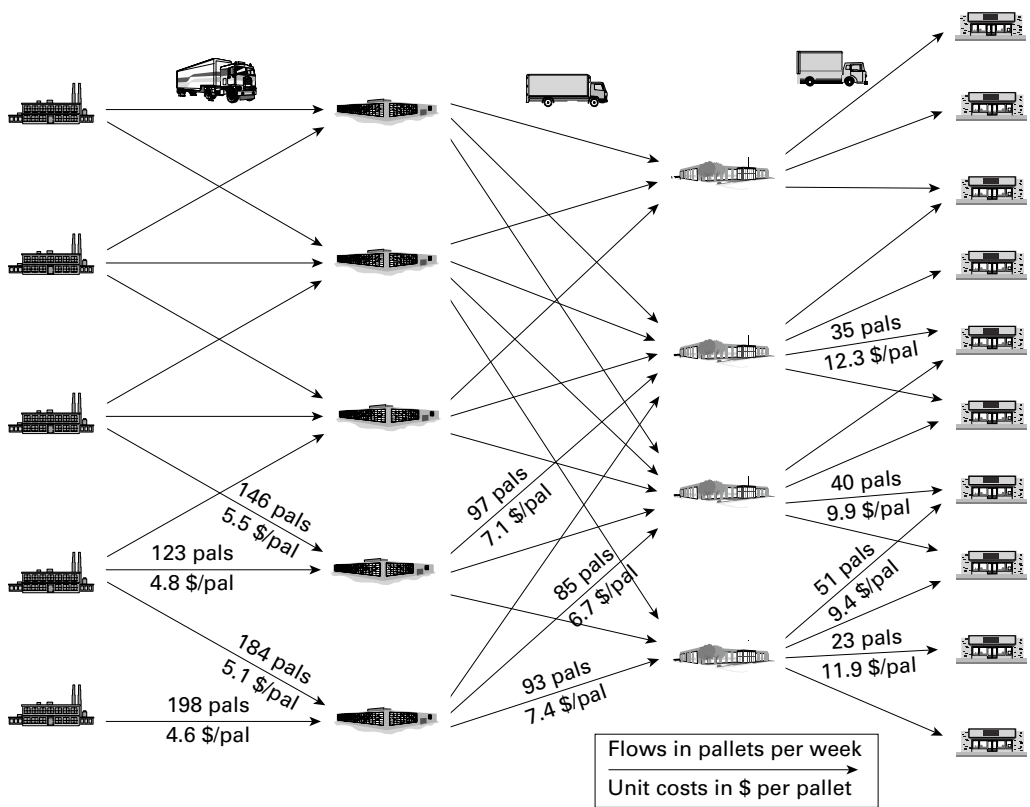
This major element of the study usually begins with a detailed written description of the current operation but is ultimately aimed at producing a mathematical description of the main existing material and product flows and costs of the logistics operation. The resultant mathematical model of the current operation will be used as the basis against which all alternative solutions are measured later in the study, so data accuracy is crucial. Developing and validating this mathematical model is a very detailed and necessarily time-consuming process but is essential to the study as a whole. Care should be taken when choosing the period of trading being studied. Peak or seasonal times will provide distorted or inflated results. Therefore, a normalized or average period should be chosen for analysis. In addition, the actual service level position needs to be identified.

The complicated nature of the data requirements is illustrated in the (relatively simple!) network diagram of Figure 10.2, where examples of some of the typical major flows and costs are given. The network consists of five production points and shows product flow through finished goods warehouses and distribution centres to retail stores. For each pathway (or transport link) there is an associated volume flow and unit cost of which only a few are shown as examples in the diagram. Storage and handling costs and throughputs are not shown.

4. Data collection and initial analysis

This section provides a summary of the data that will be used as the basis for determining the current situation and for the subsequent logistics modelling and analysis that will underpin the entire strategy planning process.

Several important decisions concerning data collection should be made very early in the data collection process. These decisions will affect key areas such as the type of data to be collected, the different data categories that need to be determined and suitable time periods. These include:

Figure 10.2 Logistics network flow diagram, showing some examples of major flows and costs

- The unit of measure:** this should be suitably representative of the whole logistics operation that is being assessed. This is often not easy to determine, as there may be several different descriptive measures that are used within a company – pallets for bulk stock, cartons for picking and roll-cages for transport. In some industries a common unit is used as a standard – in the brewing industry, for example, the barrel is a universal measure.
- Product groups:** it is not possible to model each individual product, so products must be categorized into suitable groups that reflect similar logistics characteristics. These might be by sector (cosmetics, personal care, cleaning), by format (powder, liquid, hazardous), or by pack type (box, bottle).
- Customer classification:** this is necessary so that different service level requirements can be assessed for key customer types. These might be industrial, consumer (retail) and consumer (direct).
- Time periods:** generally, a financial year is most suitable (and easiest), but data collection time periods will vary if, for example, seasonality needs to be determined (several years are needed for this) or if product life cycles are limited.

Typical examples of descriptive data include:

- product groups
- sourcing locations (own and bought-in products)
- number and types of sites and facilities
- major transport modes used
- handling systems used
- unit load types
- own and third-party operations
- main customer groups
- customer service levels
- logistics information systems

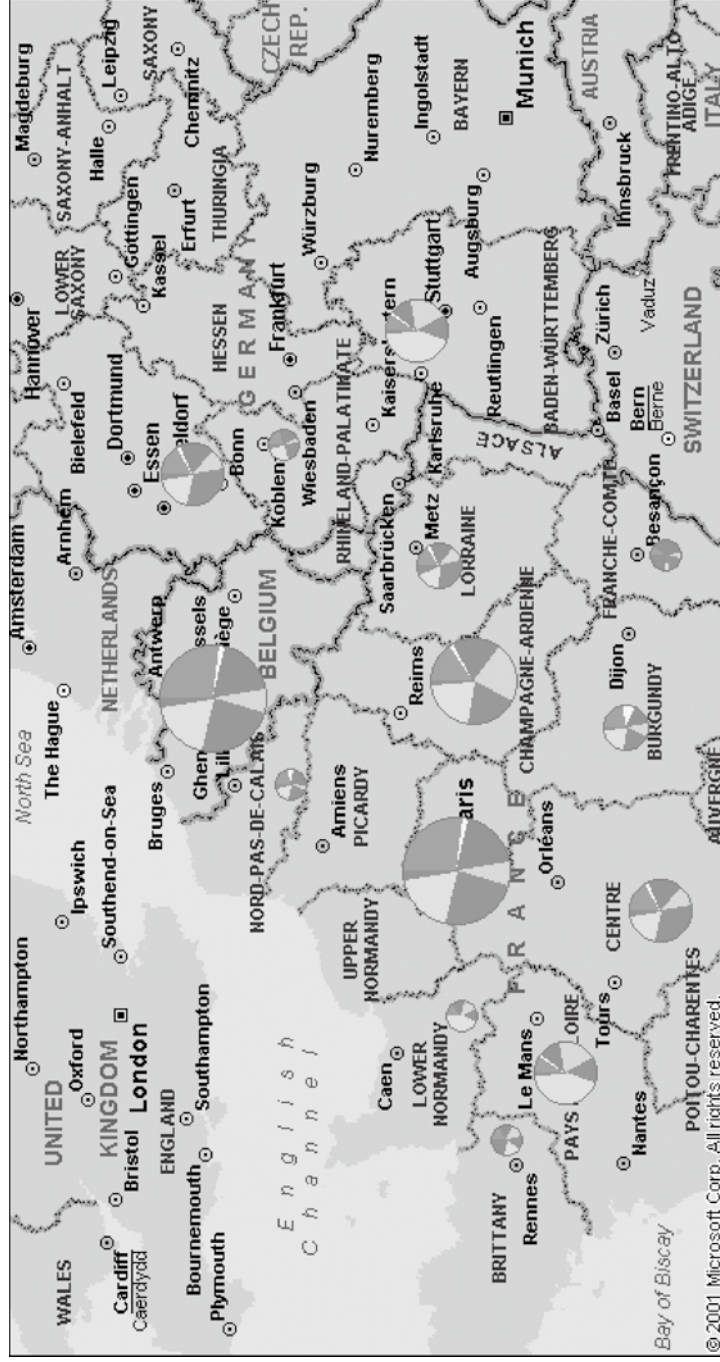
Examples of quantitative data are:

- major product flows
- transport modal split for the major flows
- demand by region, by major product group, by customer type
- market segmentation
- customer service goals and achievement
- carrier analysis
- inventory-holding profile
- product profile
- customer profile
- expected growth rates
- planned future expansion requirement

As well as preparing numerical tables of data, it is also a good idea to make visual representations. This can be essential in helping to understand the implications of the data in terms of the demand for different product groups in different geographical areas and the subsequent recommendations for DC location. There are many software packages that provide this functionality. Figure 10.3 is an example of such visual representation.

It is advisable to collect initial data in the format that can be used for the subsequent logistics strategy modelling exercise. This will apply to the following key variables and key data requirements:

Figure 10.3 Map showing a representation of the demand for different product groups in different geographic areas



Manufacturer of laundry, household cleaning and personal care products

- *Variables:*
 - location and capacity of each plant, DC and trans-shipment depot
 - cost functions for storage, primary transport and local delivery
 - demand locations and amounts
- *Data:*
 - current and future customer location and demand
 - DC throughput
 - primary transport costs (fixed and variable)
 - local delivery costs (fixed and variable)
 - inventory-holding costs

Quantitative data may not always be readily available, so descriptive information or alternative data may have to suffice. For example, it may be recognized that customers can be broadly profiled in terms of, say, national accounts, key accounts, dealers, distributors and specialist users. It may not be possible to make precise quantitative comparisons in terms of tonnage distributed per annum to each grouping, but some type of value analysis may be available.

The quantitative data derived is crucial to the analytical process carried out and thus to the final conclusions and recommendations made. Although collection is extremely time-consuming, it is important that data is correct and that it does adequately reflect the real flows and costs within the business.

5. Customer service analysis

As indicated previously in this chapter, customer service requirements provide a key input to any logistics network planning study. Appropriate customer service levels that need to be achieved must be identified. These are essential ingredients to help determine the type of logistics structure that should be developed. As discussed in Chapter 2 (see Figure 2.7), there is a vast difference between offering a low-cost (high-productivity) solution compared to a high-cost (value-added) solution, and the ideal logistics structure will vary accordingly. A logistics network is likely to serve several different markets and needs to be designed accordingly in order to satisfy all of the different customer service requirements. A detailed approach to determining customer service requirements is given in Chapter 3.

6. and 7. Determine logistics objectives and options

An assessment of corporate objectives and business strategy (as discussed in Chapter 6) together with the most relevant external and internal factors should allow for

clear logistics objectives to be determined. From these, and from the analysis of the current situation, customer service requirements, competitive analysis and facilities analysis it should be possible to generate a long list of alternative options that would be worth considering for modelling and assessment. For any strategic review, it is also important to enable any innovative alternatives to be considered within the planning process. These can often be identified through the use of techniques such as lateral thinking and brainstorming sessions.

With approaches such as these, it is usually possible to develop a long list of options (some of which may, initially, appear to be less than ideal) and then by fairly simple assessment determine which of them, or which combination, may be feasible in the context of the planning horizon. A shortlist of alternatives can then be drawn up for quantitative evaluation in the modelling process.

Logistics modelling: logistics options analysis

8. Determine modelling approach

Many modelling techniques used in logistics concentrate on the detailed representation of specific parts of the logistics operation, e.g. production optimization, DC location and vehicle routing. These methods, however, have the potential risk of optimizing only part of a logistics operation when greater economies or benefits could come from changes to other parts of the operation or from a complete restructuring of the operation.

The problem with such multifaceted optimization is that suitable techniques do not exist to consider simultaneously all the possible alternatives. The combinatorial problem of considering all products, made at all sites, shipped via all modes, to all customers, via all DCs, is simply prohibitive. If the techniques did exist, solutions would require uneconomic run times on large computers. The development of what is known as ‘Big Data’ and its analysis may offer exciting new options in the near future (see Chapter 40).

A similar situation occurs in the specialist area of production planning known as MRPII (see Chapter 13) and here, the technique of rough-cut capacity planning was introduced. Instead of trying to produce initial plans at a most detailed level, a rough-cut plan considers the overall requirement for key resources.

This type of approach can be adopted for logistics planning and can be described as trying to establish the ‘economic footprint’, roughly the physical boundary that the facility can serve. The economies of scale of production, the customer service requirement and the logistics cost are all considered to give an optimum factory size and radius of operation, hence the economic footprint. A brewery with canning lines has large economies of scale and a product with sufficient shelf life to give a medium

to large economic footprint. A bakery has much lower economies of scale and a product with a short product life and thus has a smaller footprint.

A means of 'rough-cut modelling' for the whole of a logistics operation is to use sourcing models. Costs of raw materials, production rates and capacities, together with approximate logistic costs across a geographical area, are used to calculate the trade-off between the major elements.

9. Sourcing models

With multiple products from multiple sources, it is only too easy to assume that the lowest-cost solution is to source each market from the closest available plant with available capacity. In some situations this is true, but if plants have significant changeover (set-up) times for certain product types, it *may* be more cost-effective for these to have long production runs, high inventory and high transport costs. Thus, the first step in rationalizing a logistics system is to investigate optimal sourcing patterns. One definitive pattern may not be sufficient, as sourcing could change according to market conditions, product price, raw material costs and transport costs.

Linear programming is a mathematical technique that finds the minimum cost or maximum revenue solution to a product sourcing problem. All available sources are described with capacities, changeover penalties and raw material costs. Approximate logistics costs from sources to markets are defined as linear cost functions. Under any given demand scenario, the technique is able to identify the optimum solution for the sourcing of products. Most spreadsheet packages have an optimization feature that allows this type of analysis to be undertaken. A typical sourcing model equation operates under the following constraints:

- that each plant has a measurable availability for different production and changeovers
- that customer demand should be met
- that the least-cost solution is required

The objective of a typical sourcing model equation is to minimize the following, given the run rate of each product at each plant:

- raw material cost
- materials handling cost
- production variable cost
- logistics cost from plant to customer

10. Distribution centre location modelling

The output from a sourcing study is the optimized major product flows from source points to final customer. The next stage is to take these flows and to develop the most cost-effective logistics solution in terms of the most appropriate number, type and location of DCs, transport mode, etc. Thus, the overall trade-offs of the supply chain are considered and assessed during the sourcing study, and a preliminary sourcing allocation is made. The detailed logistics of modes, rates and site structure can then be considered using a DC location study.

Cost trade-off analysis (see Chapter 9) can be used as the basis for the planning and reassessing of logistics and distribution systems. Clearly, this approach is a time-consuming and often daunting task, not least because of the difficulty in obtaining the appropriate data and information from within a company's accounting system, but also because of the somewhat complicated models that have to be used. Several different approaches can be used for this:

- *Mathematical programming* uses a number of well-known mathematical techniques (such as linear programming) that are particularly applicable to solving the DC location type of problem. They are prescriptive, using a logical step-by-step procedure to reach the optimal or 'best' solution. The main drawbacks with these techniques are that linear relationships are not always adequate (if linear programming is used) and some solutions can be 'local' optimums, that is, they are not the best from the overall point of view.
- *Heuristics* is a Greek-based word, used to describe the method of solution that is derived on a 'rule-of-thumb' principle. Heuristic methods are determined by using experience and common sense to reject unlikely solutions from the outset. In this way, problems can be reduced to a more manageable size in terms of the number of alternatives that need to be tested. This type of approach is often valid for DC location problems, because there are likely to be a number of potential DC locations that are totally inappropriate.
- *Simulation* is a widely used operational research technique, which is capable of representing complex problems and cost relationships. It is not an optimizing technique, so does not produce the 'best' answer, but it is descriptive of the different relationships and is used to evaluate any alternatives. The inability to produce optimal solutions has previously been seen as a drawback, but in fact a carefully derived simulation model, used with the practical expertise of a logistics specialist, is likely to result in realistic and acceptable solutions that can be readily implemented. Simulation models allow for various 'what if' questions to be asked to test alternative strategies.
- Certain *practical approaches* can also be used – particularly to help simplify the analytical approach. The most straightforward is map-based, whereby the

network is represented spatially on a map. Clustering techniques are used to reduce the complexity of the problem: that is, all customers in close geographic proximity are clustered together. This approach is relatively quick, if a little simplistic, and is made much easier because it is very visual, allowing for alternative configurations to be identified. The next level of sophistication is to use a spreadsheet-based approach. This allows for a much better level of analysis, enabling the quantification of the problem and potential solutions in fairly quick time. Spreadsheets can also be used to provide maps of the output.

The most common approach to determining DC location solutions is to use a logistics strategy simulation or optimization model. A variety of software programs has been developed. The common technique is to simulate the cost of operation for a particular configuration. As indicated, these methods are essentially ‘what if’ simulations that will always give best results in the hands of an experienced user. Recent innovations have included the use of high-resolution colour graphics to give a detailed representation of the geography and logistics involved.

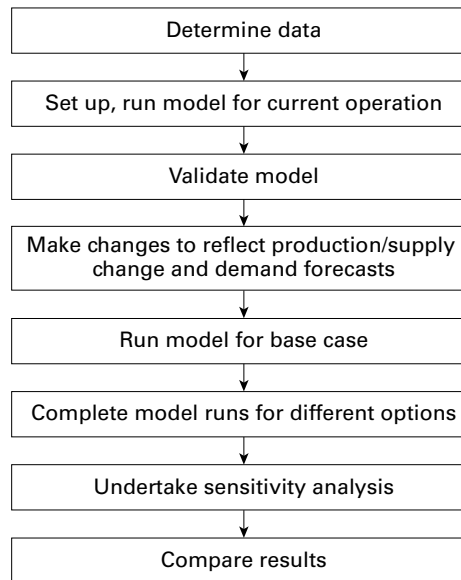
11. Determine base case

The main steps necessary for DC location modelling are outlined in Figure 10.4. An essential stage of logistics simulation is model validation. This involves the configuration and calibration of the model so that the current situation is accurately reflected in the baseline model that has been developed. The validation exercise involves taking a known situation and reproducing flows and customer service to test whether the costs are predicted with reasonable accuracy. It is essential to ensure that the model or method of analysis is truly representative of the system being investigated. Thus, there is a constant requirement during this part of the modelling process to check and test the appropriateness of the model and the results produced. When agreement has been achieved or variances have been understood, then a variety of alternative options can be tested against this ‘base case’.

12. Analyse, cost and compare options

At this stage of the planning process, it becomes possible to start to test the key options that have been identified as feasible solutions. It should be noted that often the simulation of a future scenario will involve the synthesis of new databases of customer location and demand. This may require new costs and performance data to be identified – much of which may be outside the experience and data records of the company and so will necessitate supplementary data collection and evaluation.

Models will typically produce a great deal of cost and performance data as their output. It is also important to check the impacts on customer service with these option changes as this is key and may not be as clearly measured as some of the cost

Figure 10.4 Logistics modelling: the main steps for a DC location study

implications. It is also important to be aware of the need to ‘future-proof’ the results by testing a range of options that test various growth implications to ensure that the ‘new’ logistics structure is able to cope with a varying degree of future growth scenarios. This may be with respect to elements such as different demand increases, customer location changes, cost variability and business strategy developments (such as more home delivery, new product developments, different sourcing implications).

An additional stage in the modelling process when sourcing models have been used is to rerun the allocation with the logistics costs that have been modified in the logistics simulation. This should not lead to major changes if the original cost estimates are realistic and robust solutions are obtained.

Evaluate results, develop implementation plan

13. Evaluate results against logistics and business strategy

Having modelled the logistics options and selected one or more that perform well when measured against service and cost, the impact of these on the total business strategy must be assessed. Three main areas where this will impact are:

- 1 *Capital costs:* if increased factory storage, new DCs, new equipment or new vehicles are required, then capital or leasing arrangements will be needed. In certain situations, capital constraints can exclude otherwise attractive options.

In other cases, an excessive increase in working capital (e.g. stockholding) may exclude an option.

- 2 *Operating costs*: the minimum operating cost is frequently the main criterion for selection between options. In some situations, increased operating costs can be accepted in the light of future flexibility.
- 3 *Customer service*: although options should have been developed based on customer service targets, the selected shortlist must be examined for the customer service level achieved. The balance of the mix might have changed in an effort to reduce costs. Stock held close to the customer might need to be increased to improve service reliability.

One means of matching logistics strategy to business strategy is to undertake some associated qualitative analysis. There are several reasons for doing this but the key ones are, first, to support the quantitative analysis and, second, to use qualitative analysis in place of quantitative analysis where it is impossible to derive good quantitative measures. A series of key assessment criteria can be developed and used to help in the comparison of the different strategic options identified. These can then be weighted according to their importance in the decision-making process, and scored according to how each particular option is thought to perform. As well as the more obvious cost indicators, there are other criteria that may also be important. Table 10.1 gives a partial example of this, showing the qualitative measures for 'service/marketing' (representing 25 per cent of the total assessment factors) and 'other' factors (25 per cent). The remaining 50 per cent (not shown) would be represented by cost factors.

Methods for the planning of the next level of distribution elements such as warehouse configuration, stock location and levels, vehicle fleet size and mix, and vehicle routing and scheduling are covered in the appropriate chapters elsewhere in this book.

14. Implementation

When an appropriate option has been finally agreed and the remaining distribution requirements have been determined, then the process of implementation can start. This should follow the standard business practices used for any major project implementation plan. In addition, suitable cost and performance monitoring processes should be set up and used (see Chapter 38).

Table 10.1 Example of part of a qualitative assessment used for a European study

	Weighting %	Score 1 to 5	Total
Service/marketing	25%		
Service – reliability	8%	4	32%
Service – response/speed	4%	4	16%
Complete order delivery	1%	5	5%
Market presence (ie stockholding)	1%	1	1%
Product quality	3%	3	9%
Company image	4%	1	4%
Flexibility of service	4%	1	4%
Total	25%		71%
Others	25%		
Flexibility (for subsequent change)	3%	5	15%
Ease of management/control	4%	2	8%
Change from current – physical	1%	1	1%
Change from current – personnel	1%	2	2%
Risk (financial)	4%	4	16%
Risk (customer service)	4%	3	12%
Risk (loss of business)	5%	5	25%
Management of change	3%	4	12%
Total	25%		91%
Overall total			162%
Positive impact	5		
No impact/no change	3		
Large negative impact	1		

Logistics management and organization

11

Introduction

In this chapter, consideration is given to the way in which logistics and distribution are organized within a business. The importance of the integration of the logistics function into the business as a whole has been emphasized at various times throughout this book. There is a need for the organizational structure to reflect a similar form of integration. Thus, logistics organizational issues and human resource or 'people' aspects are addressed in this chapter.

There are several factors covered, the first being a brief summary of those aspects that concern the relationship of logistics and distribution with other corporate functions, introduced earlier in Chapter 2. Allied to this, a number of different organizational structures are discussed. These include traditional structures as well as those that provide more emphasis on logistics and those that allow for a process-oriented, cross-functional integrated approach to the organization.

The role of the logistics and distribution manager is considered – both with respect to his or her position within the company and also with respect to key functional responsibilities. A more 'grass-roots' view of logistics is taken, with a discussion on the payment systems used within the distribution and logistics environment.

Logistics relationships with other corporate functions

In Chapters 1 and 2, logistics and the supply chain were considered in the context of business and the economy as a whole. In particular, the interfaces with other corporate functions were discussed, the major ones being with production, marketing and finance. There are many occasions when the importance of these corporate relationships has been emphasized, not least because of the move to a cross-functional,

process-oriented view of the supply chain. This importance is particularly valid where the planning of corporate strategy is concerned. The need to adopt such a view was discussed in Chapter 6.

There are two key points that bear re-emphasis at this stage. First is the fact that logistics is, for many companies, already an integral part of the corporate being. Because of this, the second major point becomes apparent – the need for logistics planning and strategy to be recognized and used as a vital ingredient in the corporate plan.

The first point – that logistics is such an important element within a company's total business structure – can be illustrated using the interrelationships of logistics with other functions:

- with production: production scheduling, production sequencing, production control, plant warehouse design, raw material stocks
- with marketing: customer service, packaging, distribution centre location, inventory levels, order processing
- with finance: stockholding, stock control, equipment financing, distribution cost control, personnel costs

The need to include the planning of logistics and distribution in the overall corporate plan is thus self-evident. The business planning process was previously shown in Chapter 6, Figure 6.2. Even within this strategic framework it can be seen that distribution and logistics factors should provide a vital input. Within the strategic planning process, such elements as market analysis and policy determination cannot be derived without an understanding of customer service requirements and channel choice alternatives. With any policy assessment exercise and in any subsequent determination of competitive strategy, knowledge of key logistics elements is essential. Any factors related to the procurement, storage and movement of goods must, of necessity, be relevant to the determination of a company's business plan.

The reason that companies may fail to allow sufficient logistics input into the corporate planning process is probably due to the dynamic nature of the logistics environment and operation. Logistics is seen to be very much about doing and providing. As such, it can be viewed and treated as a short-term factor, with little direct relevance to long-term planning. Logistics is a function with both long- and short-term horizons. Its very dynamism tends to mould the one into the other, making it difficult at the operational level to distinguish between the two. In addition, the consequence of inappropriate planning is often seen as a short-term operational problem. In effect, the size and extent of financial and physical investment makes it imperative that the differentiation between the long and the short term is made and that, where necessary, the relevant elements of distribution and logistics are included in the overall business plan.

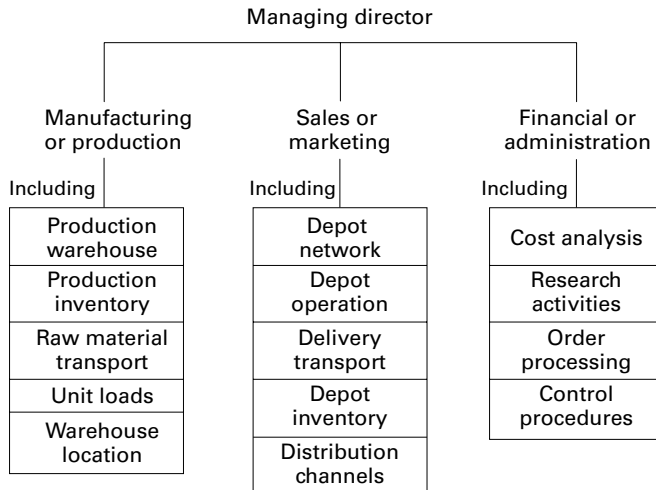
Logistics organizational structures

Associated with the danger of not including relevant logistics factors within the corporate business plan is the need to recognize that the logistics function may also require a specific organizational structure. Logistics is sometimes not seen as a discrete function within the organizational structure of a company. Although distribution and logistics is generally recognized as an important element of many companies' operations, a number still fail to adapt their basic organizational structures to reflect this changing view.

Various different physical distribution functions may be allocated among several associated company functions. This failure to represent distribution and logistics positively within the organizational structure is often a result of historical arrangement rather than a specific desire to ignore the requirement for a positive logistics management structure. Clearly, some positive organizational structure is essential if the logistics function is to be planned and operated effectively.

A typical traditional structure, showing key logistics and physical distribution elements spread among different corporate functions is illustrated in Figure 11.1. The problem with this type of organizational structure is that lines of communication are unclear from the logistics standpoint. Thus, it is often impossible to optimize the efficiency of the different logistics sub-functions, let alone create an overall logistics system that is both effective and efficient.

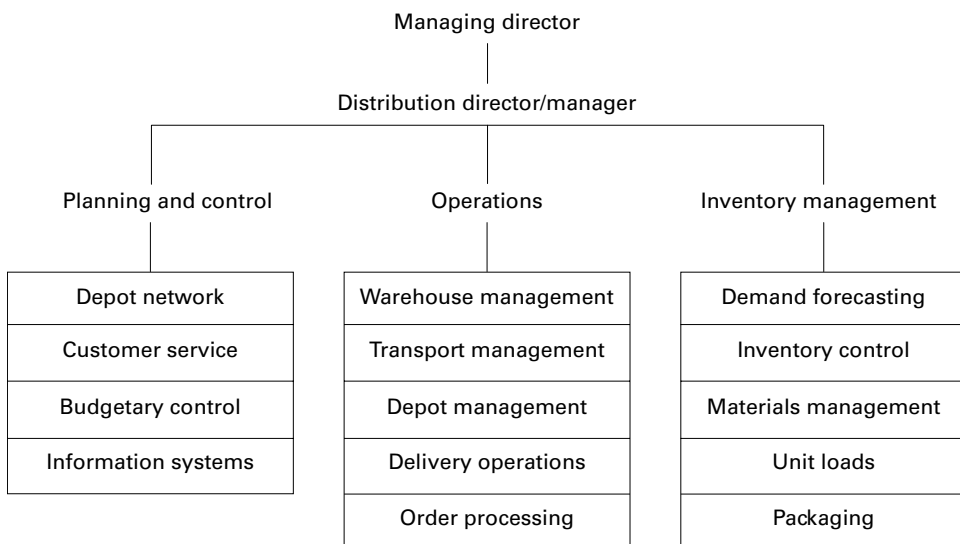
Figure 11.1 A traditional organizational structure showing the positioning of key logistics functions



Most of the more forward-looking logistics-aware companies have seen the need for some form of organizational structure to reflect the recognition now being given

to the importance of distribution and logistics activity. This new functional approach emphasizes the need for logistics to be planned, operated and controlled as one overall activity. The precise structure will obviously differ from one company to another. A typical structure might be as illustrated in Figure 11.2. This type of structure allows logistics to be managed as a function in its own right, although the need for close liaison with other company functions remains vital.

Figure 11.2 A functional organizational structure showing logistics activities linked together



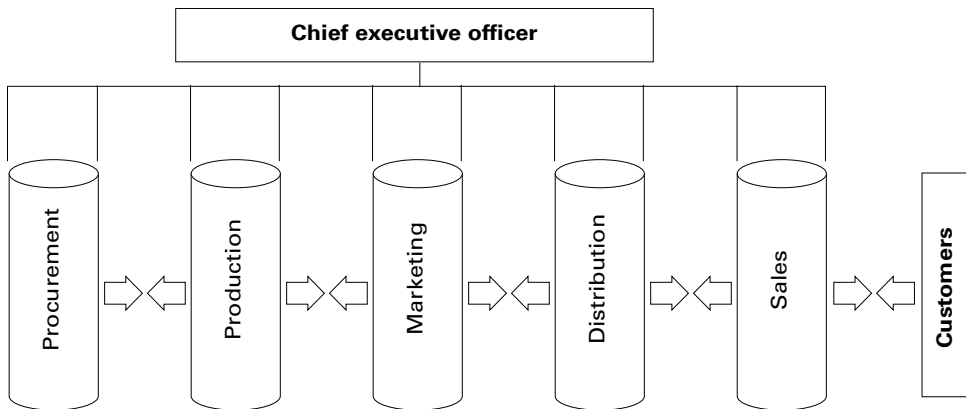
Organizational integration

One important factor that has evolved with the move towards supply chain integration is the recognition of the need to rethink the way in which logistics operations are organized. This has led to a change in thinking in organizational terms away from functional structures and towards process-oriented structures. This is in many ways a reflection of the key changes that have been outlined in previous chapters:

- the emphasis on the customer, and the need to ensure that internal processes support the requirement to achieve customer satisfaction
- the concentration on time compression throughout the whole supply chain, and the need to identify and manage suitable trade-offs
- the move to globalization and the requirement to plan and manage the logistics network as a complete system

Traditional organizational structures do not really lend themselves to this way of thinking. They are essentially functional and inwardly focused, with their director reporting to a chief executive officer (see Figure 11.3). Each activity operates as a self-contained silo where there is a tendency for their functional boundaries to create barriers to integration – with the power barons at the head of each function perhaps fighting to protect their own power base, rather than pursuing overall company objectives.

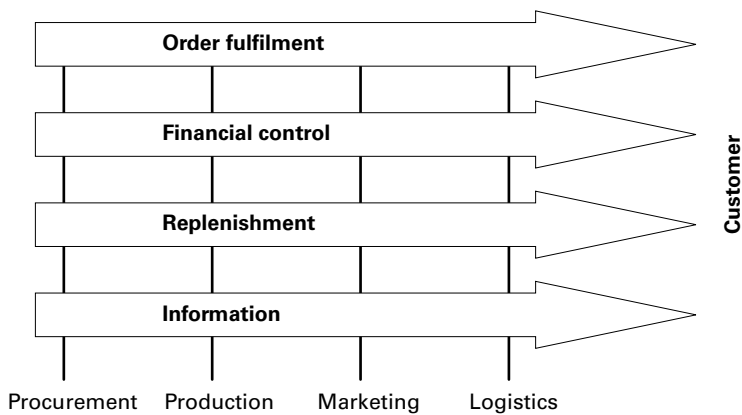
Figure 11.3 A traditional silo-based functional organizational structure



Thus, there has been a move away from these silo-based functional structures towards more process-oriented organizations. These are based on key business processes, such as those described in Chapter 7. They attempt to reflect the need to support, in particular, the customer-focused approach that many companies are trying to achieve. These new structures try to increase the visibility of market demand and enable an integrated supply chain response. An example of such an approach is shown in Figure 11.4.

This type of structure is known as mission management and is based on the concept of the management of systems or flows. This is undoubtedly relevant to logistics and distribution, which are concerned with material and monetary flows as well as the associated information flows often from raw material through various processes, storage and movement to the final customer.

Clearly the potential problems of mission management lie in the difficulty of managing and coordinating across functional boundaries. However, where good management practices are followed, and in the appropriate operational context, organizational structures such as these can work very effectively. They are particularly relevant for customer-service-oriented businesses. Some of the larger chemical companies, for example, adopt this type of management structure to provide co-ordination and control throughout the supply process of particular products.

Figure 11.4 A customer-facing, process-driven organizational structure

Mission management is cross-functional, and as such can pose problems in a traditionally functional organization. For many companies, this type of mission management structure has not been an easy alternative, with traditional managers loath to make such a dramatic change to an approach that they have been familiar with for many years. Because of this, a further development, matrix management, has evolved. Here, the product or flow is planned and managed by a 'flow' or logistics manager, while the traditional functions provide the necessary inputs as they are required.

For some companies, a mixed or matrix approach seems to have been the most successful. This accepts that there is a need, at the planning level, to reorganize on a process basis, which crosses traditional boundaries, but recognizes that it is important to retain specialists at an operational level to ensure the efficient running of operational functions such as transport and warehousing. The different emphasis in these two approaches is demonstrated by comparing Figures 11.5 and 11.6.

As well as changes to process-oriented management structures, there have been broader supply chain initiatives, in particular the need to rethink buyer–supplier relationships. A major aim is to move away from the traditional, somewhat combative arrangements that have occurred with buyer/seller price-led relationships towards the building of stronger and more positive partnerships that reflect the need for companies, within a supply chain, to work together to achieve commercial success. This involves the development of a structure where the link is not merely between the sales team on the one hand and the buying team on the other. The new structures are designed to promote coordination and cooperation with other relevant groups across company boundaries. This might include research and development, marketing, distribution and any other functions that, with a suitable link, can benefit from such a partnership approach. Figure 11.7 demonstrates the change in approach from a traditional single point ('bow-tie') to a coordinated multiple approach ('diamond').

Figure 11.5 Mission management, which acts directly across traditional functional boundaries

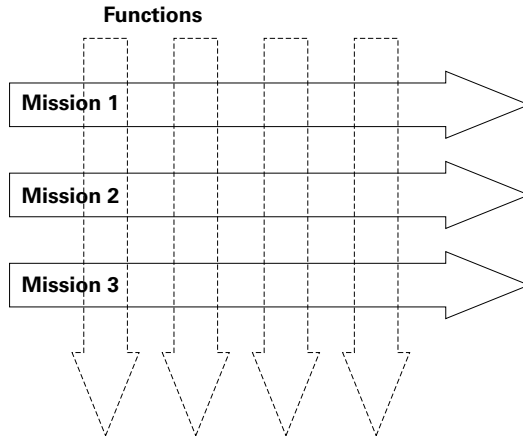
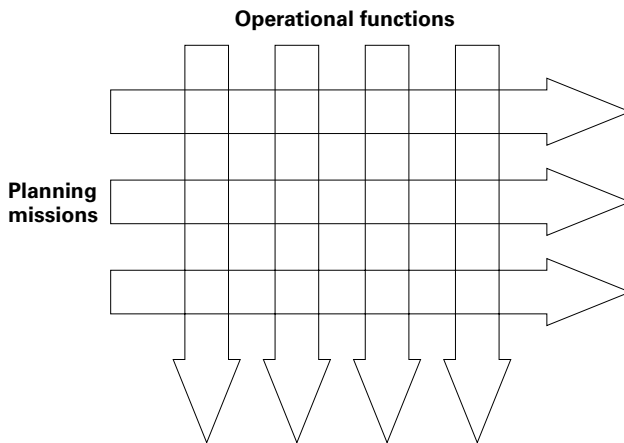
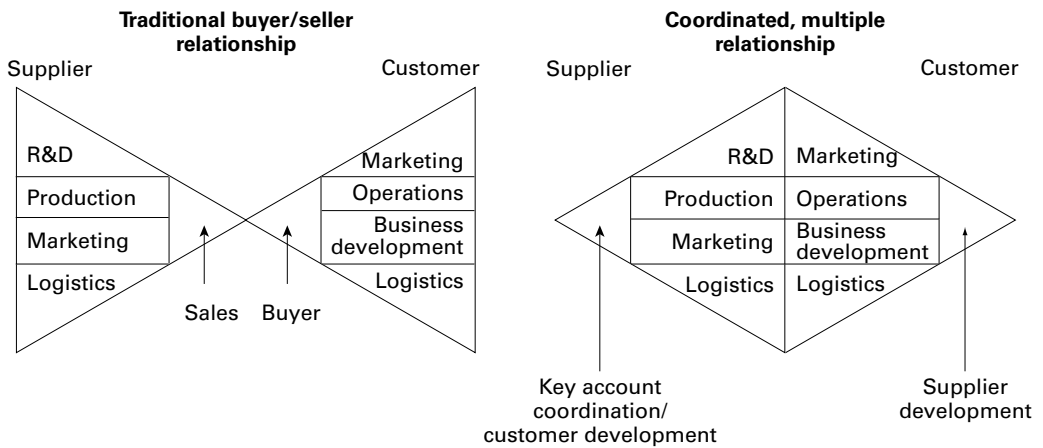


Figure 11.6 Matrix management, which emphasizes both planning and operational elements



The role of the logistics or distribution manager

The role of the logistics or distribution manager can vary considerably from one company to another, dependent on the internal organizational structure, the channel type (own account, third party, etc), the industry or product, and the customer profile. Factors such as these will certainly affect the extent of the operational role and

Figure 11.7 Buyer/seller relationships: a single versus a multiple linked approach

SOURCE Christopher and Peck, 2003

the nature of the planning role. It is useful here to consider the part that the logistics or distribution manager can play in both the planning and the operational processes.

With respect to the *planning process*, in an earlier section of this chapter, the need for companies to include the planning of logistics and distribution in the overall corporate strategy was emphasized. It is possible to identify several key factors in which the logistics manager can contribute to and benefit from an involvement in the planning process. These include:

- providing a positive input into corporate strategic planning
- gaining a better understanding of the company and its business
- the potential for improving the effectiveness of the logistics operation the company is providing

These factors include both the physical and the information systems and requirements of the operation.

More detailed points for each of these three elements include:

- 1 *Providing an input into corporate strategic planning:*
 - a an understanding of the functional interfaces
 - b full involvement with distribution's activities
 - c familiarity with the external environment as it relates to distribution
 - d insights regarding competitor distribution strategies
 - e familiarity with customer distribution needs
 - f knowledge of channels of distribution
 - g distribution data

2 *A better understanding of the company and its business:*

- a** appreciating the company and its strategic goals
- b** a clearer knowledge of other functional activities
- c** clarification of the impact of corporate strategy on distribution activities
- d** increased sensitivity to the distribution environment
- e** a greater awareness and appreciation of integrated information systems

3 *Improving the effectiveness of the logistics operation:*

- a** developing a broader perspective of distribution
- b** increased delivery responsiveness
- c** improving rapport/liaison with others
- d** identifying distribution opportunities
- e** recognizing customer needs
- f** improving communication between functions

Logistics-related planning activities are a vital input in the overall business strategy. The more specific elements were outlined in the early chapters of this book. They involve a medium- to long-term planning horizon and will include aspects such as the number of facilities, their size and location, transport networks, fleet size and mix of vehicles, stock levels, information systems, etc.

As already indicated, the *operational role* for managers can vary significantly according to the size and nature of the business, the product, the channel type and the customer profile, among other factors. Also, there are a number of different job titles and job functions that exist. These range from the distribution or logistics manager, who might have overall responsibility for an entire distribution network, including central distribution centres, regional distribution centres, primary transport (line-haul) and delivery vehicles, stock location and control, computer systems, etc, to a shift manager or supervisor who might, for example, be concerned with the detailed performance and control of an order-picking operation on a night shift.

Traditionally, the three main operational areas of responsibility are related to:

- 1** *transport:* primary transport (line-haul), delivery operations, vehicle routeing and scheduling, vehicle procurement, etc
- 2** *warehousing:* goods inward, bulk storage, order picking, marshalling, materials handling equipment, etc
- 3** *information:* stock location, stock control, order processing, budgeting, monitoring and control, etc

For many logistics managers, these areas may be expanded to cover other aspects such as procurement, inbound logistics, inventory levels, forecasting, telesales,

production planning, reverse logistics, packaging, etc. In addition to these broad functional areas, there is a staff role concerning the management of human resources, union negotiation, health and safety, and the linkage to other corporate interfaces such as production, supply, marketing, sales and finance. Over and above all of these aspects of the operational role, and probably common to all types of distribution organizations, is the responsibility for, and the need to control, the balance between the service to the customer and the cost of providing this service.

Some logistics managers may have an even broader remit that covers key elements of *supply chain planning*. These might be summarized as:

- to lead the design, creation, configuration and parameter setting of the entire supply chain
- to create the framework and the dialogue that determine the performance targets along the whole chain
- to drive the systems and monitor and report the entire logistics operational performance against agreed targets
- to review how problems can be solved and performance improved

Payment systems

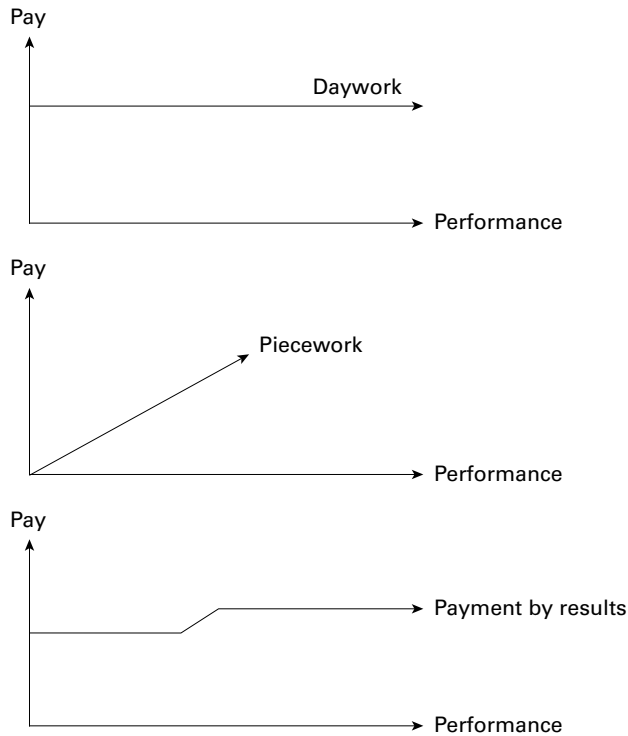
One relatively neglected area in the literature on logistics and distribution concerns the various payment mechanisms and incentive schemes that are used within the industry. Having looked at the broad roles and responsibilities of the distribution or logistics manager, it is interesting to gain a better understanding of the grass-roots position related to the type of payment systems that are commonly in use.

There are a number of different types of payment system. These can be broadly divided into the three main systems of daywork, piecework and payment by results. These are illustrated in Figure 11.8. Daywork is a method of payment based entirely on the hours attended at work; piecework is payment entirely related to the amount of work undertaken; and payment by results is a mixture of these, providing a basic wage plus a bonus based on work undertaken.

There are a number of variations of these systems:

- *Daywork* (also known as graded hours, fixed day, etc): this is based entirely on the hours worked.
- *Measured daywork*: this consists of a basic attendance wage plus a bonus for achieving a given level of work performance.
- *Stepped measured daywork* (stabilized incentive scheme, premium payment plan): this introduces 'steps' in the measured daywork scheme, so providing additional incentive.

Figure 11.8 The main types of payment system, showing the relationship between performance and pay



- *Merit-rated bonus scheme* (incentive bonus scheme): this is a bonus scheme on top of a basic wage, but it is not productivity-related. It might be related to attendance, achievement of performance targets, etc.
- *Piecework*: payment is entirely based on the amount of work completed.
- *Payment by results*: in its purest form this is piecework, but usually it is a results-based payment on top of a basic wage.
- *Commission*: this is a piecework or payment-by-results scheme, but is based on effort and achievement (e.g. sales, cost savings); this is a common type of management bonus scheme.
- *Group or plant-wide schemes*: these are collective bonus schemes based on collective performance, which could be related to costs versus sales, increased output or improved efficiency.
- *Fringe benefits*: these are various non-performance-related add-ons covering such items as Christmas bonus, subsidized canteen, clothing allowance, etc; eventually, these types of benefit can become taken for granted.

- *Profit-sharing scheme*: this is related to the company profit, and is aimed at fostering employee interest in the company.
- *Share schemes*: these are usually limited to managers and directors, though there are some notable company-wide share schemes.
- *Team working*: these are rewards for small groups, usually used for management teams.
- *Annualized hours*: these are formalized systems that treat working time on the basis of a number of hours per year rather than hours per week; they have become recognized as useful schemes where there is a distinct seasonal or peak nature to the work and thus are matched to the needs of the business to meet customer requirements and are popular in warehouse operations.

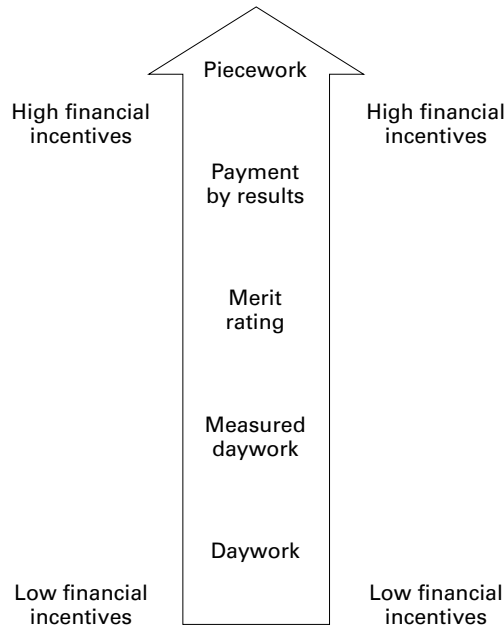
For motivational financial schemes it is important to distinguish between schemes that provide an incentive, reward or bonus, because they can have a varying impact on workforces. The main differences are:

- *Incentives*: these stimulate better performance in the future because they are payments for the achievement of previously set and agreed targets. Incentives tend to have the most direct impact on employee behaviour and motivation because the conditions of payment are known in advance.
- *Rewards*: these recognize good performance in the past. They are likely to have a less direct impact on behaviour and motivation due to the level of uncertainty of the amount of the payout.
- *Bonuses*: these are rewards linked to performance but paid out in a lump sum.

Clearly, the applicability of these methods of payment varies considerably from one type of distribution operation to another, and from one type of distribution job to another. Productivity-related incentive schemes are only valid in operations that will benefit from schemes of this nature, i.e. where increased worker effort will mean an increase in output. For many distribution operations, the need for accurate, timely order picking may far outweigh the number of picks made per picker per hour. Additionally, it is likely to be both dangerous and illegal to propose a driver incentive scheme that gives additional payment for the speed with which the work is completed!

It is interesting to consider two particular aspects related to payment schemes, and to show how these vary according to the type of scheme operated.

The first is the relationship between different schemes and *financial incentives*. This is illustrated in Figure 11.9, which demonstrates how piecework, for example, at one end of the payment scheme spectrum, requires high financial incentives to operate effectively. The other extreme, daywork, can operate with low financial incentives.

Figure 11.9 Hierarchy of payment schemes in relation to financial incentives

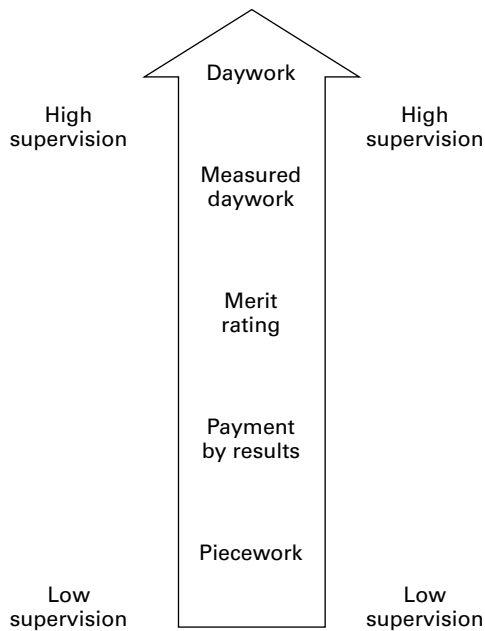
In contrast, Figure 11.10 shows the extent of *supervision* required for the different payment schemes. Here it is daywork that requires the most amount of supervision and piecework the least.

It can be seen from the two figures that one is the direct converse of the other. This demonstrates that, in general, high levels of supervision are required to support payment schemes that offer low financial incentives. Conversely, in general, payment schemes with high financial incentives require the least amount of supervision.

The relevance of these different schemes for distribution is best summarized according to the main breakdown of distribution personnel – drivers and warehouse staff.

Drivers are most likely to be paid on hours worked or hours guaranteed – some form of daywork. There may also be a special rate for the job, based on work experience or driving qualifications. In terms of incentive, a form of ‘job and finish’ might be operated, giving extra leisure rather than extra cash as the incentive. Financial bonuses might be offered as a form of payment by results based on such things as miles/kilometres run, cases delivered, etc. Once again it must be emphasized that any bonus payments are prohibited if they endanger road safety.

Warehouse staff are also likely to receive remuneration based on hours worked or guaranteed. In the more controlled environment of a warehouse, daywork is likely to be measured. Additionally, there are likely to be different rates according to different job functions (fork-lift truck drivers, pickers, etc). Merit-rated bonuses

Figure 11.10 The extent of supervision required for different payment schemes

based perhaps on attendance might be offered, and certainly productivity-related bonuses are likely to be very common, based on cases picked, pallets moved, etc. Measured performance schemes are operated based on work study standards for specific tasks. In addition, as already indicated, many companies are now introducing annualized hours because it can lead to a much more efficient use of the labour force.

Omnichannel fulfilment

12

Introduction

With the mix of store and internet shopping continually evolving the subject of omnichannel fulfilment provides logistics managers with a considerable challenge. In this chapter, the main issues posed by omnichannel fulfilment are explored, together with alternative supply chain structures both for food and non-food retailing. Finally, an approach to implementation is examined.

Most large retailers sell their products through a mix of different distribution channels, particularly via ‘bricks-and-mortar’ stores and over the web. The latter is often referred to as ‘e-commerce’ and may be accessed by personal computers or by mobile phones/tablets (known as ‘m-commerce’). When buying goods, consumers may interact with retailers through these and other communication channels:

- *initial awareness of the product*: television, magazines, internet advertising, store displays
- *information about the product*: website, telephone, email, mobile ‘apps’, store salesperson
- *purchase of the product*: via website, by telephone, by mail, at store
- *delivery*: home delivery, collection from drop-point, collection from store
- *returns*: by mail/parcel, collection by van, return to store

A consumer may thus use a variety of these channels in relation to a single purchase. For example, he or she may see something in a magazine, find out more details while visiting a store, purchase on the website, collect from the store and arrange to return it to a distribution centre by post. This potential mix of channels presents a number of challenges with regard to marketing, sales and physical distribution. It is important in this context that a consistent brand experience is provided to consumers across these channels at each stage of the transaction. This mix of channels in the same transaction, together with a consistent brand experience across channels, are the essential characteristics of ‘omnichannel’ retailing, as opposed to the term ‘multichannel’ retailing, which may just be regarded as selling through different

channels. The interaction between channels can be positively promoted by retailers, for example by positioning computer screens in-store so that shoppers can browse the online range of goods or by offering next-day delivery from a distribution centre for any items out of stock in the stores. Various terms are used to describe these interactions, for example:

- *BORIS*: buy online, return in-store
- *BOPIS/BOPUS*: buy online, pick-up in-store (also known as *click-and-collect*)

Previous chapters have noted the various channels of distribution, how the supply chain may be segmented and how logistics networks may be planned. This chapter now brings together these different aspects in relation to how retailers serving consumers through multiple channels may segment, design and manage their supply chains.

Issues

There are a number of issues faced in omnichannel fulfilment. First of all, *different order profiles* tend to occur in each channel. Most retailers serve stores from their own distribution centres, supplemented by some direct delivery to the stores by manufacturers of specific goods (e.g. high-volume and fresh products). Stores tend to order in reasonably large quantities and therefore full-case or pallet quantities are normally required. However, the order profile is quite different for internet shopping which involves direct-to-consumer (D2C/DTC) orders typically of very small quantities: for example, an order for photographic products may be one digital camera and one carrying case. Thus, whereas store deliveries tend to comprise a small number of orders, with many order lines (i.e. many different product lines on an order) and many items per line, the internet channel is normally characterized by many individual consumer orders, with few order lines and few items per line. This profile also occurs for automated home ordering, where appliances such as refrigerators, coffee machines and printers order new items immediately home stocks become low; this type of connectivity between devices and the web is known as the Internet of Things (IoT). In addition, direct-to-consumer orders normally need to be individually packed ready for home delivery.

The *service expectations* of the retail store and the internet customer may be significantly different. Consumers ordering on the internet often expect rapid home delivery (or a fixed time delivery), regular updates on the order status, and for the whole order to be 100 per cent accurate and damage free. Stores hold a small buffer stock of different items, so traditionally the service level expectations for store deliveries have not been quite so demanding. A further consideration is the *product range* offered through each channel. Retailers may decide to offer the same range on

the internet as they offer in their stores, a restricted range or an extended range of products.

Seasonal peaks are often more accentuated in the case of internet sales, particularly for non-food items. Thus, some retailers experience internet sales during the seasonal peak that are a few hundred per cent higher than normal sales levels. This causes severe logistics challenges, including finding space within the warehouse for inventory in the build-up to the peak, hiring and training seasonal workers and handling the sheer throughput of goods at peak within the advertised service levels.

The percentage of *returns* by consumers is often far higher for internet orders than for store orders, particularly in the case of non-food (e.g. fashion) retailing. Peak returns have traditionally occurred after the peak sales season, but there is now a trend towards price reductions during the peak sales season (e.g. 'Black Friday' and 'Cyber Monday' during the UK Christmas period) and therefore high levels of returns now often have to be handled at the same time as continuing peak sales levels. In certain market segments the level of returns can be over half of the goods dispatched so this can be a major issue. In addition, some retailers actively encourage returns of old items (e.g. previously bought clothing) as part of their environmental credentials.

These contrasting characteristics have *implications* for supply chain design. Thus, different types of distribution centre operation may be required (e.g. case picking to low-level order picking truck for store orders and item picking from conveyors for internet orders), as well as different vehicle types (e.g. articulated trailers or large rigid vehicles for store deliveries and small vans for home delivery). In addition, there may be implications for the disposition of inventory. For example, if different distribution centres are set up to handle each channel then this would involve separate stockholdings of each product line. Also, pack sizes may be different for each channel and this would necessitate separate stockholdings.

It should be noted that within each of the two main channels described above (i.e. store and internet channels), there may be numerous sub-channels, each with its own characteristics. For example, the store channel may include own stores, franchise stores, in-store kiosks, discount stores and pop-up stores. These often have different order characteristics and therefore may need to be segregated in terms of distribution networks or operations.

Food retailing

Food retail stores are normally served by regional distribution centres (RDCs) from where vehicles deliver to stores in a specific geographical area. In order to minimize the duplication of stocks across the regions, slow-moving goods are often stocked at national slow-moving goods centres (SMCs) from where products are transported

overnight and cross-docked at the RDCs to merge in with the store deliveries of fast-moving and medium-moving goods.

Retail food products may require frozen (i.e. about -18°C to -25°C), chilled (i.e. about $+2^{\circ}\text{C}$ to $+5^{\circ}\text{C}$) or ambient (i.e. normal) temperatures. Therefore, the warehouses and vehicles must be multi-temperature (i.e. with separate zones or compartments for each temperature range) or different distribution networks need to be established for each temperature regime. For example, a retailer may have a separate network of frozen warehouses, from where refrigerated vehicles deliver the products at frozen temperatures to the stores.

In order to serve the internet channel for home delivery or store collection, food retailers have a number of distribution options:

- *Regional distribution centres*: one option is to serve the internet orders from the existing RDCs. This may reduce the need for extra warehouse infrastructure and it also facilitates the options of either delivering to the consumers' homes or delivering to the stores for the consumers to collect. However, the geographic areas to be covered by vans based at the RDCs for home delivery tend to be very large and this makes multi-drop transport to homes fairly inefficient. Another disadvantage is that the RDCs have been set up for pallet and case picking and may not be suited to handling a multitude of small orders that require item picking. If there are different existing networks for frozen, chilled and ambient goods, then there is the added complication (and cost and time delay) of consolidating loads together for single deliveries to consumers' homes.
- *Stores*: a second option is to pick the orders at the stores and deliver the goods on vans based at the stores. This utilizes an existing network of locations close to the consumers, thus being suitable for multi-drop home deliveries. This is a commonly used option, but does have the disadvantages of possible interference with shoppers (i.e. by the internet pickers who would be traversing the same aisles as consumers in the stores) and potential conflict between car and van parking. In addition, it is not possible to guarantee a particular product line to a consumer at the time of ordering on the web, as the product may be out of stock on the shelf by the time it is picked.
- *E-fulfilment centres (eFCs)*: a third option is to establish specialist e-fulfilment centres. These can be specifically designed for the efficient picking of internet orders and stock can be reserved for consumers at the time of ordering. If items are out of stock at the e-fulfilment centre, then this is known at the time of receiving the internet order and substitutes can be offered to the consumer. This option is also suited to 'pure-play' internet food retailers who do not have an existing RDC or store network. However, distances to consumers can be lengthy, making efficient multi-drop home deliveries difficult to achieve. A network of e-fulfilment centres is therefore one option. Some omnichannel retailers use a

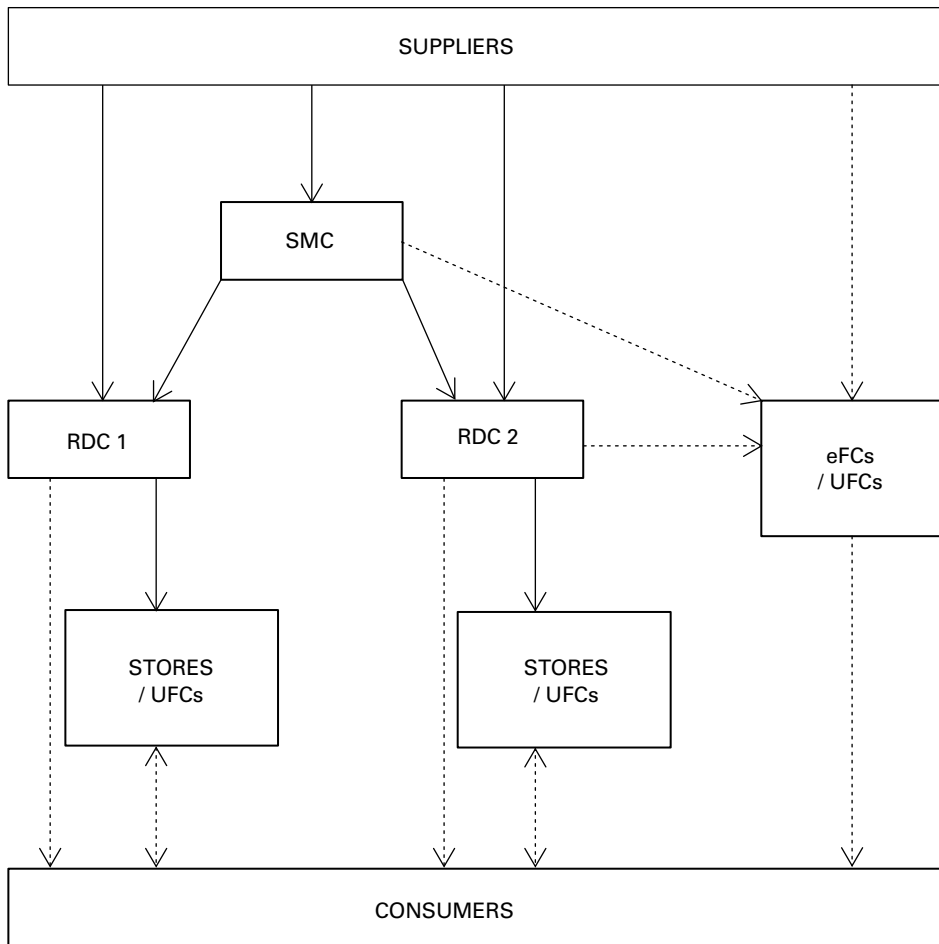
combination of options, such as e-fulfilment centres in major centres of population (where vehicle drop densities can be high) and the store option in rural areas. Small e-fulfilment centres in towns and cities are often known as urban fulfilment centres (UFCs), micro-fulfilment centres (MFCs) or 'dark stores'. These require sites that are close to residential areas, have planning permission to operate 24 hours per day, and have large yards to accommodate the delivery vans. Such sites can be difficult to locate in some geographic regions. In some urban areas retail parks have been repurposed to provide land for UFCs. Also, UFCs may be set up at the back of (or above) existing stores and micro-fulfilment systems are available to provide automated solutions for storage and order picking. These micro-fulfilment solutions may utilize 'goods to picker' technologies such as conveyors or autonomous mobile robots (AMRs) bringing goods to pickers from miniloads (see Chapter 21 for details).

These distribution options are shown diagrammatically in Figure 12.1.

The actual delivery of products to the consumers' homes (or workplaces, pick-up points, secure boxes, etc) was discussed in Chapter 5 under 'The consumer'. These deliveries often have to be made to fixed time slots agreed with the consumer at the time of order so as to ensure that someone is at home to receive the goods. This is not only important for consumers but also for cost efficiency – further attempts at delivery add to the transport cost and may also necessitate new perishable items being picked for the consumer, with the consequent difficulties of recycling the old items that have begun to perish. One option is to arrange to deliver directly to consumers' refrigerators and freezers located in the house or outside, based on suitable access arrangements.

Non-food retailing

Non-food retailing includes goods such as clothes, electrical appliances, books, toys and beauty products. Traditionally, the distribution networks serving *retail stores* comprise one or more national distribution centres (NDCs). This is because the cost trade-off, described in the analysis of logistics networks in Chapter 9, is greatly influenced by the high inventory-holding costs. With non-food goods there are often a large number of stock-keeping units (SKUs), with a long tail of fairly slow-moving goods. It is frequently not cost-effective to replicate these stocks across regions. There are exceptions, and where there is sufficient volume through a large number of stores then regional distribution centres may sometimes be found. In the case of NDC structures, there may be just one NDC or, if this would be too large, then there may be a number of NDCs each holding a specific product group. Where this occurs, there is a need for the consolidation of goods from different NDCs prior to dispatch to the stores (or sending separate vehicles from each NDC to the stores).

Figure 12.1 Potential omnichannel fulfilment options for food retailing**Key:**

↓	Flow of goods to serve store channel
-.-↓	Alternative flows of goods to serve home shopping channel
SMC	Slow-moving goods centre
eFC	e-Fulfilment centre
RDC	Regional distribution centre
UFC	Urban fulfilment centre

In the case of *‘pure-play’ internet retailers* (i.e. retailers that only sell over the internet and do not have any stores), then these often have a single NDC, normally located near the hubs of the parcel carriers. This is so that they can offer a late cut-off time in the evening to consumers and still have time to pick and deliver parcels to the hub ready for overnight distribution and delivery the following day. In the UK, for example, these hubs are generally located centrally in the Midlands region. However, if the NDC feeds chiefly into the postal service then it may be located away from the

Midlands, as the postal service has multiple hubs around the country. For large 'pure-play' internet retailers, it may not be practical to have a single excessively large NDC (for reasons such as site availability, staff availability, effective management or business resilience) and therefore separate NDCs for each product group may again be required. Where internet retailers grow even larger then they may eventually have sufficient drop density from their own deliveries to make it cost-effective to set up their own network of local depots, at which vans are based for final delivery or from which local couriers collect. Where throughput volumes are sufficiently high then it may also be worthwhile to hold fast-moving lines at these local depots so that same-day, even within-the-hour, services can be offered (although a large number of stocking points are required to provide national within-the-hour services). In addition to these networks, internet retailers may arrange for suppliers to send goods directly to consumers' homes, thus bypassing their own warehouse networks. Some internet retailers have started in this way and then as they have become larger have switched to their own warehouse networks so as to gain closer control over service levels, perhaps maintaining direct supplier delivery channel for slower-moving goods or large items.

For *omnichannel retailers*, it is necessary to provide high service levels to both their store and internet/catalogue channels while taking advantage of any synergies that may be possible. The choice of how to segment markets, products or geographical areas between the distribution centres (DCs) is therefore very important in terms of how to structure the overall distribution network. There are several different forms of segmentation that might be used:

- If the supply chains are *segmented* in terms of *store and internet channels*, then this has the advantage of providing focus to the often rapidly growing internet channel. As noted earlier, the types of orders tend to be quite different for these two channels and therefore separate DCs can be designed to fit the requirements of each. For example, a case picking operation may be suited to the store orders (e.g. picking from pallets onto trolleys or low-level order-picking trucks) while an item-picking operation may be more suited to internet orders (e.g. picking items from tote bins transported from a miniload system by conveyor to a picking station, followed by transfer to parcel-packing stations). However, this segmentation has the distinct disadvantage of increasing overall inventory levels, as safety stocks will be needed for both store and internet channels (see the 'square root rule' in Chapter 15). The decision as to whether to have separate inventory, common inventory or some form of hybrid 'ring-fenced' inventory (which allows inventory transfer between channels, but may incur inter-NDC transport costs) is a key factor in the distribution network strategy. Another disadvantage of segmenting by store and internet channels is that the collection/delivery interface with the customer may not be completely separate. If internet orders are to be

delivered to consumers' homes (or drop points, such as petrol or train stations), then it makes sense from a transport viewpoint to serve this channel from a separate DC. However, many omnichannel retailers have found that 'click-and-collect' has become increasingly popular. This is where consumers order on the internet but wish to collect from a store. In this case, the goods then need to be transferred back to the store delivery network, thus incurring transport costs (and a time delay) between the different NDCs. In addition, there may be a need to transfer returns between the store and internet supply chains – for example, goods with slightly damaged packaging may be returned by a consumer who bought them on the internet and it may then be decided to sell these at a discount in a store sale. Similarly, it may be decided to sell off overstocked internet items through store sales.

- An alternative *segmentation* is by *product group* (i.e. having a network of NDCs each holding a different product group). This would solve the problem of additional safety stocks and the unnecessary movements of goods between NDCs in relation to 'click-and-collect' and returns. However, there would generally need to be a consolidation of loads between the NDCs so that a single delivery can be made to each store (i.e. containing goods from all product groups). This again would incur inter-NDC transport costs. Consumers may also have a preference for receiving all the items ordered in one delivery, rather than receiving multiple packages on different days.
- A similar *segmentation* would be by the *storage and handling characteristic* of each product (e.g. one NDC holding small items, one holding medium-size items and one holding oversize items that may require two people to handle). This type of segmentation may benefit the warehousing element as appropriate specialist storage and materials handling equipment could be installed in each NDC. The difficulty of consolidating loads would still arise, unless separate transport networks are necessary for each grouping (e.g. large household items may require specialist vehicles or may be delivered directly to consumers using two-man delivery vehicles). One option is to locate the NDCs close to each other on the same distribution park (sometimes referred to as creating a warehouse 'campus'). If there are a large number of NDCs it may even be worthwhile to have a dedicated sortation centre on the 'campus' to consolidate loads.
- A further *segmentation* could be by *geographical region*. There would be a network of RDCs, each serving stores and consumers in their region. This would provide short delivery distances to the stores, potentially improving store replenishment times and reducing secondary transport costs on multi-drop trips to stores within each region. However, safety stocks would be increased as separate stocks of each SKU would need to be held at each RDC. The transport costs for the internet orders would depend on exactly how these are to be delivered. If

internet orders are delivered by parcel carrier then they would be sent to a parcel hub, frequently located in the centre of a country, and therefore an RDC network may not be suitable. However, if they are sent by post then the goods could be fed into multiple hubs and, in this case, an RDC network may be suitable. For direct delivery by van to consumers, note that a large number of stockholding depots (e.g. e-fulfilment centres) are required to provide high service levels (e.g. within-the-hour delivery). Such depots may be able to provide 3D printing capabilities for suitable items.

- Where large quantities of goods are *purchased from overseas*, then warehouses known as import centres may be set up in or close to ports in order to postpone the decision as to which region of the country to send the goods. This is referred to as ‘distribution postponement’ and has the benefit of allowing the supplier to forward the goods to meet known demands at RDCs in specific regions. This concept is often known as ‘port-centric logistics’ whereby ports set up distribution parks within their boundaries to facilitate the establishment of such import centres. These may also have the benefit of enabling the use of greater weight shipping containers (as they may not be restricted by weight regulations affecting national road networks) and may also reduce the amount of vehicle mileage running with empty containers, as the containers can be unloaded immediately at the port. There is, however, a danger of this approach creating an extra ‘decoupling point’ in the supply chain (see Chapter 16), with the possibility of extra stockholding. The total supply chain therefore needs to be planned with care.

The choice of segmentation is therefore fairly complex and, in addition to the distribution network structure, retailers need to decide whether to manage the warehouses themselves or use third-party operators, and whether to use dedicated or shared-user facilities – the latter often providing flexibility for evolving requirements, particularly for smaller retailers (see Chapter 35). One common trend is for small internet retailers to use the web and/or warehousing services of a very large internet retailer so as to gain economies of scale.

Implementation

For omnichannel fulfilment, it is important to meet the service level expectations of each channel while minimizing operational costs. In order to achieve the latter, synergies need to be achieved wherever possible between the distribution operations of each channel. However, as described in this chapter, it can be difficult to find a solution that can take full advantage of all the potential synergies between inventory-holding, warehousing and transport costs. Often solutions that provide synergies in terms of one aspect of costs involve higher costs elsewhere (e.g. having

separate warehouses for case picking for stores and item picking for home shopping may lead to efficient warehouse operations but will involve higher inventory costs, as separate safety stocks will be needed for each). This is complicated further by the crossover of flows between channels (e.g. consumers ordering items on the internet for collection at stores, known as ‘click-and-collect’). Thus, while multiple channels may complement each other and help drive overall sales, it is necessary for omnichannel fulfilment to be able to support this mix fully.

A total-cost approach is therefore needed, analysing what type of distribution network would provide the required service levels at the lowest cost (as described in Chapter 10). There is also a difficulty in formulating a future planning base, as requirements for the fulfilment of orders are continually changing (e.g. some stores are replenished in item quantities for certain product groups resulting in order picking, although not packing, being similar to internet orders). Flexibility is important, although this can be difficult to build into fixed assets such as warehousing, and therefore planning for different likely scenarios is one useful approach. The whole supply chain needs to be built with flexibility in mind – including decisions as to product sourcing (e.g. domestic, ‘onshore’ or ‘offshore’ sourcing), transport mode (e.g. road, rail, sea or air freight), distribution network infrastructure (e.g. how to segment the warehouses), inventory positioning (e.g. where to locate the ‘decoupling point’ – see Chapter 16) and final delivery (e.g. own or third-party carrier).

Once implemented, a large multi-tiered distribution network requires advanced management techniques, such as the use of distributed order management (DOM) systems, to optimize the location and movement of inventory.

Manufacturing logistics

13

Introduction

This chapter aims to provide the reader with an overview of the processes involved in the production of goods and services. These processes are known under various names, including manufacturing logistics and operations management (OM). The logic behind OM is based on systems thinking with a system defined as:

A collection of interrelated components that work together towards a collective goal.

A system receives inputs and converts them into outputs via a transformation process.

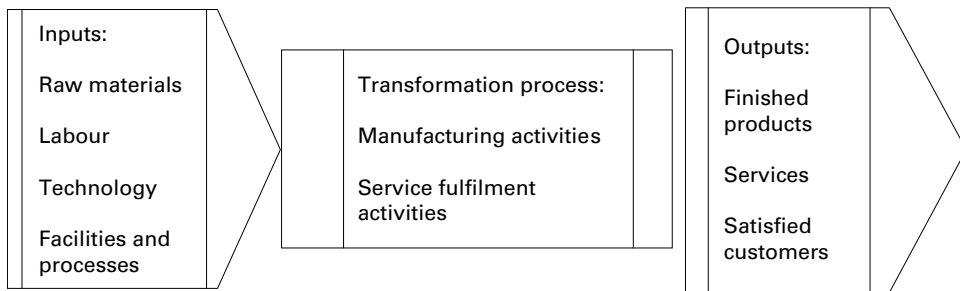
This is most obvious in a manufacturing context where raw materials and labour play the part of inputs that are transformed by the production process into outputs in the form of finished products.

We need to place this system mentally into the wider supply chain context and understand that OM deals with the conversion process between procurement and finished product storage and distribution. This chapter also aims to give the reader an overview of some of the most common forms of manufacturing planning and control techniques. It is not intended to examine these systems in great depth but rather to explain the basic principles of the various approaches and explain some of the terminology.

The following approaches are covered:

- just-in-time
- material requirements planning (MRP) and manufacturing resource planning (MRPII)
- flexible fulfilment or, as it has come to be known, postponement
- distribution requirements planning (DRP) and demand-driven material requirements planning (DDMRP)

As a further aid to understanding the parameters of OM a basic input–output transformation diagram is included here (Figure 13.1). OM covers all the activities encompassed by the transformation process. These may include designing processes,

Figure 13.1 A basic input–output transformation diagram

organizing human resources, scheduling and sequencing production, quality control, performance management and execution of the organization's strategy.

Typology of operations

The means of production of the goods or services may take many different forms. One way of classifying them is through a system known as the four Vs:

- *volume*: the amount of goods and/or services produced
- *variety*: how many different products and/or services are offered
- *variability*: to what extent the demand for the goods and/or services fluctuates
- *visibility*: how much of the process of delivering the product and/or service is revealed to the customer – face-to-face services where the customer interacts directly with the provider have a high level of visibility, whereas the consumer of a mass-produced item purchased from a third party will have a low level of visibility

Each of the four Vs is measured on a spectrum from high to low and compared with the other Vs to create a picture of the operation in question. Once this classification is understood it will indicate certain strategies and operational tactics that may be appropriately used in managing them. For example, a consultant may be described as having low volume, high variety, moderate variation in demand and high visibility – whereas a manufacturing plant that only makes three products is likely to have high volume, low variety, moderate variation in demand and low visibility. The factory in question would seek to lower unit costs of production and would be a candidate for high capital investment in machinery to automate the process. By comparison, the consultant will have high unit costs that reflect the high level of flexibility and complexity associated with his service. Automation and systemization would be virtually impossible in such a service-oriented operation.

Manufacturing process types

The volume of product to be produced and the variety of products will dictate the most appropriate process type to use. Process types for products may be categorized as follows:

- 1** Project: very low volume (one-off) and high variety. For example, building a ship. Usually large-scale, complex, and the product is stationary.
- 2** Jobbing: low volume and high variety such as building a customized product for a customer. For example, custom-made furniture.
- 3** Batch: medium volume and medium variety. The classic example is the small bakery that produces several types of bread in batches to serve the local community.
- 4** Mass: high volume and low variety. A car assembly plant is a good example of a mass production process.
- 5** Continuous: very high volume and very low variety. An oil refinery would be a good example.

Service process types

The equivalent process classification for service processes based on volume and variety are as follows:

- 1** Professional services: low volume and high variety. A good example would be a business consultant service.
- 2** Service shops: medium variety and volume. The services delivered by a high-street bank fit this category.
- 3** Mass service: high volume and low variety. Rail services and airports would be classified as mass service.

Production facilities and layouts

The design of production facilities should reflect the manufacturing process type chosen. Layouts are closely correlated with the volume and variety of products being produced and are classified in the following way:

- 1** Fixed position: all the required resources are moved to the point of production, as in the case of shipbuilding above and a project process.
- 2** Process or functional: this is where the production resources have similar functions and are therefore grouped together and the products are moved between them. This is appropriate layout for a high variety of products with similar requirements.

For example, a factory that is divided into functional areas such as machining, painting and assembly.

- 3 Cellular: a work cell is more than a single machine location but smaller than a manufacturing department. A small group of workers are brought together in one part of the factory to produce a certain product or range of products. In their cell they will have all the machines, resources and materials available to produce these products. Production workers in the cell produce the product in a mini production line, ideally passing the product progressively from one worker to the next. This system speeds up processing time, while quality, coordination, communication and teamwork between workers are all improved by this technique. The travel distance and travel time in the factory are also reduced by this system of cellular working.
- 4 Product: an assembly line is the best example of this layout. All the resources for producing the product are arranged and dedicated to a particular product. Often these are automated to some degree.

Operations management performance objectives

These have been defined as encompassing five crucial areas of producing goods and/or services:

- quality: right first time, fit for purpose
- cost: minimizing cost without compromising quality, and making a profit
- speed: delivering as fast as practicable
- dependability: delivering on promises made to the customer in full
- flexibility: adapting what you do or how you do it to reflect changes in customer or market requirements

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Push and pull systems

A 'push' system of manufacturing is one where goods are produced against the expectation of demand, which includes both known demand in the form of existing orders and forecast demand. In other words, goods are not produced specifically to order but are produced against a forecast demand. One fundamental issue relates to the lead time gap: where the amount of time it takes to source and manufacture goods is longer than the customer's willingness to wait, especially in today's world of internet retailing. This gap has to be reduced, eliminated or filled with finished goods inventory in order to satisfy customer demand in an acceptable timescale.

In other words, the lead time gap is the gap between the customer's expectation and tolerance for waiting for fulfilment of their order and the company's ability to source, manufacture and deliver the order.

Demand forecasting has to be carried out where raw material suppliers' lead times for delivery and customer delivery requirements have to be considered. If there is a one-month lead time for a given raw material then it will be necessary to estimate what the level of production will be in one month's time in order to satisfy forecast demand for the product. These forecasts are usually based on historical sales information. The difficulty arises when either there is a higher level of demand than expected and sales are lost, or there is a lower level of demand and finished product stocks grow too large. Lost revenue from missed sales opportunities is the result on the one hand, and higher inventory carrying costs or product obsolescence costs are the result on the other. MRP and MRPII (described later in this chapter) are 'push' systems.

A 'pull' system of manufacturing is one where goods are only produced against known customer orders. This is because only actual orders from customers are being produced on the production line. None of the goods are being made to keep as finished product stocks that may be sold at a later date. Therefore, firm customer orders are 'pulling' all the materials through the process from the material suppliers and culminating in the delivery to the final customer. Just-in-time is a 'pull' system.

Dependent and independent demand

Once a decision has been made to manufacture a given product either to fulfil a customer's order or for stock, a requirement is created for the constituent parts of this product. This requirement, which is contingent on the production of the product in question, is known as dependent demand. In other words, because it is planned to make a given finished product, this decision triggers the demand for all the constituent parts of that product. In this situation there is no uncertainty and activities may be planned accordingly. Therefore, when the production scheduling activity is taking place, the quantity and required delivery dates of the constituent parts are known to the schedulers.

Independent demand is quite the opposite. In this situation the schedulers do not have a clear view of customer demand and are therefore forced to forecast demand in the best way they can. The demand for spare parts for products sold in the past is a good example of this type of demand. This is a very difficult situation, which is full of uncertainty. The schedulers must try to ensure goods and services are available when the customers require them. Almost by definition in this situation there will always be a state of imbalance between supplies of the goods and services and the demand for those same goods and services.

Just-in-time

This approach was first developed in Japan by Toyota, the automobile manufacturer, in the 1970s. In its early days it was known as the ‘Toyota manufacturing system’ or ‘Toyotarism’. The label ‘just-in-time’ was applied later. It is basically a set of management philosophies that work together as a ‘pull’ system with the intention of meeting demand as it occurs.

One of the central ideas of this system is the elimination of waste (*muda* in Japanese) from the manufacturing process. In this context, ‘waste’ does not refer simply to reworking or scrapping substandard products. Waste within the just-in-time environment means waste in all its manifestations. It seeks to reduce what is known as ‘the seven wastes’:

- 1 overproduction
- 2 waiting
- 3 transporting
- 4 inappropriate processing
- 5 unnecessary inventory
- 6 unnecessary motions
- 7 defects

Elimination of wasted time

Because only customers’ orders are being produced and the speed of the production process is known, it is possible to synchronize deliveries of raw materials to the end of the production line (or to the precise point on the production line in some cases) with little time to spare before use. The whole purpose of this exercise is to reduce the working capital used in the overall manufacturing system. In turn, this produces a better return on capital employed. The other benefits are that there is little or no requirement for factory space to be used for storage, and a reduced requirement for labour to manage the stock. This is the origin of the name ‘just-in-time’.

Movement through the manufacturing process

If materials move through the system in a straight line it is reasonable to suppose that the minimum distance has been covered. In many manufacturing systems this is not always possible. In fact it has been identified in some manufacturing processes that components and sub-assemblies are moved around the factory in a very erratic

pattern before they all come together in the finished product. Attempting to minimize the overall distance that materials have to travel through the system helps avoid wasted travelling time and effort.

Kanban

The word *kanban* (the signal) refers to a system of cards (other methods such as marked squares on the floor or balls are used in some cases), which is used to organize the progress of materials through the manufacturing process. It may be easier to understand the system if one imagines squares marked on the floor of the factory. The squares contain work-in-progress required by the next step in the manufacturing process. The squares become empty as the materials are used. The next batch of materials may only move into a square when the square is empty. This approach is replicated as materials move progressively from one step to the next. Thus no build-up of goods occurs, and materials move through the system in an orderly fashion.

The problem is that goods will have to move through the system at the speed of the slowest element in the chain. However, large online work-in-progress stocks will be eliminated. This too contributes to the reduction of working capital being used by the system.

Right first time

Quality problems in the form of scrapped or reworked products are waste of the first order. The Japanese developed several strategies to counter this problem. In one case they built their factory with no area to store scrap, on the principle that having an area for scrap encouraged its production. Quality circles were created, where workers were allocated time specifically given over to discussing quality issues and their elimination, the target being zero defects. The philosophy of *kaizen*, or continuous improvement, was engendered as a working culture in these organizations, with support at the very top. Systems of quality management such as total quality management (TQM) and ISO 9000 seek to achieve the same ends.

The causes of scrapped or reworked production may not originate in the factory itself and may be caused by substandard raw materials being supplied to the process. Increasingly, suppliers' performance is critically appraised and measured in defective parts per million or in some other way. The preferred approach is working in a positive environment with suppliers to eliminate problems quickly. Involving suppliers in new product development helps eliminate potential problems before they are translated into the production process (see Chapter 14).

Many companies have now adopted Six Sigma as a formal process improvement technique. Literally, this aims to control a process to the point of $\pm$ six sigma (i.e.

standard deviations), which equates to 3.4 defects per million. The processes in this technique normally consist of DMAIC (define, measure, analyse, improve and control).

Finished product stocks

Under just-in-time (JIT), these stocks only contain goods produced to a specific customer order. This too contributes to a reduction in working capital.

Because of the needs of brevity it has only been possible to skim the surface of the JIT philosophy. Subjects such as the reduction of set-up and changeover times, team working and empowerment, total productive maintenance, levelled production schedules and many more are arguably no less important.

Material requirements planning (MRP)

This principle of production scheduling is based on the premise that if one knows what product needs to be produced then one should also know how many constituent parts are required in order to make the product. It is basically a 'push' system based on forecasted demand for the overall product. A useful analogy is the preparation of a meal. Let us say that the meal in question is a traditional UK cooked breakfast. Depending on taste you may choose two rashers of bacon, a fried egg, some mushrooms, tomatoes and toast. While describing the contents of the breakfast, we have also prepared a list of the constituent parts. If we needed more than one single breakfast then we would simply multiply the quantities of ingredients by the number of breakfasts required. We now have our 'bill of requirements'. This would allow us to go shopping for the ingredients and also allow us to purchase accurately only the ingredients required to avoid wastage through having too many ingredients or disappointment through not having enough ingredients to meet the demand. The success of this system relies on us knowing how many breakfasts are required and how many diners actually turn up for the meal. In other words, success relies on matching the forecast with actual demand.

If we were building a complex piece of machinery rather than our meal then we could apply the same principles. The numbers of different machines could be broken down into the numbers of sub-assemblies required, which in turn could be further broken down into components. Orders could be placed with suppliers for the required quantities and delivery times agreed. These orders would be made in the light of any existing stock of parts already available for use. This sounds very simple but in practice is an enormously complicated process.

The situation is further complicated when orders are cancelled at short notice or increased without warning. The adjustments will need to be made quickly in order

to avoid failing to meet customer requirements or conversely being left with an excessive amount of component stock.

The following is a simple explanation of the basic structure of an MRP system.

The master production schedule (MPS)

The MPS is a list of all the products or services to be supplied within a specific period of time. This period of time must be sufficiently long to allow for the ordering and delivery of required sub-assemblies and parts, as well as allowing sufficient time for manufacturing the product in question. The schedule may be made up of both forecast and known demand, i.e. customers' orders. It also lists all the required outputs from the system and when the goods and services are required, through the use of a 'due date'. Therefore, the contents of the schedule will dictate the contents of the bill of requirements.

The bill of requirements

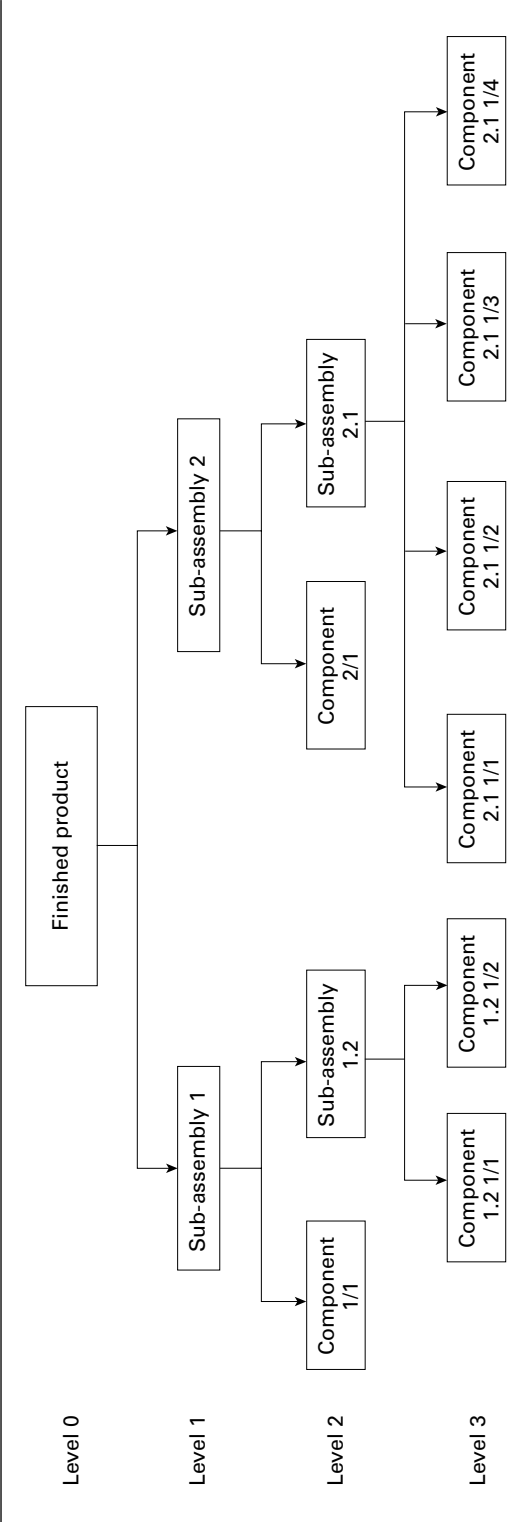
This is also referred to as the bill of materials (BOM). As explained earlier, this will list all the sub-assemblies, components and parts required in total to produce all the goods listed in the master schedule. It will also show the different levels at which these constituent parts are put together in order to produce the finished goods.

For example, the finished product may contain two sub-assemblies that together complete the product (see Figure 13.2). The finished product is said to be at Level 0. These assemblies will be numbered sub-assembly 1 and sub-assembly 2. Together these sub-assemblies are said to be at Level 1. Both sub-assemblies are made up of one component and one further sub-assembly each. This level is described as Level 2. Owing to the fact that the two major sub-assemblies at Level 1 contain one further sub-assembly each at Level 2 then a further level is created at Level 3. At Level 3 it can be seen that one of the sub-assemblies at Level 2 contains two components and the other contains four components.

This process (sometimes referred to as 'netting') is continued until all the constituent parts are broken down and listed at different levels. It can be quickly seen that, if the bill of requirements for each product is viewed from the opposite direction to the finished product, i.e. the highest-level number first, then one is looking at a sequence for assembly. The components are put together to form sub-assemblies, which in turn are put together to form the finished product.

This bill of requirements, having detailed all the required parts and sub-assemblies, will allow the MRP program to create the required orders to be placed with suppliers. One important thing to remember is that it also lists in detail the order and timing for when these parts are required.

Figure 13.2 A bill of requirements for one product



Noting the level of detail in the bill of requirements for just one product described above, it may be easier to understand the level of complexity involved in scheduling many different products that may contain many more components. It will also underline the complexity involved in changing the master schedule due to cancellations or additional orders.

Opening stock

The master schedule and the bill of requirements together form the framework of what is required and when it is required, but two other factors must be fed into the computer program at the same time. The first of these is the current level of unallocated stocks of parts, components and sub-assemblies available for immediate use. There may be in total larger stocks on hand but these may already have been allocated to production via the system and are therefore unavailable. This information will, of course, modify any orders for raw materials placed on suppliers.

Opening capacity

The final fundamental factor required by the MRP program is the current level of available unallocated production capacity for not only the finished product but any components or sub-assemblies that are manufactured in-house.

All of the above information – the master schedule, the bill of requirements, the opening stock and the opening capacity – will be fed into the MRP computer program. The program will then produce, as required, the following:

- a list of purchase requirements, which lists what needs to be purchased and when
- a manufacturing schedule, which lists what will be made and when it will be made
- the closing stock of parts, components and sub-assemblies after the master schedule has been completed
- the closing capacity available after the master schedule has been completed
- a list of anticipated shortfalls in production – these may be due to shortages of parts or capacity

The whole MRP process is iterative and therefore must be repeated periodically. This may be done on what is known as a 'regenerative' basis or a 'net change' basis. The 'regenerative' basis involves assuming that no previous MRP calculation has taken place. Therefore, known or forecast demand is used to create a new bill of requirements, with available parts of stock and available production capacity being allocated disregarding any previous calculations. For the purposes of this approach,

all parts and capacity are assumed to be unallocated, as existing orders and work-in-progress will be covered by the new master schedule. This approach tends to be used where demand and, therefore, output are fairly consistent. This method also has the advantage of not perpetuating any previous computation errors as each new calculation starts from fresh current data.

The 'net change' approach concentrates on changing only those parts of the production plan that have changed rather than recalculating the whole plan. Thus, if changes are made to the master schedule then only those parts of the plan that are affected will be changed. This method tends to be used more in situations where demand is more volatile and so changes are more frequently needed.

Manufacturing resource planning (MRPII) and further developments

As the name implies, manufacturing resource planning (MRPII) deals with more than simply production scheduling. While the basic material requirements planning (MRP) is incorporated into MRPII, the wider system brings other activities into the picture. The objective is to harmonize and control more of the activities within the production plant. Areas outside an MRP system but included in an MRPII system usually are: maintenance management; cost accounting; stock management; sales orders; procurement; personnel levels.

MRPII systems themselves are often incorporated into much wider enterprise resource planning (ERP) systems which also include the company's financial and transaction systems. In addition, these systems normally link to manufacturing execution systems (MES) which control the activities on the shop floor. While the MRPII schedule provides the information of what needs to be produced when, the MES actively controls the flow of orders through the production process, taking into account factors such as machine breakdowns and maintenance, staff absenteeism, variations in set-up times and quality problems. This combination can therefore provide real-time adaptive production scheduling.

This ability to adapt manufacturing plans in real-time requires information provided by technologies such as the Internet of Things (to provide immediate updates on orders, work-in-progress movements, manufacturing resources and inventory levels), artificial intelligence (to be able to plan and learn from the complexities of the operations) and Big Data (to provide the necessary analytics). Robotic process automation (RPA) can be used to bring together and automate the end-to-end supply chain, so that for example the detection of a low stock level of an item at a customer's premises could instantly feed into the manufacturing plan and operations.

Flexible fulfilment (postponement)

Flexible fulfilment is a method of manufacturing that attempts to delay the final definition of a product to the last possible stage in the supply chain – hence the popular description of ‘postponement’ for this system.

The advantages gained from this method can be dramatic, especially where companies trade on a global scale. Consider the problems raised by the different voltages available around the world for the use of portable electrical goods. If the manufacturer supplies goods around the globe, then stocks of finished products might have to be kept for each different type of power supply, very likely in or close to the particular market in question. This will increase inventory carrying and, especially in the electronics business, the possibility of product obsolescence. However, if it were possible to have a number of different power supply packs that all fitted the same product then it would be necessary to have only one ‘global’ product, which could be quickly adapted by changing the power module alone to suit the market concerned. This would mean that there would no longer be country- or market-specific products, and products could be transported and sold anywhere in the world at short notice.

This method has considerable implications for product design in that products need to be designed so that any variations dictated by markets can be adapted by changing modules only. Different keyboards for laptop computers are required to allow for the different alphabets to be found around the world. Manufacturing a laptop with a keyboard that is not easily substituted for another creates large inventories of language- or alphabet-specific stocks in those countries. Postponement means that the bulk of the laptop is produced and shipped around the world, but the final definition of the product only takes place when the alphabet-specific keyboard is attached.

Other examples of postponement can be seen when promotions of a product such as ‘Buy product A and get product B free’ occur. The attachment of product A to product B creates a third product, C. This product can be produced by wrapping the two products, A and B, together in some form of outer. This operation can be undertaken in the distribution centre prior to final delivery, which will avoid the necessity of forecasting and shipping stocks from further up the supply chain. The product C could almost be made to order via the wrapping process. If the promotion goes well then only increased levels of products A and B need be shipped.

The effects on distribution activities

These developments in manufacturing planning and control systems have had a significant impact in the management of traditional distribution activities. In the case

of flexible fulfilment, where final modifications to products are taking place in distribution centres, this has caused traditional distribution managers and companies to redefine their role and approach. Distribution companies have had to start offering these services as part of their portfolio of services. Distribution managers have had to create the working environment for these activities to take place as well as providing a suitably trained workforce to deal with the new requirements.

The effects on distribution systems of just-in-time (JIT) deliveries have led to more frequent deliveries of smaller quantities to stringent delivery timetables. This has had effects on vehicle fleets and scheduling as well as developments in linked information systems between manufacturer, supplier and transport provider. Without these developments, JIT would be virtually impossible.

Distribution requirements planning (DRP) systems were developed as a logical extension of MRP systems. The principles have simply been extended into a forward distribution planning system so that orders pass through the distribution network and arrive with the customer at the required time. DRP can act as a 'push' or a 'pull' system depending on whether they are triggered by forecasts or actual orders.

Demand-driven material requirements planning (DDMRP) systems, on the other hand, are specifically designed to 'pull' orders through multi-echelon supply chains. These can plan activities at each echelon, from raw materials through manufacturing to final distribution, based on final demand so as to overcome the 'bullwhip' effect (described in Chapter 15).

Additive manufacturing

This is the name given to products produced by a 3D printer. Materials such as metal, plastic, ceramics, rubber and even chocolate may be used to manufacture a product by spraying the material and building up layers in three dimensions.

3D printers already produce items such as dental crowns and specialized spare parts. The implications of this method of manufacturing on logistics are considerable. It has become possible for a customer with a 3D printer in a remote location to download design instructions from the internet and, providing he has the right materials to hand, he or she may manufacture the spare part on site without any need for delivery. Of course, the implications may be more profound and not limited to the field of logistics. During and after the 2020–21 Covid-19 pandemic there occurred a lot of supply chain disruption. As a consequence, many organizations are considering improved supply resilience by increasing inventories and 3D printers are very likely to have a role in this regard.

With the continuing growth in the use of robotics, the human labour content will reduce even further. The competitive advantage of cheap labour will be eroded and industries that have moved offshore may start to return to their home countries.

There is already some evidence of this happening and it is called reshoring. Shop-floor jobs will require high levels of technical skills in the future.

Materials such as carbon fibre and graphene are replacing steel and aluminium. Graphene has an astonishing array of properties, including electrical and thermal conductivity, as well as mechanical strength. Nanotechnology, where measurements of a billionth of a metre are used, baffle the mind but open up amazing possibilities in pharmaceutical manufacturing. The thought of viruses being used to make batteries seems impossible but is actually happening.

Many, if not all, of these developments will impact directly on how we organize and execute manufacturing and distribution logistics activities in the near future.

PART THREE

**Procurement,
inventory and
demand forecasting**

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Procurement and supply 14

Introduction

Procurement and supply is one of the key links in the supply chain and as such can have a significant influence on the overall success of the organization. Ensuring that there are sufficient supplies of raw materials at the right price, of the required quality, in the right place and at the right time is obviously crucial to any manufacturing plant. So important is this process that over the years many organizations have developed large departments to deal with the sheer weight of supplier transactions. Recently, however, many companies have been reducing the number of suppliers they deal with in order to reduce the cost of these transactions.

In addition to supplier reduction programmes, many companies have tried to move away from the traditional adversarial relationship with suppliers and towards a more partnership-based approach. This style of relationship recognizes that both parties need to make a profit to survive but that there may be areas where, through cooperation, real cost may be removed from the supply chain and competitive advantage gained by working together.

Of course, procurement is not just about raw materials. The following may also need to be acquired:

- utilities – gas, water, electricity and telephones
- fuel – diesel, petrol and heating fuel
- capital assets – machinery, vehicles and buildings
- corporate travel and hotels
- stationery
- consultancy
- outsourced services – distribution contracts, IT services, etc
- IT equipment – hardware, software and support

Very large sums of money are involved in the above areas of purchasing, with different emphasis placed on different elements depending on the business of the

organization concerned. For a transport company, fuel may represent as much as 35 per cent of the total operating budget, but for a manufacturing plant the major cost may be in the plant running costs. These costs need to be carefully managed, but the first step is to determine some purchasing objectives.

Managing suppliers is another crucial aspect of procurement. ‘How many suppliers should we have?’, ‘How will we assess their performance?’ and ‘Should we make or buy this component?’ are all key questions that need to be answered if a procurement strategy is to work to the benefit of the business.

Over the last decade many companies have invested in both hardware and software to facilitate the use of e-procurement, which may be defined as: the electronic integration and management of all procurement activities including purchase request, authorization, ordering, delivery and payment between a purchaser and a supplier.

Procurement is a very large subject. The objective in this chapter is only to highlight the key areas.

The procurement cycle

A typical procurement cycle progresses sequentially through the list below:

- 1** The identification of the need to procure a good or service.
- 2** Production of a requisition document that needs to be approved and passed to the procurement department.
- 3** A request for quotation (RFQ) is sent to a selection of suppliers.
- 4** Suppliers respond with prices and a period of negotiation may be entered into.
- 5** A supplier is selected and a purchase order (PO) is raised, which records the details of agreed price, delivery terms and place, and items or services to be provided.
- 6** The PO is signed and authorized by a manager. It is then sent to the supplier.
- 7** The goods or services are delivered and inspected.
- 8** The supplier sends an invoice.
- 9** The invoice is approved and paid or held pending resolution of any discrepancies found.
- 10** The procurement department assesses the performance of the supplier based on quality, timeliness, price and the completeness of the order. This is known as post-contract review.

Different organizations may structure the cycle slightly differently or call the stages by different names. The scope and scale of the purchase will dictate how much

attention it receives. Most of the steps listed above could be completed online, especially for routine and repeat orders. Large capital purchases would require some of the stages to be quite complex. It is important to understand that the technical specifications need to be approved by technical specialists. This is not a job for the procurement people.

Authorization of purchase orders and therefore expenditure should not be in the hands of the purchasers. To ensure integrity of the process these roles and responsibilities need to be separated. The purchasers will do the job of selection and negotiation but the final authority to spend company money should not be theirs. This separation of roles acts as a protection for all parties involved in the transaction.

The scope of procurement

Modern procurement departments aim to:

- align their objectives with those of the organization rather than simply optimizing the performance of the function
- exploit modern e-procurement techniques to reduce the cycle time for processing orders as well as reducing transaction costs
- use the internet to identify new sources of raw materials and suppliers of goods and services
- get involved early in the process of new product or service design
- source and organize globally if the scope and scale of the organization needs this
- build partnerships with crucial suppliers while utilizing online catalogues or purchase cards for routine purchases
- seek value-for-money deals rather than simply buying the cheapest
- reduce inventory carrying costs through intelligent acquisition such as vendor-managed inventory
- adhere to the 3 Es: economies – spending less; efficiencies – spending well; and effectiveness – spending wisely
- enhance the competitiveness of the company

Setting the procurement objectives

When setting procurement objectives, consideration should be given to the following:

- whether to make yourself or buy from a supplier

- ensuring the continuing supply of raw materials and other supplies
- vendor-managed inventory (VMI)
- the quality and number of suppliers
- standardization and product specification
- the price
- the origin of the supplies
- the method of supply, e.g. JIT-style deliveries
- the mode of transport used
- a hierarchy of importance, e.g. key raw materials would have precedence over office stationery

Ensuring the supply of raw materials

Clearly, without an assured flow of raw materials into a manufacturing plant serious problems will ensue. These could take the form of plant stoppages, which will be enormously expensive. If expensive plant, machinery and labour are standing idle then costs may be incurred at an alarming rate. Not only will cost be incurred, but customers may be let down, as goods are not available for delivery at the appropriate time.

With this in mind, procurement management can adopt several policies to ensure that supplies are always in the right place at the right time:

- The manufacturer could purchase the supplying company. This used to be common in vertically integrated organizations.
- Sufficient safety stocks may be held at the manufacturing plant to cover such eventualities. These stocks would attract inventory carrying costs, but the alternative may justify this investment.
- A manufacturer may insist on the co-location of the supplier next to or close to the plant itself.
- Where commodities such as wheat or crude oil are concerned, then options to buy certain quantities may be negotiated in advance.
- A manufacturer may develop very close relationships with suppliers, for example through a system of quality-assured suppliers or vendor-managed inventory.
- Take advantage of opportunities to purchase supplies at unusually low prices. However, such purchases must be weighed in the light of the additional inventory carrying costs that may be incurred. Such additional costs could exceed the savings accrued from the opportunity purchase.

Vendor-managed inventory (VMI)

Where VMI is used, the vendor takes responsibility for the inventory held in the client's premises. The vendor monitors inventory levels and organizes replenishment. Ownership of the inventory passes to the client when the inventory is utilized. For VMI to be effective, the management of information is crucial. Vendor and client will have linked computer systems, often using electronic data interchange (EDI). This allows the vendor to monitor inventory levels and for purchase orders and invoices to be effectively transmitted between the partners.

The main advantage of VMI is that the overall level of inventory in the client's warehouse can be reduced. The vendor is able to schedule deliveries efficiently, as it has better visibility of the client's requirements, and can incorporate these requirements at an early stage into production schedules. For the process to work there needs to be high levels of trust between the two partners. This is often derived from the cultural compatibility of the companies involved. The partners' IT systems also need to be compatible.

Where the client retains an element of involvement in managing the vendor's inventory, this is referred to as co-managed inventory (CMI).

The quality of supplies

Ensuring that the goods and services purchased are of the right quality is important in that substandard supplies cause waste and a variety of problems:

- If the goods are unusable then their presence has created a shortage in the required quantity, which in JIT environments may be crucial.
- Substandard goods will need to be stored awaiting collection. This could be a problem if storage at the receipt stage is restricted.
- They will incur transaction costs, as paperwork and time will be involved in rectifying the error.
- They will undermine confidence in the supplier and the supply process.

Insisting on suppliers having quality management systems in place can help avoid these problems, as can extrinsic audits of suppliers' premises. These audits may be carried out by the company's quality auditors. Supplier assessment programmes will help highlight the main offenders.

The cost of poor quality may be broadly divided into two categories: the cost of conformance and the cost of non-conformance. The cost of conformance may be further subdivided into the cost of appraisal and the cost of prevention. Examples of appraisal costs include the costs of inspection and testing. Examples of prevention costs include training, right-first-time campaigns and product design costs. The cost

of non-conformance may also be further subdivided into the internal costs and external costs of non-conformance. Internal costs of non-conformance include scrap and rework as well as lost production time. External costs of quality failure include lost customer confidence and therefore future sales, returned goods and product liability costs.

The ideal situation would be for a five-star supplier to ship-to-stock. This would save a lot of inspection costs but could only be predicated on a superb quality record of the supplier in question. Such a supplier is likely to have achieved a 'partnership' status with the company.

Product specification

An important method of avoiding purchasing substandard supplies is the development of product specifications. If vendors are given very clear and precise instructions about what is being ordered, this will go a long way to avoiding costly misunderstandings. This is especially true where there are many different options associated with components of a product. For example, when purchasing a car the same model may be offered for sale with different types of engine, gearbox, paintwork and interior trim. It is important that the choices made are clearly communicated in writing to the vendor in the form of a request for quotation (RFQ). Product specifications should also be included in the purchase order when it is issued to the supplier.

One extremely effective method of both reducing suppliers and ensuring consistent accurate specifications is to adopt a system of standardization for certain products. It should also contribute to a reduction in the procurement transaction costs as buyers will simply access standard specifications and signal to the supplier that a repeat order is required. If the process of standardization is widespread then it will also have the beneficial effect of reducing the inventory of spare parts required.

The price

This is the area that most people associate with the purchasing process. The price will be determined by certain factors:

- The relative negotiating skills of the purchasing and selling team.
- The relative power of the supplier or buyer in the marketplace. Where there are many suppliers, the buyer's position will be strong. The converse is also true in that where there are many buyers and few suppliers then it follows that the supplier will be strong.
- The quality of the goods in question.

- Detailed knowledge of the product being purchased. For example, when multiple retailers purchase commodities such as flour they will have familiarized themselves with the costs of wheat and production before entering any negotiation.
- How much of the product is generally available for purchase. In other words, if the product is scarce then prices tend to be higher as purchasers pay higher and higher prices for the goods. The opposite is true when the product is plentiful.
- The distance the goods have to travel from their point of origin to the delivery point. Associated with this is the mode of transport used. The cost of transporting the raw materials may represent a large part of the purchase price.
- If the goods are being purchased by a buying group, then prices should be lower. A buying group is a number of companies grouped together in order to pool their buying power.

If the product specification can be defined precisely, then prices can be assessed on a like-for-like basis between suppliers. Discounts may be obtained from suppliers in various ways:

- by offering prompt payment
- increasing the quantity ordered – as a general rule, the unit price of the item will go down as the quantity ordered increases
- through the fact that your company may be a crucial company to the supplier
- through special or promotional offers, e.g. if the goods being supplied are at the end of their product life cycle
- the origin of the supplies

In recent years many large organizations have decided to source their supplies offshore. The logic for this trend is that in some parts of the world, such as China and India, the costs of labour and production are very low. However, labour costs in both China and India have been rising as a consequence of this trend, which has allowed some other countries and continents to emerge as competitors in the low-cost labour market. For example, Bangladesh, Vietnam and Sri Lanka in Asia and Egypt, Ghana and Kenya in Africa, not forgetting Central and South America. Many companies based in the United States of America are outsourcing to Mexico in a process called near-shoring due to the proximity. Companies can potentially gain a significant competitive advantage by offshore sourcing. However, a number of factors need to be taken into account. If the goods have to travel halfway around the globe then not only will the transport costs be high but the lead times to delivery may be unacceptably long. The price paid for the goods at origin may be low but the landed cost will include a proportion of the transport costs, any duties or taxes paid and handling charges. It will be the landed cost of the item that will be recorded in

the company's inventory as the finance department seek to correctly apportion the full cost of acquisition.

In addition, pipeline inventory will be increased if sea transport is used. This can have the effect of impeding market responsiveness due to the long replenishment lead times. There are inherent problems with regard to dealing with different country's cultures. Further to this, the documentation associated with international sourcing is diverse and complicated. Dealing with different cultures and international documentation requires specialist knowledge and expertise (see Chapter 33).

It is also the case that not all parts of the world enjoy political stability. If supplies are interrupted for unspecified periods of time by political strife then a company could be in dire trouble if it does not have an alternative source of raw materials. The global Covid-19 pandemic during 2020–21 has highlighted the fragility of long supply chains and the consequences of interruption (see Chapter 41). Important decisions must be made with these factors in mind.

The method of supply

Smaller, more frequent deliveries typify a JIT system of supply. Inventory carrying of raw materials may be measured in hours only, and deliveries may even be made directly to the production line itself. As more and more companies seek to reduce inventory carrying costs then these types of arrangement have become more common.

The speed of processing goods received in a warehouse can be significantly improved if suppliers provide the goods in the right quantities, at the allotted time, correctly labelled and barcoded where necessary. How the raw materials are to be supplied needs to be determined and then discussed in advance with suppliers because they may not be able to meet the necessary criteria. It will be no good insisting on barcoded products if a supplier is unable to comply and, if a supplier cannot comply, a buyer's receiving operation may be severely compromised.

The mode of transport used by suppliers

Many transport and delivery requirements need to be discussed prior to agreeing to deal with a supplier. In the past, company procurement managers have in some instances been guilty of making spot purchases of goods on the basis of price alone, only to discover that the consequential cost of handling has been unreasonably high. Typical questions that need to be answered include:

- Will the goods be shipped by road, sea, rail or air?
- What sort of unitization is used?
- Will the goods be on pallets?

- What size are the pallets?
- Will the goods be stuffed loose inside containers and require considerable time and labour cost to unload?
- Should a railway siding be built to accommodate rail traffic?

The hierarchy of importance

In our visits to firms, it never ceases to amaze us how most purchasing departments still treat a critical microchip in the firm’s key product much the same as a paperclip purchase.

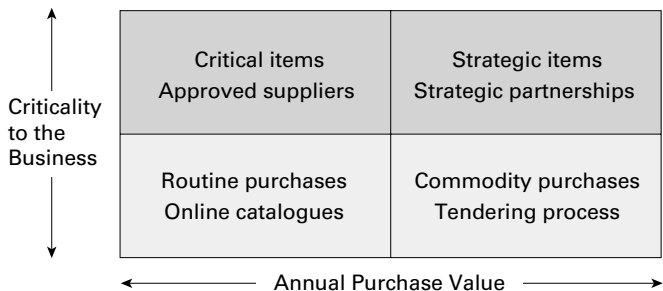
JACK BERRY, ARTHUR D LITTLE INC

This quotation says it all really. It is vital that appropriate amounts of time and effort are spent on the purchases that most matter to the organization. Therefore, procurement management must ensure that purchasing is segmented accordingly. Products and services need to be classified according to their criticality to the business and the value of annual purchases. The four categories usually used are:

- 1 routine purchases
- 2 commodities
- 3 critical items
- 4 strategic items

Figure 14.1 demonstrates how purchases may be easily categorized by assessing how critical an item may be to the organization and by calculating the annual value of purchases. A strategic item is one that is both very critical to the business and has a high annual purchase value. At the other end of the scale, a routine purchase is one that has a low annual purchase value and is not critical to the business.

Figure 14.1 Categories of purchase with the appropriate buying process



Once purchases have been categorized in this way, the process by which they are to be purchased may be decided upon. Buying processes include:

- online catalogues or purchase credit cards
- tendering
- a system of approved suppliers
- strategic partnerships

Figure 14.1 also shows how the appropriate buying process may be matched with a purchase category. Online catalogues available to employees will allow them to purchase routine items quickly and easily. This speeds up the process and limits the cost of these transactions. The same is true for purchase credit cards.

The tendering process for high annual purchase value commodities will be appropriate where obtaining the best price is important. A network of approved suppliers and a formal system for approving suppliers are most appropriate where items are critical to the business but have a low annual purchase value. Suppliers will have been able to satisfy the purchasing department that they are able to meet certain criteria satisfactorily on a consistent basis. The criteria used may include delivery reliability, quality of goods supplied and value for money.

Strategic partnership (see the section on partnerships later in this chapter) will be most appropriate where the purchase has high annual value and is critical to the business. In these cases, it is in the interest of both purchaser and vendor to develop a strong working relationship.

Make or buy?

The decision to make goods or provide a service as opposed to buying it is one that is rarely straightforward. It is not always simply a question of cost. Other issues such as the company's reputation or production capacity may be included in the mix. The following is a list of some of the factors often considered:

- **Cost:** if the goods or services are to be provided in-house, then it is not simply the direct costs involved that need to be considered but the wider costs, such as the opportunity cost of the capital employed. In other words, could the capital tied up in this exercise produce a better return if invested in another activity? If the activity is to be provided by a supplier, then the costs associated with managing the supplier and the transaction costs (e.g. for processing invoices) should be included in the analysis.
- **Ensuring supply:** as mentioned above, if goods or services are not available when required then significant extra costs may be incurred. The reliability of the supplier and the quality of its offering is another crucial part of the decision-making process.

- **Production capacity:** some parts of an operation may be provided by subcontractors because a company does not have sufficient capacity within its operation to do the job itself. This may be a very sensible approach to take in certain circumstances. A vehicle fleet, for example, should be kept working full-time. Therefore, it is better to have sufficient vehicles to achieve this end and subcontract any further work created by short-term increases in demand. Of course, the opposite is true in that if a production plant has spare capacity then it may be correct to use it rather than have it stand idle.
- **Competitive advantage:** there may be certain products, components or processes that the company wishes to keep secret and so it will not allow any other company to gain information about them. A revolutionary new product may fit this situation.

Managing the suppliers

Key areas for managing suppliers include:

- the choice of supplier
- supplier numbers
- supplier management – adversarial or partnership approach
- supplier appraisal and performance

Choosing the suppliers

Choosing your suppliers will involve all the elements already discussed, but there are one or two further points that have to be considered. Of course, this only applies in a situation where there is a choice. There are certain situations where no choice exists at all and one is forced to deal with a monopoly situation.

If a partnership approach is desired then suppliers need to be able to respond to this type of situation. They must also be companies that are sufficiently well established. Company accounts are public information and are easily obtained. A check should be made to establish that a company is financially stable. It would be very unfortunate to spend time developing a partnership only to see a new partner going into liquidation.

Another consideration is whether or not a supplier wishes to become closely involved with a major customer. It will be necessary to share information, and the supplier may also deal with competitors. This could place a supplier in a difficult position and it may decline the offer of closer ties. Another fear may be that the customer could become so close that it gets taken over.

How many suppliers?

This will obviously vary from industry to industry. The high costs associated with transactions are driving companies into supplier reduction programmes. The suppliers who remain will hopefully be the ones who perform best on supplier appraisals. They will also be the ones who have been prepared to share information and get involved in EDI to reduce the cost of purchasing and who have the geographical coverage to match the client company. Increasingly, global companies are seeking to do business with global suppliers.

Supplier management: a partnership or adversarial approach

In a traditional adversarial relationship between buyer and seller each party sees itself as being in competition with the other. The inevitable result of this kind of relationship is that one or other party inevitably 'wins' in any negotiation. This is often referred to as a 'win-lose' situation. Who and why one party is successful in this sort of relationship has much to do with the relative power that resides in one camp or the other. For example, a vendor with a rare product that is absolutely crucial to the process of the buyer would tend to be in a more powerful position. This would be especially true if the item on sale could not be substituted by another. The problem with this type of association is that, because both parties are secretive and defensive, inefficiencies in the supply chain are the result. These usually take the form of excess buffer stocks held by both parties, stockouts and a lower level of customer service.

The idea of seeing a supplier as a partner makes a great deal of sense from a logistics point of view. The Toyota organization, like many other Japanese companies, has long seen its suppliers as co-makers of the product. The Japanese system of *keiretsu* (literally 'headless combine') epitomizes the approach. A network of suppliers is intimately bound to the client company in a complex web of interdependence. This type of association should be seen as a 'win-win' situation in which both parties gain more from the relationship than from the adversarial style.

It is worth introducing a word of caution at this point. Toyota reduced its supplier base to such an extent and was so reliant on JIT deliveries that when a fire occurred at the premises of one of its suppliers it was forced to stop its production lines in Japan for a week. At the time, Toyota owned 22.6 per cent of the supplier, Aisin Seiki, a manufacturer of vital brake components. The fire occurred early in 1997 and brought Toyota to a standstill. This was not an isolated incident either, because in 1995, after the Hanshin earthquake in western Japan, car manufacturers were cut off from some of their suppliers by the disaster. By contrast, Honda does not have

such a closely knit *keiretsu* and has a policy of dual supply for all raw materials as a hedge against just such a situation.

More recently, after the devastating earthquake and tsunami in March 2011 in east Japan as well as the loss of electrical power due to the problems with the nuclear power plant at Fukushima, many manufacturers experienced substantial disruption to their supply chains. Toyota estimated that along with Lexus it lost 220,000 units of production globally in the first 20 days after the earthquake happened. Subsequently, the total loss of production units reached 670,000 globally.

These are extreme examples and should in no way inhibit companies from building closer ties for mutual benefit. As with all partnerships, the partner has to be selected with care, as not all suppliers will wish either to engage in this sort of relationship or be suitable. In practice it is usually the partner with the greater power that dictates the terms of the partnership. It is very difficult for a small company to approach a larger company with a view to instigating such a partnership. A lack of equality in the partnership will lead to the more dominant partner dictating terms regarding many aspects of the relationship. This phenomenon has led some commentators to question whether a true partnership can ever exist between two commercial parties when one partner holds most of the power. Nevertheless, clear advantages have been documented where two companies work more on a collaborative basis than an adversarial one.

Some prerequisites for a successful partnership will include:

- compatible cultures
- high levels of trust already in place
- compatible computer systems to aid the electronic sharing of information
- the financial stability of both parties
- a willing attitude to exploring the advantages of partnership

In a partnership, members of equivalent departments in both organizations will meet regularly to discuss areas of mutual interest. For example, new product development people from both organizations will sit down together to see how products may be produced in such a way as to avoid causing problems for each other. In a similar way, logistics personnel will associate more freely. Traditionally, in the old adversarial way, only buyer and seller would meet.

Through this closer liaison, information sharing occurs for mutual benefit. Real benefits have been achieved by linking together computer information systems. In this way, a retailer with an electronic point-of-sale (EPOS) system can provide the supplier with real-time data about the current level of demand for a given product. This information can lead to real reductions of inventory carrying in the supply chain and a reduction in stockouts. As the relationship matures then initiatives such

as VMI may be introduced. Ordering and invoicing may be carried out via EDI, thus reducing transaction costs by the removal of expensive paper-based systems.

Supplier appraisal and performance

The poor performance of suppliers will adversely affect the satisfactory delivery of goods and services to the final customers by the purchasing company. Therefore, supplier performance must be continually monitored and poor performance communicated to them effectively and in a timely manner. The old computer adage of 'garbage in, garbage out' applies equally well to suppliers and their performance as it does to computers. If your suppliers provide low-quality goods for inclusion in your products then it is logical to assume that your products will also be of a lower quality. By the same token, if they provide their products late then this will impact your ability to deliver to the final customer on time. This could be reflected in higher levels of raw material inventory needing to be carried against the uncertainty of supplier's delivery or, worse still, very unhappy customers due to missed delivery deadlines.

There are many ways to assess supplier performance and whatever methods are used they will reflect the detailed nature of the relationship between the two organizations. The quality of the goods or services delivered, the completeness of the delivery and its timeliness form a useful base, but much more detailed evaluations may be necessary. The basic performance measure of 'full loads (complete orders) on time' is used by many.

Expediting

Unfortunately, expediting is an uncomfortable fact of life for procurement departments. The job of an expeditor is to chase suppliers to ensure that goods are delivered on time or that the remnants of a part-order are delivered.

It goes without saying that if there is a high level of expediting required then something is wrong with the procurement process. Either the suppliers have been poorly selected or are performing badly. The level of expediting is a bellwether for the health of the procurement operation in general.

Procurement performance measures

As with all areas of management it is important to measure performance. Some key performance measures are listed below:

- the speed of converting a requisition into a purchase order
- the number of purchase orders processed in a day per person
- full loads (complete orders) delivered on time
- the number of stockouts
- the total cost of raising a purchase order
- prices paid against market standards
- the level of expediting
- the number of complaints from internal customers
- the number of complaints from suppliers

Of course there are many more and some that are specific to certain industries. The above is a representative selection.

Collaborative planning, forecasting and replenishment

As the name implies, collaborative planning, forecasting and replenishment (CPFR) is a collaborative business process where two companies work closely together to improve the efficiency of their supply chains. The client and the supplier will link their computer systems to the extent that the supplier has visibility of the inventory held by the client as well as the latest sales and forecasts for the line items involved. Information regarding promotional activity will also be shared with the supplier.

Despite the compelling logic for adopting such an approach to efficient replenishment, take-up has been slow. Some of the reasons for this relate to the difficulties in aligning the two parties' IT systems as well as their business processes. Fears about the security of sensitive market information have also hampered progress. A further reason has been the practical difficulties of agreeing how to share the overall benefits, particularly where higher costs may be incurred by one party in the supply chain. However, some large organizations such as Procter & Gamble have found success using this process.

With the benefit of experience some commentators have questioned the overall efficacy of CPFR relationships. Reservations centre on the fact that successful CPFR is highly dependent on accurate retailer forecasts. If the forecasts are inaccurate, and very often this is the case, then CPFR may not deliver the expected outcomes.

Factory gate pricing

This is sometimes also referred to as purchasing on an 'ex works' basis. This is very often one area associated with the buying process that is overlooked, although in recent years it has been more widely discussed. The cost of transporting the goods to the buyer's facilities may hide some extra cost that the buying company could avoid. Often companies show a remarkable lack of interest in this area, preferring to see it as somebody else's problem. The reality is that some costs could be eliminated and a higher level of control over the inbound supplies may be achieved.

If raw materials are being sourced from a variety of locations, whether it is on a national, continental or global scale, then there may be a possibility of removing some of the associated transport costs by employing a third party to coordinate this process. Large freight-forwarding companies may be able to pool one company's transport requirements with others so that a better price is obtained.

Another way of removing cost from the inbound side of a business is to use the vehicles delivering finished goods to collect from suppliers. This will allow a company to buy raw materials at ex works prices and utilize its delivery fleet more effectively as well. It may be possible to have the same organization that handles final deliveries coordinating inbound raw material transport needs as well (see also Chapter 5).

E-procurement

E-procurement may be defined as: the electronic integration and management of all procurement activities including purchase request, authorization, ordering, delivery and payment between a purchaser and a supplier.

Procurement professionals have seen the benefits of the widespread use of the internet and IT systems in general. The internet has opened up a global marketplace for both consumers and professional buyers alike. Web-based companies such as Amazon, eBay and more recently Alibaba.com have created vast trading sites that connect buyers and sellers all over the world. Some industries have created industry-specific portals that facilitate the connection of suppliers and buyers. The internet can be used not only for the purchase of certain goods but the delivery as well. For example, software, music and films may all be delivered in this way.

Other manifestations of e-procurement include:

- online auctions where pre-qualified bidders compete to win contracts or buy assets

- sending and receiving of documents such as purchase orders, bills of lading, RFQs, invoices and delivery confirmations
- the use of online catalogues

Portals may also be used earlier in the process for facilitating collaborative product design.

Costs saved in procurement are transferred immediately to the bottom line of a company's profit-and-loss account.

Corruption

There are many opportunities for corruption to rear its ugly head in the field of procurement, such as contracts awarded to friends or family; payments made to procurement staff to ensure preferential treatment; invoices passed for payment when no goods or services have been supplied; and many more.

It is important that proper checks are made when recruiting staff to procurement positions. There should be a system of oversight for all purchasers' work. Roles and responsibilities need to be separated in order to preclude corrupt practices from taking place. Managers need to be observant about employees who seem to have some newfound wealth and about the people who come and go in the offices.

There will always be corruption, but good systems and processes – with clearly delineated roles and responsibilities – will help. Managers and senior managers need to be ever vigilant and closely question staff about the who, what and where of certain purchases. A good discipline for a manager is to take a selection of POs at random on a regular basis, then ask questions and examine them in detail. This sends a simple but powerful message that the process is being closely monitored.

Inventory: the basic concepts

15

Introduction

Decisions regarding the amount of inventory that a company should hold and its location within a company's logistics network are crucial in order to meet customer service requirements and expectations. Potentially, however, there is a large cost associated with holding inventory. It is vital to get the balance of cost and service right. This chapter sets out to explore the basic concepts behind the inventory-holding decision.

In the first part of the chapter, the main reasons for holding inventory are considered. The many different types of inventory are then described. These include raw material stocks and all of the different types of stock held throughout the supply chain up to finished goods stocks. The implications of inventory-holding policy on other logistics functions are highlighted, with particular emphasis on the need to provide the balance between cost and service that was indicated in previous chapters. The need to avoid the sub-optimization of logistics resources is also discussed.

The two main inventory replenishment systems are described. These are the periodic review and the fixed point reorder systems. The stock level reorder point is important, and must take account of the stock required to cover the lead time before the new stock is received as well as the safety stock required to cover for variations in demand and supply. The impact that end user demand changes have on requirements further up the supply chain is outlined. The means of identifying reorder quantities using the EOQ method is described, and it is noted that it is important to take other factors into account when determining order quantities in this way.

The need to hold stocks

There are a number of reasons why a company might choose or need to hold stocks of different products. In planning any distribution system, it is essential to be aware of these reasons. The aim is to ensure that stock levels are adequate and not excessively high. The most important reason for holding stock is to provide a buffer

between supply and demand. This is because it is almost impossible to synchronize or balance the varying requirements of demand with the vagaries of supply. These and other important reasons are summarized, as follows:

- To keep down production costs. Often it is costly to set up machines, so production runs need to be as long as possible to achieve low unit costs. It is essential, however, to balance these costs with the costs of holding stock.
- To accommodate variations in demand. The demand for a product is never wholly regular so it will vary in the short term, by season, etc. To avoid stockouts, therefore, some level of safety stock must be held.
- To take account of variable supply (lead) times. Additional safety stock is held to cover any delivery delays from suppliers.
- Buying costs. There is an administrative cost associated with raising every order. To minimize this cost, it is necessary to hold additional inventory so that orders do not have to be repeated too frequently. It is essential to balance these elements of administration and stockholding, and for this the economic order quantity (EOQ) is used.
- To take advantage of quantity discounts. Some products are offered at a cheaper unit cost if they are bought in bulk.
- To account for seasonal fluctuations. These may be for demand reasons whereby products are popular at peak times only. To cater for this while maintaining an even level of production, stocks need to be built up through the rest of the year. Supply variations may also occur because goods are produced only at a certain time of the year. This often applies to primary food production where, for example, large stocks result at harvest time.
- To allow for price fluctuations/speculation. The price of primary products can fluctuate for a variety of reasons, so some companies buy in large quantities to cater for this.
- To help the production and distribution operations run more smoothly. Here, stock is held to 'decouple' the two different activities.
- To provide customers with immediate service. It is essential in some highly competitive markets for companies to provide goods as soon as they are required (ex-stock).
- To minimize production delays caused by lack of spare parts. This is important not just for regular maintenance, but especially for breakdowns of expensive plant and machinery. Thus, spares are held to minimize plant shutdowns.
- Work-in-progress. This facilitates the production process by providing semi-finished stocks between different processes.

Types of stockholding/inventory

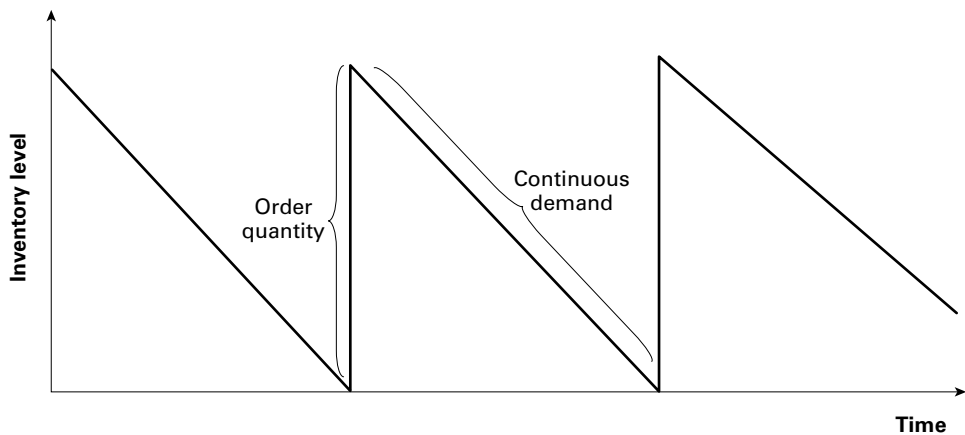
There are a number of different stock types that can be found in company supply chains. These are generally held at strategic positions throughout the company logistics network and in particular at the interfaces with suppliers or customers. The main categories are:

- *Raw material, component and packaging stocks:* generally used to feed into a production or manufacturing process.
- *In-process stocks:* sometimes known as work-in-progress (WIP), these consist of part-finished stock that is built up between different manufacturing processes.
- *Finished products:* stocks that are held at the end of the production line normally in a finished goods warehouse and sometimes known as finished goods inventory (FGI).
- *Pipeline stocks:* probably the most common type of stockholding, these are held in the distribution chain for eventual transfer to the final customer.
- *General stores:* containing a mixture of products used to support a given operation, such as a large manufacturing plant.
- *Spare parts:* a special category because of the nature of the stock, which provides a crucial back-up to a manufacturer's machinery or plant where any breakdown might be critical, and also held by service and maintenance companies for supply to their customers to support service contracts. Service industries, such as utilities, hospitals, and maintenance, repair and overhaul (MRO) providers, invest in spare parts inventory to support their service offer. They have two main stock categories: 1) consumables (nuts, bolts, etc); 2) rotables and repairables (parts that require periodic maintenance or are repairable).

Within the above categories, stock can again be broken down into other major classifications:

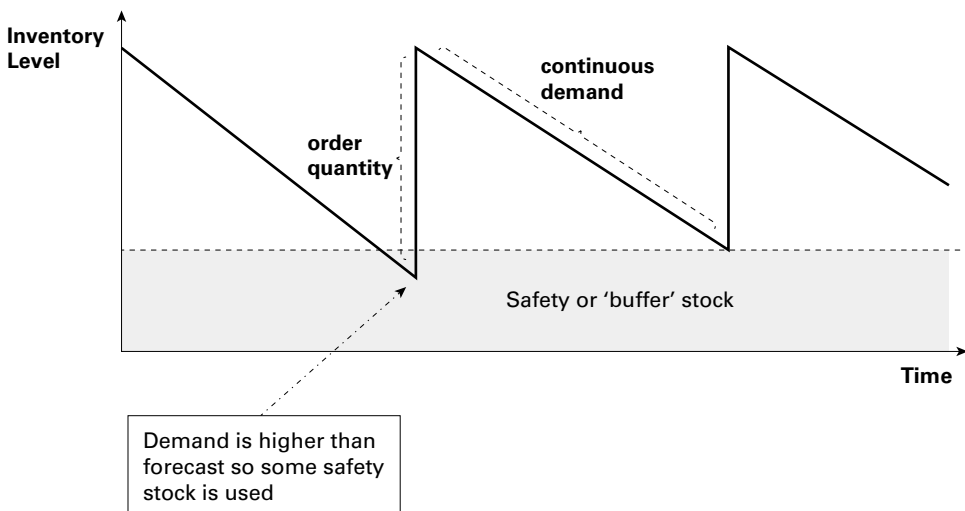
- *Cycle stock or working stock:* this refers to the amount of inventory available for normal or average expected demand in a given period, excluding safety stock. It is the stock created by products arriving in large quantities to meet frequent but small-quantity demands. A typical example is the major production stock within a production warehouse, where it reflects the batch sizes or production run lengths of the manufacturing process. This flow of inward supply and outward demand for a product in a warehouse is not balanced and is often depicted as a classic 'saw-tooth' as shown in Figure 15.1. The sharp rise in stock level represents the delivery of an order, and the steady decline in stock level represents the regular demand for the product over time (although this would in reality be more irregular than that depicted in Figure 15.1).

Figure 15.1 Inventory level showing input (order quantity) and output (continuous demand)



- *Safety stock*: this is the stock that is used to cover the unpredictable daily or weekly fluctuations in demand. It is sometimes known as ‘buffer’ stock, as it creates a buffer to take account of this unpredictability. This is depicted in Figure 15.2.

Figure 15.2 Inventory level with safety stock in place



- *Speculative stock*: this can be raw materials that are ‘bought forward’ for financial or supply reasons, or finished stock that is pre-planned to prepare for expected future increases in demand.

- *Seasonal stock*: this is product that is stockpiled to allow for expected large increases in demand. Typically, in Western Europe, this would include inventory built up prior to the Christmas demand peak.

Stockholding policy implications for other logistics functions

There are many ways in which the need to hold stock affects other logistics functions and vice versa. It is essential for effective planning that the various costs associated with inventory are minimized in relation to other logistics costs. As already discussed in previous chapters, it requires a process of balance between these functions to avoid any sub-optimization and to create a cost-effective total solution. With this in mind, it is useful to review those areas where this balance may be needed.

The *number of distribution centres* (DCs) in a distribution system significantly affects the overall cost of that system. The reasons given for having a large number of DCs are generally the perceived need to have a 'local presence' within a market and the need to provide a given level of service to customers. A distribution system that does have many sites will require high stock levels, specifically with respect to the amount of safety stock held. In addition, a large number of sites is likely to mean fairly small delivery areas, reflecting poor stock turn and higher unit costs in the warehouse.

Many companies have, in recent years, undertaken DC rationalization exercises whereby they have cut significantly the number of sites within their distribution network. This applies to both retailing and manufacturing companies. Although this leads to an increase in local transport costs because delivery distances are greater, there are large savings to be made in inventory reduction – specifically in safety stock reduction.

A simple rule of thumb exists for estimating these savings, known as the 'square root law'. Basically, the law states that the total safety stockholding in a distribution system is proportional to the square root of the number of depot locations. The law thus gives a broad indication of prospective inventory savings from any DC reduction project. For example, a site reduction from, say, 10 to 5 can lead to inventory savings of 29 per cent, as indicated in the following calculation:

$$\begin{aligned}
 \text{Inventory reduction} &= 1 - \frac{\sqrt{5}}{\sqrt{10}} \\
 &= 1 - \frac{2.24}{3.16} \times 100 \\
 &= 29\%
 \end{aligned}$$

Another major factor to be considered is the effect that an excess of inventory can have on the *size and operation of a DC*. Excessive stock occurs for a number of reasons, such as obsolete stock, dead stock, unnecessary storage of slow-moving lines, etc. This may mean that a DC is larger than necessary, that the site operation is hindered through a shortage of working space or even that extra outside storage is required.

One means of tackling these problems is to be more aware of the range of products held. This can be achieved by using techniques such as Pareto analysis (ABC analysis) or criticality analysis. (See Chapter 7 for a more detailed discussion of these and to see a criticality matrix.) Pareto's law provides the '80/20 rule', which states that there is an 80/20 relationship for products under a variety of circumstances. For example, it is often found that approximately 20 per cent of storage lines represent 80 per cent of the throughput in a warehouse.

Using Pareto analysis, it is possible to categorize product lines on the basis of:

'A' lines = fast movers (approximately 20 per cent)

'B' lines = medium movers (approximately 30 per cent)

'C' lines = slow movers

'D' lines = obsolete/dead stock (C+D representing approximately 50 per cent)

Policy decisions can then be made, for example: 'A' lines could be held at all DCs and have a 98 per cent availability; 'B' lines could be held at all DCs but only at 90 per cent availability; 'C' lines could be held only at a limited number of DCs and at 85 per cent availability; and 'D' lines should be scrapped.

Clearly this policy will differ according to product type, industry type, service level requirements, etc. The essential point is to be aware of the appropriate stockholding costs and to recover the costs accordingly.

There are several ways in which stockholding policy and practice can affect *transport operations*. The major example is one that has already been indicated and concerns the number of DCs in a distribution system. Whereas inventory savings can be made by reducing site numbers, this will be associated with an increase in local delivery costs because delivery distance will increase as DC catchment areas become larger. The key is to get the most cost-effective balance between transport costs and inventory and warehouse costs (as discussed in Chapter 10).

Another example where inventory policy might influence transport is in the use of backloads for return journeys by primary (line-haul) vehicles and sometimes by delivery vehicles. Empty return journeys are a recognized cost that transport managers are always keen to minimize. It may be possible to arrange for raw materials or bought-in goods to be collected by own vehicles rather than delivered by a supplier's vehicles. This may lead to higher stock levels but would mean lower transport costs.

A company's stockholding policy may also affect the *distribution structure* that the company adopts. There are three main patterns:

- 1 direct systems
- 2 echelon systems
- 3 mixed or flexible systems

Direct systems have a centralized inventory from which customers are supplied directly. These systems are of two main types – either supplying full vehicle loads, or direct-to-consumer (DTC) services, particularly for internet orders.

Echelon systems involve the flow of products through a series of locations from the point of origin to the final destination. The essential point is that inventory is stored at several points in the distribution chain. There may be several links or levels within these structures, perhaps from production warehouses through a central stockholding point to regional and/or local DCs. Typical examples include some of the manufacturers of fast-moving consumer goods (FMCG) products.

Mixed systems are the most common. They link together the direct and the echelon systems for different products, the key element being the demand characteristics of these products (order size, fast-/slow-moving, substitutability, etc).

Inventory costs

Inventory costs are one of the major logistics costs for many manufacturing and retail companies, and they can represent a significant element of the total cost of logistics. As has been discussed in several previous chapters, there are many major cost trade-offs that can be made with all the other key logistics components. It is important to be able to understand what the key cost relationships are within a company. To do this, an awareness of the major elements of inventory cost is essential.

There are four principal elements of *inventory-holding cost*. They are:

- 1 Capital financing cost: this is the cost of financing the capital tied up in inventory, normally calculated as the cost of the goods multiplied by the rate of interest paid to the bank. It may also be represented as the opportunity cost of tying up capital that might otherwise be producing a better return if invested elsewhere. This is almost always the largest of the different elements of inventory cost.
- 2 Service cost: the cost of stock management and insurance.
- 3 Storage cost: the cost of space, handling and associated warehousing costs involved with the actual storage of the product.
- 4 Risk cost: this occurs as a consequence of pilferage, deterioration of stock, damage and stock obsolescence. With the reduction in product life cycles and the fast rate of development and introduction of new products, this has become a very important aspect of inventory cost. It is one that is frequently underestimated by

companies. It is particularly relevant to high-tech industries, the fashion industry, and fresh food and drink.

Other important costs that need to be understood are the reorder and the set-up costs for an individual product. The *reorder cost* refers to the cost of actually placing an order with a company for the product in question. This cost applies regardless of the size of the order. It includes the cost of raising and communicating an order, as well as the costs of delivery and order receipt.

The *set-up cost* refers to the additional cost that may be incurred by the manufacturing plant if the goods are produced specifically for the company. A series of small orders will each necessitate a separate set-up cost. On the other hand, the larger the order, the longer the production run using a single set-up and the lower the production unit cost of the items in question. Of course, orders for large amounts of a product will result in the need for it to be stored somewhere – at a cost! This is yet another classic logistics trade-off decision that needs to be made. The means of assessing appropriate order quantities are discussed in the section ‘The economic order quantity’ later in this chapter.

The final inventory-related cost is the *shortage cost* – the cost of not satisfying a customer’s order. This cost is notoriously difficult to measure. It is used to try to reflect the penalty of not holding sufficient stock of a product, which may lead to lost profit due to lost sales, loss of future sales, loss of reputation and the cost of the urgent delivery of unsatisfied orders.

Reasons for rising inventory costs

Despite many companies’ best efforts to reduce their inventory costs, these costs have often shown a tendency to rise. There are several reasons for this, which include:

- Reduced product life cycles: many products have significantly reduced usable lives. This applies particularly to technology-based products such as mobile phones, tablet computers and e-readers. The continuous relaunch of new and revised models leads to high levels of obsolete stock due to old models very quickly becoming out of date.
- Product proliferation: due to competitive pressure, companies have tended to offer an increased number of types and varieties of their products in order to maximize demand. This has led to higher stock levels. Ways of reducing this impact include a move to modular assembly whereby a common product platform is used with variations added at a secondary stage.
- Customer expectations: higher levels of service are being demanded by customers in terms of immediate supply on demand. This means that suppliers must hold

higher stocks in order to avoid lost sales so as to avoid customers going elsewhere for their supply.

- Demand volatility: demand for products tends to vary more quickly than in the past, probably due to better and faster consumer information. Product demand can therefore either increase or decrease quite dramatically over short time periods, making it more difficult to assess the best levels of stock to hold.
- Extended supply chains: the move to globalization means that markets can now be supplied from extreme distances. This greatly increases the possibility of supply chain delays, the main solution being the introduction of more stock within the supply system. Also, there is a need for more safety stock with extended supply chains resulting from the greater likelihood of demand variability during the longer lead times (in inventory calculations the length of lead time directly impacts on safety stock).
- Just-in-time responsibilities: although the philosophy behind the just-in-time approach is to reduce inventory by streamlining the supply process, there can be significant implications when the process is not adequately balanced throughout the supply chain. In more instances than might be expected, the adoption of just-in-time by some manufacturers and retailers can mean that although they have significantly reduced stocks, there is a pressure on suppliers to keep additional inventory to ensure that a suitable final supply to the consumer is always maintained (often known as 'just-in-case' stocks).

Inventory replenishment systems

The aim of an effective inventory replenishment system is to maintain a suitable balance between the cost of holding stock and the particular service requirement for customers. The need for this balance can be illustrated by considering the disadvantages of low stock levels (which should provide very low costs) and high stock levels (which should provide a very high service).

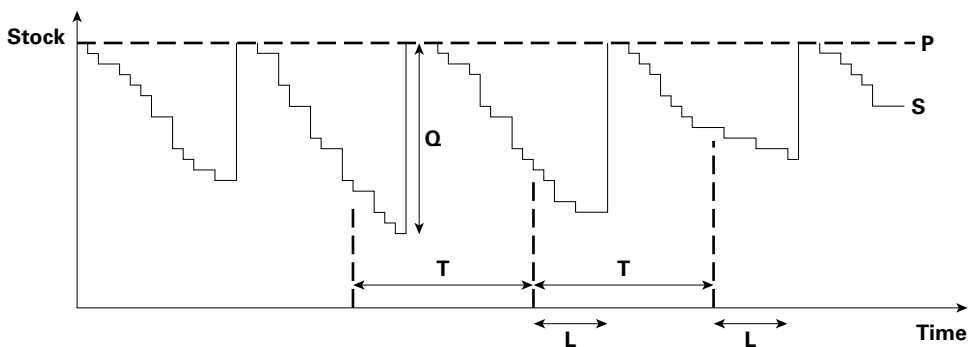
The disadvantages of low stock levels are that customers' orders cannot be immediately fulfilled, which may lead to the loss of both existing and future business, and that goods have to be ordered very frequently, which may lead to heavy ordering costs and heavy handling and delivery costs.

High stock levels have a major disadvantage because capital is tied up that might be better invested elsewhere. Also, there is the risk of product deterioration (e.g. food and drink) and of products becoming outdated, superseded or obsolete if they are stored for long periods of time (e.g. computers, mobile phones and fashion goods). A final disadvantage, previously discussed, is the expense of providing additional storage space.

Inventory replenishment systems are designed to minimize the effects of these high/low stock level disadvantages by identifying the most appropriate amount of inventory that should be held for the different products stocked. There is a variety of systems, but the two major ones are the periodic review (or fixed interval) system and the fixed point (or continuous) reorder system.

The *periodic review system* works on the premise that the stock level of the product is examined at regular intervals and, depending on the quantity in stock, a replenishment order is placed. The size of the order is selected to bring the stock to a predetermined level. Thus, the order size will vary each time a new order is placed. The system is illustrated in Figure 15.3.

Figure 15.3 Periodic review system

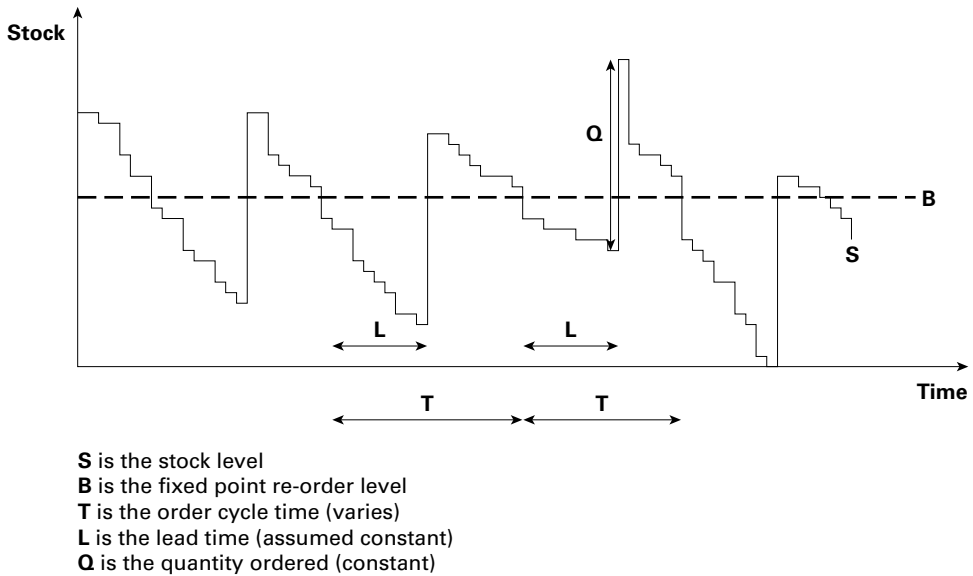


- S** is the stock level
- P** is the predetermined stock level
- T** is the re-order cycle time or review period (constant)
- L** is the lead time (assumed constant)
- Q** is the quantity ordered (varies)

In Figure 15.3, the change in stock level can be seen by the pattern represented by the line S. T represents the re-order cycle time, which is the regular interval at which stock is reviewed – say at the beginning of every month. An order is placed at a quantity (Q) that will bring the inventory for this product back to the predetermined stock level (P). Note that the quantity ordered includes an allowance for the time it takes for the product to be delivered from the supplier (this is the lead time, L). With this method, the quantity ordered is different each time an order is placed.

For the *fixed point reorder system*, a specific stock level is determined, at which point a replenishment order will be placed. The same quantity of the product is reordered when that stock level is reached. Thus, for this system it is the time when the order is placed that varies. This is illustrated in Figure 15.4.

In Figure 15.4, the change in stock level can be seen by the pattern represented by the line S. When the stock level reaches the fixed point reorder level (B), a replenishment order is placed. This is for a fixed order quantity (Q). L represents the lead time

Figure 15.4 Fixed point reorder system

for the order, and the figure shows that when the order arrives the stock level is increased by the set quantity that has been ordered. T represents the time period between orders, the length of which varies from one cycle to another for this system.

The reorder point and safety stock

The fixed point reorder system requires the use of a specific stock level to trigger replenishment. This reorder point is an amalgam of the stock required to cover the lead time before the new stock is received plus the safety stock required to cover for variations in demand and supply.

Thus, the safety stock (or buffer stock) is a term used to describe the level of stock that is required to avoid stockouts, which might be caused by uncertainties in supply and demand (see Figure 15.2). Systems need to be set up to provide the necessary level of safety stock to maintain the required service level in the face of variations in both demand and in supplier lead times. Safety stock is held when there is uncertainty in the demand level or lead time for the product. In this section, the means of determining the level of safety stock is discussed.

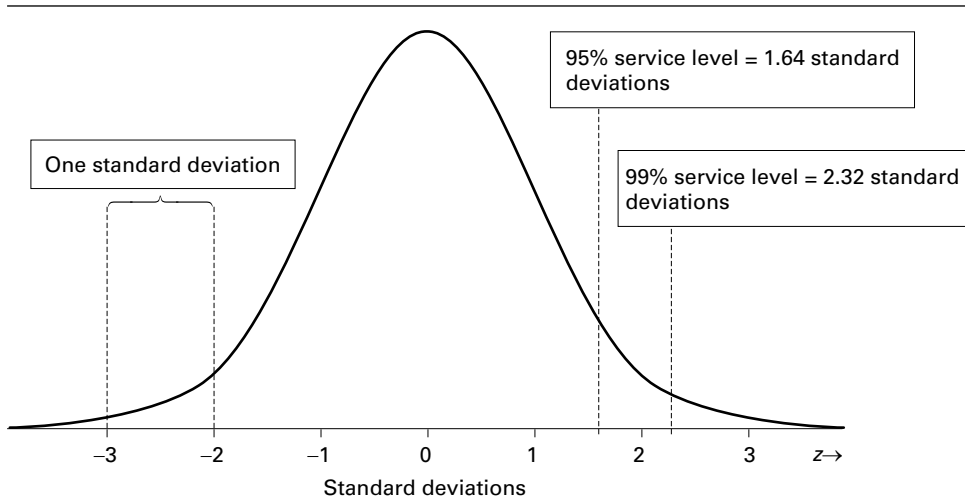
Safety stock can be calculated based on the following factors:

- the demand rate: the number of items used by customers over a given period
- the lead time: the time until the new stock is received
- the variability in lead time: supply lead times are likely to vary about an average

- the service level: the level of service based on the probability that a chosen level of safety stock will not lead to a stockout
- the forecast error: a statistical estimate of how forecast demand may differ from actual demand

Most service level variations assume a normal distribution curve. A normal distribution curve is shown in Figure 15.5, illustrating a 95 per cent service level at 1.64 standard deviations and a 99 per cent service level at 2.32 standard deviations. A normal service level may be 95 per cent, with very high priority items reaching 98 per cent or even 99 per cent.

Figure 15.5 A normal distribution curve showing 95 per cent and 99 per cent service levels



A classic approach for calculating uncertainty in both lead time and demand is given below. Both lead time and demand are normally distributed:

Demand (D) = 100 units per week
 Demand standard deviation (DSD) = 20 units
 Lead time (LT) = 8 weeks
 Lead time standard deviation (LTSD) = 0.5 weeks

The mean lead time demand is $LT \times D = 8 \times 100 = 800$ units
 and

the standard deviation of LT demand is:

$$\begin{aligned}
 &= \sqrt{(LT \times DSD^2) + (D^2 \times LTSD^2)} \\
 &= \sqrt{(8 \times 20^2) + (100^2 \times 0.5^2)} \\
 &= 75 \text{ units}
 \end{aligned}$$

For a 95 per cent service level:

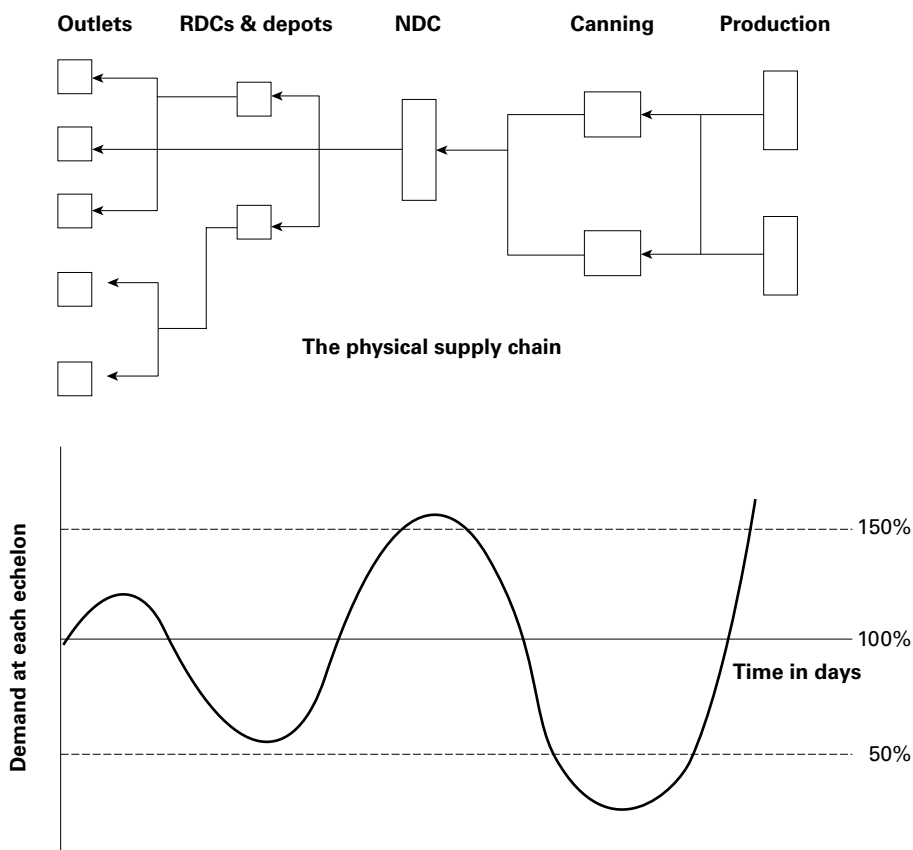
$$\begin{aligned}\text{Safety stock (SS)} &= 1.64 \times 75.5 \\ &= 124 \text{ units} \\ \text{Reorder level} &= (\text{LT} \times \text{D}) + \text{SS} \\ &= 800 + 124 \\ &= 924 \text{ units}\end{aligned}$$

Note that these methods assume that the distributions of demand and lead time are normal distributions. In some instances, however, lead times may not be normal; they can be skewed. Other distributions (e.g. Poisson) could be used as the basis for these calculations. Another method that is receiving more attention is to use actual historic variations, also known as ‘bootstrapping’. The basic idea of bootstrapping is that inference about a population can be drawn from using sample data. In this way, instead of using a Normal, Poisson or other standard statistical distribution to estimate how high safety stocks would need to be to provide a 95 per cent service level, actual historic data can be used to provide a more accurate representation of the demand distribution for that product. As well as these data analytic methods, artificial intelligence can be used to learn the most appropriate combination of techniques over time.

The bullwhip or Forrester effect

The systems described in the previous section, and variations of them, have been used for many years and generally work quite well. They do have one significant drawback, however, which is that they can create unnecessarily high or low stock levels, especially when demand occurs in discrete chunks. This is particularly true of multi-echelon distribution systems where the demand at each level is aggregated at the next level up the supply chain. Thus, small changes in demand for finished products are amplified as they move back through the supply chain. This is because each part of the chain is acting independently of the others. The result is a surge in demand up the supply chain as each inventory location individually adjusts to the demand increases. This is known as the ‘bullwhip’ or Forrester effect. It is illustrated in Figure 15.6.

An example of this might occur where an unexpectedly hot day causes an increase in demand for cold soft drinks. This will lead to additional orders from a variety of outlets – supermarkets, pubs, corner shops, vending machines, etc. As these requirements move up the supply chain through the different channels of distribution, they will be converted into additional orders of various sizes and at different order frequencies. They might be for weekly mixed pallet loads from cash-and-carry outlets, twice-weekly full pallet loads from grocery regional DCs and daily vehicle

Figure 15.6 The 'bullwhip' or Forrester effect

loads for manufacturers' national DCs. The consequence at the canning factory and point of production for the drink will be for a massive increase in demand for the product and a very confusing picture of what the true requirements are. This is echoed back into raw material and packaging supply.

Other possible causes of the bullwhip effect include:

- order batching (e.g. placing a large order at the end of a month, rather than as increased demand occurs, or batching to form a pallet load, etc) – the impact of minimum order quantities is part of this
- promotions, causing disruptions in demand patterns
- the impact of any rationing during periods of low supply availability
- demand forecast updating (e.g. reaction of forecast algorithms to increases in demand)

Thus, it can be very difficult to forecast demand based only on the immediate next or lower level of demand. Accurate forecasts need to reflect the requirements at all

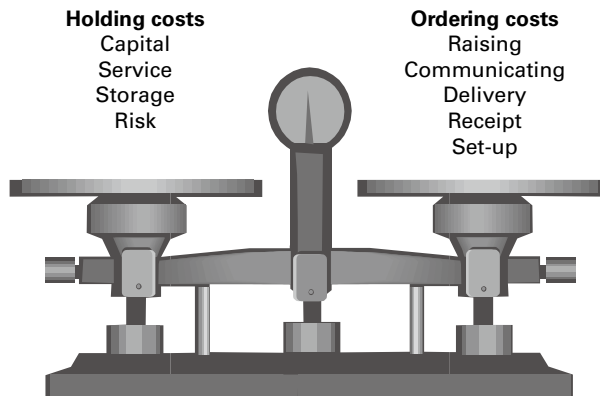
levels, which is often very difficult because companies have traditionally been loath to share information with their suppliers. This is one of the reasons for the move towards more open information systems that provide a clearer vision of stockholding and demand throughout the supply chain. These are discussed in Chapter 16.

The economic order quantity

Calculating the economic order quantity

The two reorder systems described in the previous section require either fixed or variable quantities of different products to be ordered. The next question that needs to be addressed is how much product should be reordered. To answer this question is not easy, and there are many different views as to the best means of arriving at an answer. The traditional method of calculating the appropriate quantity is known as the economic order quantity (EOQ) method. The EOQ method is an attempt to estimate the best order quantity by balancing the conflicting costs of holding stock and of placing replenishment orders. This is illustrated in Figure 15.7.

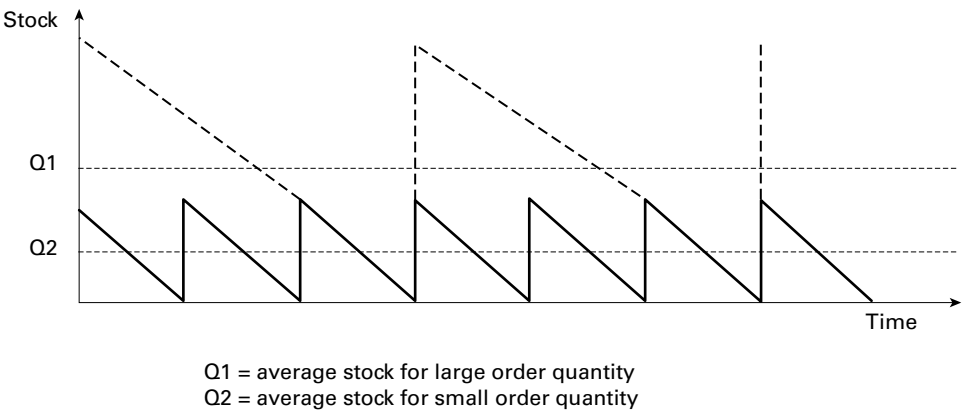
Figure 15.7 The EOQ balance



The effect of order quantity on stockholding costs is that: the larger the order quantity for a given item, the longer will be the average time in stock and the greater will be the capital, service, storage and risk costs. On the other hand, the placing of a large number of small-quantity orders produces a low average stock, but a much higher cost in terms of the number of orders that need to be placed and the associated administration and delivery costs. These two different effects are illustrated in Figure 15.8. The large order quantity gives a much higher average stock level (Q1)

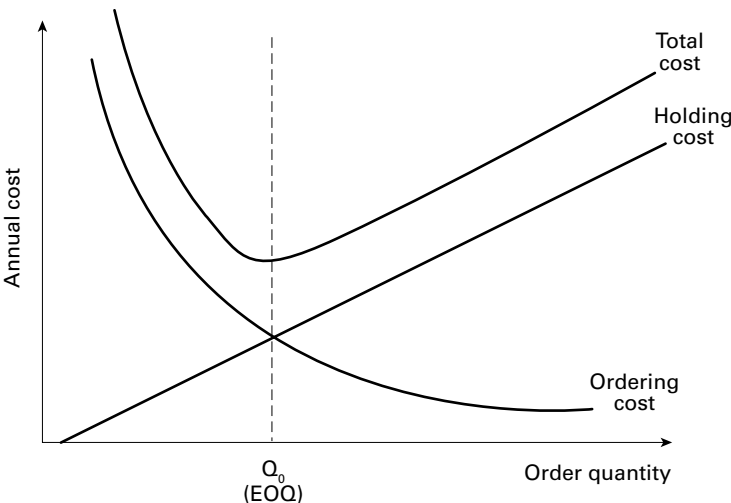
than the small order quantity (Q_2). The small order quantity necessitates many more orders being placed than with the large order quantity.

Figure 15.8 Reorder quantities



The best approach is, once again, one of balance, and it is this balance that the EOQ method aims to provide. Figure 15.9 helps to illustrate how this balance is achieved between the cost of holding an item and the cost of its reordering. There is a specific quantity (or range of quantities) that gives the lowest total cost (Q_0 in the figure), and this is the economic order quantity for the product.

Figure 15.9 The economic order quantity (EOQ) principle



There is a simple formula that enables the EOQ to be calculated for individual stock-keeping units (SKUs). This is shown in Figure 15.10, together with an example of how the formula can be applied. It should also be appreciated that the EOQ

model is based on a number of assumptions that need to be taken into account when the method is used. It is a deterministic model: the demand for the product is known with certainty and is assumed to apply at a constant rate; each order is delivered with zero lead time; stockouts do not occur. However, when used in association with other methods, such as the fixed point reorder system, and with safety stock provision, the EOQ is very valid and can be applied to many different products.

Figure 15.10 The EOQ formula with worked example

Formula:

$$EOQ = \sqrt{\frac{2PD}{UF}}$$

P = Cost of placing an order

D = Annual demand in units

U = Cost of a unit of inventory

F = Annual stock-holding cost as a fraction of unit cost

UF = Cost of holding stock per unit per year

Example:

P = £75 = Cost of placing an order

D = 2,400 = Annual demand in units

U = £50 = Cost of a unit of inventory

F = 25% (1/4) = Annual stock-holding cost as a fraction of unit cost

$$EOQ = \sqrt{\frac{2 \times 75 \times 2,400}{50 \times 0.25}}$$

$$EOQ = \sqrt{\frac{360,000}{12.5}}$$

$$EOQ = 170 \text{ units}$$

Associated factors

There are a number of additional factors that need to be considered before the final order quantity is confirmed. These factors are of two types. The first type applies specifically to an individual company operation or to a particular industry. The second type relates to factors of a more general nature, which tend to be relevant to most stock control or stock reorder systems. An important point to appreciate is that factors such as these may need to be considered as well as any suggested order quantity that derives from a stock control or stock reorder system as indicated above. Some of these factors may be included within the stock reorder system itself, but this is often not the case.

The first set relates to *special factors* which may apply to specific companies or industries. The order quantity requirement for each product must be assessed and readjusted accordingly. The factors include the following:

- New product lines. These may be one-off items, or items that are expected to show a sharp increase in demand. There will be no historic data on which to base demand forecasts, so care must be taken to ensure that adequate stock levels are maintained.
- Promotional lines. National or local promotion (via TV, newspapers, special internet offers, etc) may suddenly create additional demand on a product, so stock levels must cater for this.
- Test marketing. This can be used for assessing the likely demand for a new product. The testing process can lead to spiky unplanned demand. Tests may be undertaken over a given period of time or be in a certain geographic area only.
- Basic lines. Some companies feel that a certain number of their basic stock lines should always be available to the customer as a matter of marketing policy. To provide this service, higher stock levels must be maintained.
- Range reviews. A company may adopt a policy to rationalize, or slim down, its range of products – particularly if new lines are being introduced. To do this it may be necessary to reduce the reorder quantities for some products.
- Centralized buying. Sometimes, where centralized buying occurs, it is necessary to hold excess stock, or run out of stock, because the buying department is negotiating large bulk discounts.

The second set relates to more *general factors* which may need to be taken into account. These include:

- Outstanding orders. These are orders already placed but not delivered. It is important to include these in the analysis, as otherwise overstocking may occur.
- Minimum order quantities. For some products there may be a minimum order quantity, below which it is uneconomic (or even impossible) to place an order.
- Seasonality. Many products have a peak demand at certain times of the year. The most common peak in the UK, for example, occurs just prior to Christmas (toys, games, wines and spirits, etc). When estimating stock levels and when forecasting trends in demand, it is essential to take these into account.
- Pallet quantities. As with minimum order quantity, it is often more economic to order in unit load quantities – which are often a pallet or number of pallets. A good economic unit load order is often a full truck load.

Issues with the EOQ calculation

The EOQ method has been in use for many years and, used in association with other factors such as those previously indicated, it is still valid for many companies. There

are some issues, however, with the pure EOQ calculation – for example, it does not take into account the fact that unit delivery costs vary with the quantity ordered. This may often be a much more significant trade-off (i.e. inventory versus transport costs) than that considered by the EOQ model (i.e. inventory versus reorder costs).

Although still a useful and valid tool in many circumstances, some of the main assumptions on which it is based are less realistic for companies that have adopted a more streamlined approach to their logistics and supply chain activities. For example:

- Demand is not as predictable as it may once have been.
- Lead times are not constant: they can vary for the same product at different order times.
- Costs can be variable: order cost relationships have changed with the introduction of automatic and electronic data interchange (EDI) related ordering procedures.
- Production capacity can be at a premium: it may not always be feasible to supply a given product as and when required.
- Individual products are closely linked to others and need to be supplied with them, so that ‘complete order fulfilment’ is achieved.

Thus, the main assumptions that are the basis for the EOQ are questionable for a number of companies and their products. This can be linked to the introduction of continuous replenishment, which is now at the heart of many companies’ supply policies. This means that orders are for much smaller quantities and are required much more frequently. The rules that once applied to inventory planning are undergoing a change. Although this is certainly true for many large companies, the application of EOQ is still very relevant to many small and medium-sized enterprises. Thus, the EOQ method does rely on a number of basic assumptions, some of which may not be so applicable with the new concepts and approaches to inventory that have been derived in recent years. These concepts are discussed in the Chapter 16.

Inventory and the supply chain 16

Introduction

In the previous chapter, the basic concepts behind inventory planning and management were described. Because of new approaches in inventory thinking some of the traditional methods of inventory planning are now becoming less applicable for many companies. This applies to the economic order quantity (EOQ) concept and these issues were discussed in the previous chapter.

In this chapter inventory techniques are reviewed in relation to the different types of demand that can be found within the context of push and pull systems. This includes the differentiation between dependent and independent demand and the nature of demand with respect to push and pull systems. Also, the importance of the 'decoupling point' is explained. The need for a company to hold inventory is explored with respect to the lead-time gap. This is the difference between the length of time it takes to complete an order and the amount of time a customer is prepared to wait for that order to be satisfied. Different approaches to inventory reduction are considered, and some of the main methods of measuring inventory and its relationship with time are reviewed.

Push and pull systems

For some products, appropriate inventory-planning techniques need to be chosen based on the different types of demand that are prevalent. The nature of this demand is likely to have an influence on the most suitable approach that should be adopted to manage the inventory. Indeed, the type of inventory policy may not just be dependent on the nature of demand, but sometimes by supply as well. Several key aspects are explained below.

Dependent demand versus independent demand

One important way of differentiating between demand types is that of dependent or independent demand. Whichever of these types of demand is the major characteristic

of a product will have an influence on the nature of the inventory-management technique that is appropriate. This is also reviewed in Chapter 13.

Independent demand occurs where the demand for one particular product is not governed by the demand for any other product. Consumer demand for a tablet computer is, for example, independent as it is not required to support another product. Indeed, most consumer products are independent of the demand for other finished goods. This is an important distinction, because products with an independent demand require the use of forecasting to help determine expected demand levels and associated inventory requirements. The EOQ approach is commonly used for products with independent demand.

Dependent demand occurs where the demand for a particular product is directly related to or dependent on another product. In the case of a desktop computer, for example, the demand for the power leads or the connecting cables would be directly dependent on the number of computers sold as finished goods. Dependent demand can be classified in two ways. It may be vertical (e.g. the chip actually required in the production of the computer) or it may be horizontal (e.g. the instructional manual that is packed with the computer as a finished product). Typically, most raw materials, components and sub-assemblies have their demand dependent on the demand for the finished product. Because of this dependence, there is a far more limited requirement for the forecasting of the demand for these elements, as the actual needs are directly related to the finished product requirements themselves. MRP and MRP II systems are used for these elements (as described in Chapter 13).

‘Push’ versus ‘pull’

One feature that is particularly relevant concerns the nature of the demand requirement. Is it a ‘push’ system or a ‘pull’ system?

- A push system is where inventory replenishment is used to anticipate future demand requirements (build-to-stock).
- A pull system is where the actual demand for a product is used to ‘pull’ the product through the system (build-to-order).

A push approach to inventory planning is usually based on a set plan that is predetermined according to certain rules of inventory reordering. This approach is a proactive one in the sense that it is planned on the basis of known demand (existing customer orders) and estimated, or forecast, demand for products from customers. The aim is to anticipate the extent and location of this demand and ensure that adequate stock is available in the right place at the right time. Typically, a push system is applicable for dependent demand and for cases where there are uncertainties in supply, source or production capacity limitations or the need to cater for seasonal demand. This was outlined in Chapter 15.

The pull approach is a reactive one where the emphasis is on responding directly to actual customer demand, which pulls the required product through the system. The idea of a pull system is that it can react very quickly to sudden changes in demand. The pull system is most useful where there is independent demand and where there is uncertainty of demand requirements or of order cycle time, otherwise, a push system must be used. The most common form of pull system is just-in-time, as the orders are placed only when working stock is at such a level that a replenishment order is triggered.

The 'decoupling point'

For many companies there is a need to adopt a hybrid system that combines the concepts of both the 'push' and 'pull' types of approach. Hybrid systems are often used in practice because most companies operate at some point in between pure build-to-stock and build-to-order systems. Thus, a typical manufacturer might base its early production decisions on forecasts resulting in an inventory of semi-finished products. The final steps are then based on the actual customer order, which involves the customization of the semi-finished product into the finished product (called postponement). This point in the supply chain is known as the 'decoupling point'. It is when the process moves from build-to-forecast to build-to-order, or from 'push' to 'pull'. This is when the major stockholding of products should occur.

Figure 16.1 The decoupling point at different positions in the supply chain showing where inventory is held

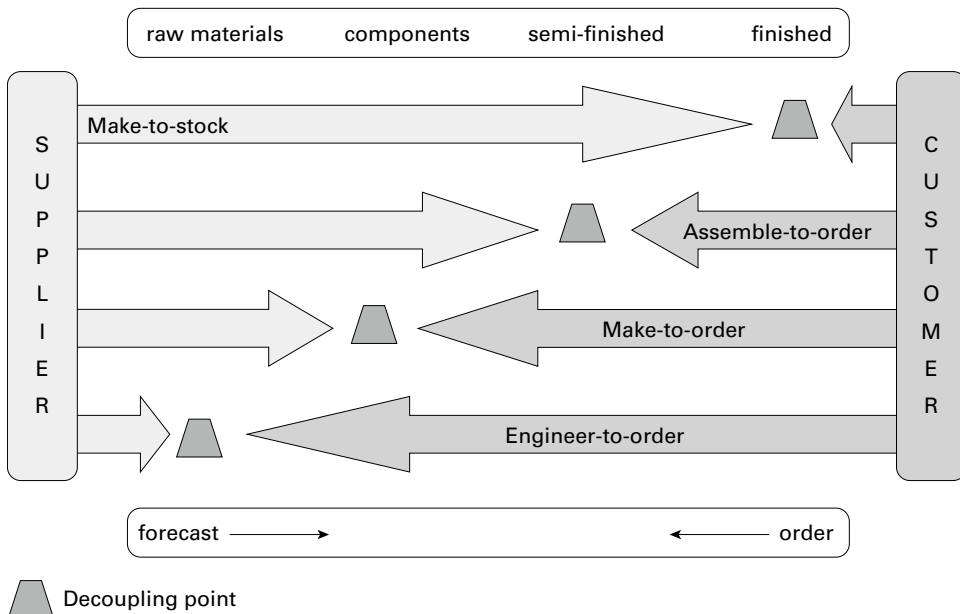


Figure 16.1 illustrates some of the key alternatives for positioning the decoupling point in the supply chain. Inventory is shown to be held at different points in the supply chain dependent on the type of manufacturing and how this relates to different customer demand. Key manufacturing types are represented as:

- *Make-to-stock*: here, customers are serviced from finished goods inventory. The finished goods stock is manufactured ready for use by the final customer. Inventory may then be held by a variety of players within the distribution system (distributors, wholesalers, retailers) and at a variety of locations (finished goods warehouses, distribution centres, satellite depots). This positioning is determined in line with the choice of distribution channel (see Chapter 4) and choice of logistics location (see Chapter 10).
- *Assemble-to-order*: a number of pre-assembled modules and different products are combined to satisfy a customer requirement. Key to this is to bring together the complete order, of which some may be specially ordered and some may be from stock.
- *Make-to-order*: whereby the products that are ordered are made specifically for the customer from raw materials and component parts.
- *Engineer-to-order*: this alternative takes one further step back as the products are also designed with the customer and are then manufactured by the supplier (and/or by other suppliers).

The determination of this decoupling of demand from supply is extremely important as it provides the basis for designing inventory management policy across the whole supply chain. Key to this is that the flow of goods upstream of the decoupling point is controlled by forecasts – thus it is a type of ‘push’ system. Downstream of the decoupling point, the flow of goods is based directly on customer orders – thus it is a ‘pull’ system.

An important additional point is that the position of the decoupling point in the distribution chain (for the make-to-stock scenario) is largely determined by the customer lead time offered. For example, if same-day or two-hour service level is offered then stock must be held in multiple locations close to the customers. On the other hand, if a 24-hour or longer service level is offered the decoupling point can be further upstream and therefore more centralized.

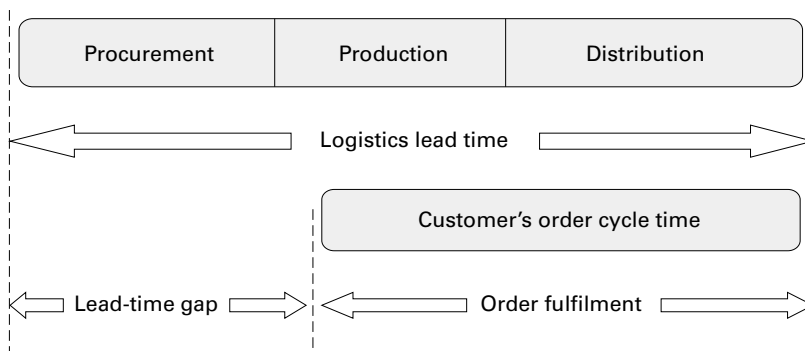
The lead-time gap

One of the major reasons for the build-up of finished goods inventory is because of the long time that it takes to manufacture and deliver products. Ideally (for the manufacturer) the customer would be prepared to wait the full amount of time that

is required. If this were the case, there would be no need to hold any stock at all. This, of course, happens only rarely for special ‘made-to-order’ products. The vast majority of products are required either immediately, as for many consumer products at the point-of-sale in shops, or within a short timescale, as for industrial products and also for consumer products when the retailer orders them in the first instance from the manufacturer.

The total time it takes to complete the manufacture and supply of a product is often known as the logistics lead time. Customers are generally prepared to wait for a limited period of time before an order is delivered. This is the customer’s order cycle time. The difference between the logistics lead time and the customer’s order cycle time is often known as the lead-time gap. The concept of the lead-time gap is illustrated in Figure 16.2. It is the existence of this lead-time gap that necessitates inventory being held. The extent of the lead-time gap, measured in length of time, determines how much inventory must be held. The greater the lead-time gap, the greater the amount of inventory that must be held to satisfy customer requirements. Thus, the more this gap can be reduced, the less inventory will be required. Recently there has been a move towards identifying different approaches for reducing this gap. A number of these approaches are described in the next section.

Figure 16.2 The lead-time gap



SOURCE Cranfield University

Inventory and time

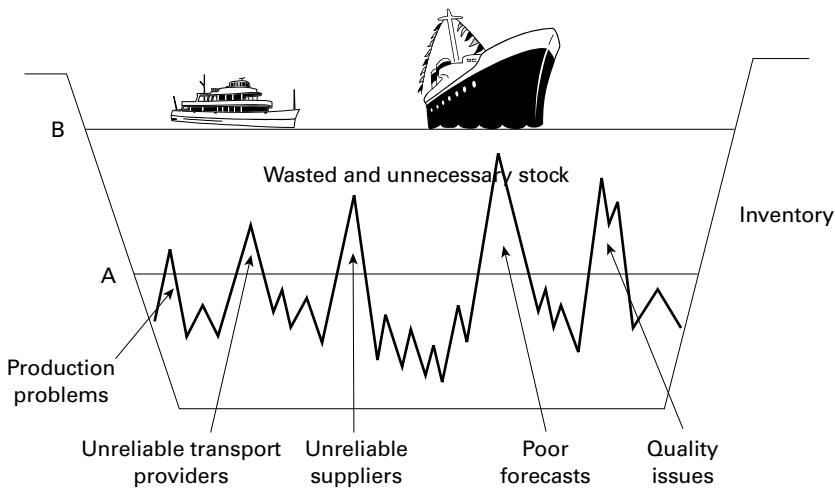
High levels of inventory can hide a number of problems that occur throughout the supply chain. Companies may have sound and acceptable reasons for holding stock – as outlined in the previous chapter – but sometimes high levels of inventory can conceal other issues that are unidentified and should be addressed. The implications of this are illustrated in Figure 16.3. This shows that there can be significant waste

in many logistics systems, concealed by unnecessary inventory (the difference between A and B). These can be problems such as:

- unreliable suppliers
- inaccurate forecasts
- production problems
- quality issues
- unreliable transport providers

There is, of course, a very real cost associated with these high inventory levels. This is caused by the amount of capital tied up in the value of the inventory itself, and also in the other associated costs. These include the costs of the storage facility and the cost of obsolescence when products become outdated and have to be sold at discount rates or even scrapped.

Figure 16.3 High inventory levels can hide other supply chain problems



Finding a solution to these inventory-related problems can lead to a significant reduction in the requirement to hold stock. In Figure 16.3, their elimination would mean inventory coming down from level B to level A. How can inventories be lowered in this way? As well as confronting the particular problem areas directly, another approach is through what is known as lead-time reduction. This approach recognizes the importance of time within the inventory decision-making process. The aim of lead-time reduction is to reduce the amount of unnecessary time within the order-to-delivery process and thus reduce the need to hold so much inventory as cover for this time delay. This can be achieved in a number of different ways, as follows:

- Manage the supply chain as one complete pipeline. This will allow stock to be reduced at various stages in the total pipeline because it is clear that other stock exists to provide the necessary safety stock cover. The section on ‘Analysing time and inventory’ in this chapter will explain this further.
- Use information better. If there is a clearer picture throughout the supply chain of what the true final demand for a product is, then it will be much easier to provide more accurate forecasts of the likely demand at other points in the supply chain. Such an approach could help prevent issues such as the bullwhip effect described in Chapter 15.
- Achieve better visibility of stock throughout the supply chain for all participants. This will allow for clearer and more confident planning of stock requirements at the various stockholding points in the chain and thus reduce the need to hold safety stocks.
- Concentrate on key processes. Make sure that the greatest planning and monitoring effort is spent on the most important processes in the supply chain. These may well be those that are providing the biggest bottlenecks or hold-ups in the system. It will often be necessary to undertake specific analysis to identify these bottlenecks using flowcharts such as those described in Chapter 7.
- Use just-in-time (JIT) techniques, where applicable, to speed up the flow of products through the supply chain. These will reduce lead times and thus mean that less stock is required within the supply chain.
- Use faster transport. This is, of course, one of the classic trade-offs in logistics. Faster transport will almost certainly cost more, but there will be an associated reduction in the need to hold stock, and inventory cost savings will be made accordingly. This may provide an overall cost reduction in the supply of that product as a whole. It is also likely to result in a faster and more responsive service level.
- Develop supply chain partnerships. It is important to understand the need to identify lead-time reduction opportunities that lie outside a company’s own boundaries. The most spectacular savings in stock reductions occur where companies in the same supply chain can work together, share information and build up a trust that allows them to reduce stocks with confidence.

Analysing time and inventory

To help understand the relationship of time and inventory it is useful to be aware of the concept of activities that add value to the supply chain and those that do not add value. An activity that adds value is one that provides a positive benefit to the

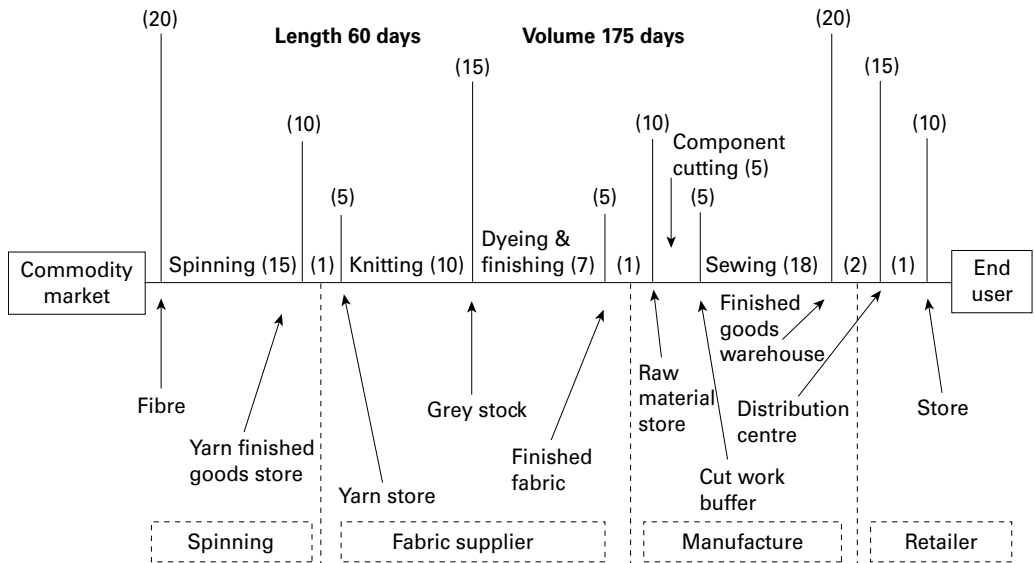
product or service being offered. This can be assessed in terms of whether the customer is prepared to pay for this activity. An activity that does not add value is one that can be eliminated from the supply chain process and will not materially affect the finished product as far as the final customer is concerned. The analysis of supply chain activities in terms of the extent to which they add value to a product has thus become an important factor in the assessment of supply chain efficiency. The aim is to identify and eliminate those activities that add cost but do not add value. The holding of inventory within a supply chain is often one such activity, and many companies are now trying to eliminate unnecessary inventory from their supply chains.

One method of highlighting unnecessary inventory is through the use of supply chain mapping. This technique enables a company to map the amount of inventory it is holding in terms of the length of time that the stock is held. An example of this technique is provided in Figure 16.4. This is one of the original examples used from the US clothing industry. It shows:

- Value-adding time, which is represented along the horizontal axis. This shows the total of the manufacturing and transport time for the whole supply chain process from the initial raw material (fibre) to the supply of the finished product to the end user. It is value adding because the product is changed either through a production process or through a movement process (the value added to the process in the movement of product is by creating time and space utility). The total manufacturing and transport time amounts to 60 days.
- Non-value-adding time, which is represented by the vertical lines that rise from the horizontal axis. These show the various occasions when the part-prepared or finished product is held as some form of inventory. This is adding no specific value to the product. This amounts to 115 days.
- The total time, or pipeline time, is the addition of the value-adding horizontal time and the non-value-adding vertical time. This is a time (or volume) of 175 days. This therefore includes all the time that it takes through all the different manufacturing, storing and transport processes.

Note that in some instances transport is treated as non-value-adding (movement between production processes) and in others as value-adding (movement to the final customer).

The example clearly indicates the opportunities for reducing time within the supply chain by reducing unnecessary inventory. Some inventory will be required, but as illustrated by this particular example there is a lot that is not. For example, there are 20 days of inventory in the finished goods warehouse and 15 in the distribution centre, and they come next to each other in the supply chain. With better visibility in the supply chain, there is almost certainly scope for eliminating inventory

Figure 16.4 An example of a supply chain map showing inventory mapped against time

SOURCE Scott and Westbrook, 1991

at this point. This situation is typically found where the FG warehouse is a supplier and the DC is a customer. Each is, perhaps, not fully confident of the other's commercial acumen and so they both hold additional inventory (above the prescribed safety stock allowance) to avoid any potential problems that might arise. Very few companies undertake this type of analysis, and those that do are usually surprised by the results they get as large inventory levels are identified. It should also be emphasized that this type of analysis has particularly dramatic results where a complete supply chain can be measured. (See Chapter 17 for further discussion on inventory planning for the supply chain.)

Inventory planning and demand forecasting

17

Introduction

In the previous two chapters the basic concepts behind inventory planning and management were described and some of the more recent developments concerning the way that inventory is viewed across the supply chain as a whole were discussed. It was noted that inventory requirements can differ from one product to another for a variety of reasons, including the nature of the demand requirement. Different demand requirements for a product can depend on whether it is part of a ‘push’ or a ‘pull’ system, and whether demand is dependent or independent of the demand for another product or the position of the decoupling point in the supply chain for that product.

This chapter is concerned with inventory planning and the use of demand forecasting to help determine the amount of inventory that should be held in the logistics network to meet customer service. Different inventory-planning horizons are described.

The main qualitative and quantitative demand forecasting methods are introduced. Qualitative forecasting methods are largely judgemental or experimental. A number of different quantitative forecasting methods are described, the main categories being: causal, common projective, advanced projective and life cycle. Among the common projective techniques that are explained are the moving average, exponential smoothing and regression analysis. It is also shown that demand can be broken down into trend, seasonal and random factors by using the time series approach. A planned approach to demand forecasting is provided.

Finally, there is a description of some of the main inventory-planning techniques that are used for manufacturing, retailing and the supply chain as a whole.

Inventory-planning horizons

Planning horizons for logistics were introduced and discussed at the beginning of Chapter 2. It was shown that these are generally classified as strategic (medium- to long-term), tactical (short- to medium-term) and operational (daily to short-term). Inventory-planning horizons are similar but are more often classified as follows:

- *long-term*: more than three years and covering, for example, new product development and facilities planning for manufacturing
- *medium-term*: three months to three years and covering, for example, aggregated demand, production schedules, inventory, materials and component requirement levels
- *short-term*: less than three months and covering, for example, forecast throughput, inventory levels, supply synchronization, etc

Long-term planning is used at the strategic level, as discussed in Chapters 2 and 6, and is not relevant to the level of inventory planning that is covered in this chapter. Medium-term planning includes techniques such as material requirements planning (MRP) and distribution requirements planning (DRP), which were introduced in Chapter 13 and will be summarized in the final sections of this chapter. The main focus of this chapter is on short-term planning for inventory, commencing with the important elements of demand forecasting.

Demand forecasting

Different forecasting methods

Different methods of demand forecasting are used to try to estimate what the future requirements for a product or SKU might be so that it is possible to closely meet customer demand. Forecasting, thus, helps in the inventory-holding decision process to answer questions about what to stock, how much to stock and what facilities are required. It is often said that ‘all mistakes in forecasting end up as an inventory problem – whether too much or too little!’

There are several different approaches that can be used for forecasting. These are shown in Figure 17.1. The major categorization is between *quantitative* and *qualitative* forecasting methods, with the former being numbers-based and the latter relying on opinions. For the short-term inventory forecasting of individual SKUs, the quantitative methods are most commonly used and these will be given most attention in this chapter.

Qualitative forecasting methods

As can be seen from Figure 17.1 qualitative forecasting methods can be split into judgemental and experimental methods.

Judgemental methods

Judgemental methods are subjective assessments based on the opinions of experts such as suppliers, purchasing, sales and marketing personnel, and customers. These methods are used when historic demand data is very limited or for new products where there is no numerical demand data available. They include:

- *Executive brainstorming*: the opinions of a small number of senior managers in the company are taken together and an estimate of likely aggregate demand levels is made from the collective view.
- *Scenario planning*: a group of suitably experienced company employees and key customers is formed and they draw up and agree likely demand outcomes with regard to the products in question.
- *Delphi studies*: a panel of experts, both internal and external to the company, is formed. Each person is asked individually for their estimates of demand and then an iterative process occurs whereby each person sees the overall group range of results and alters their input as they think appropriate until a reasonable consensus view is determined.

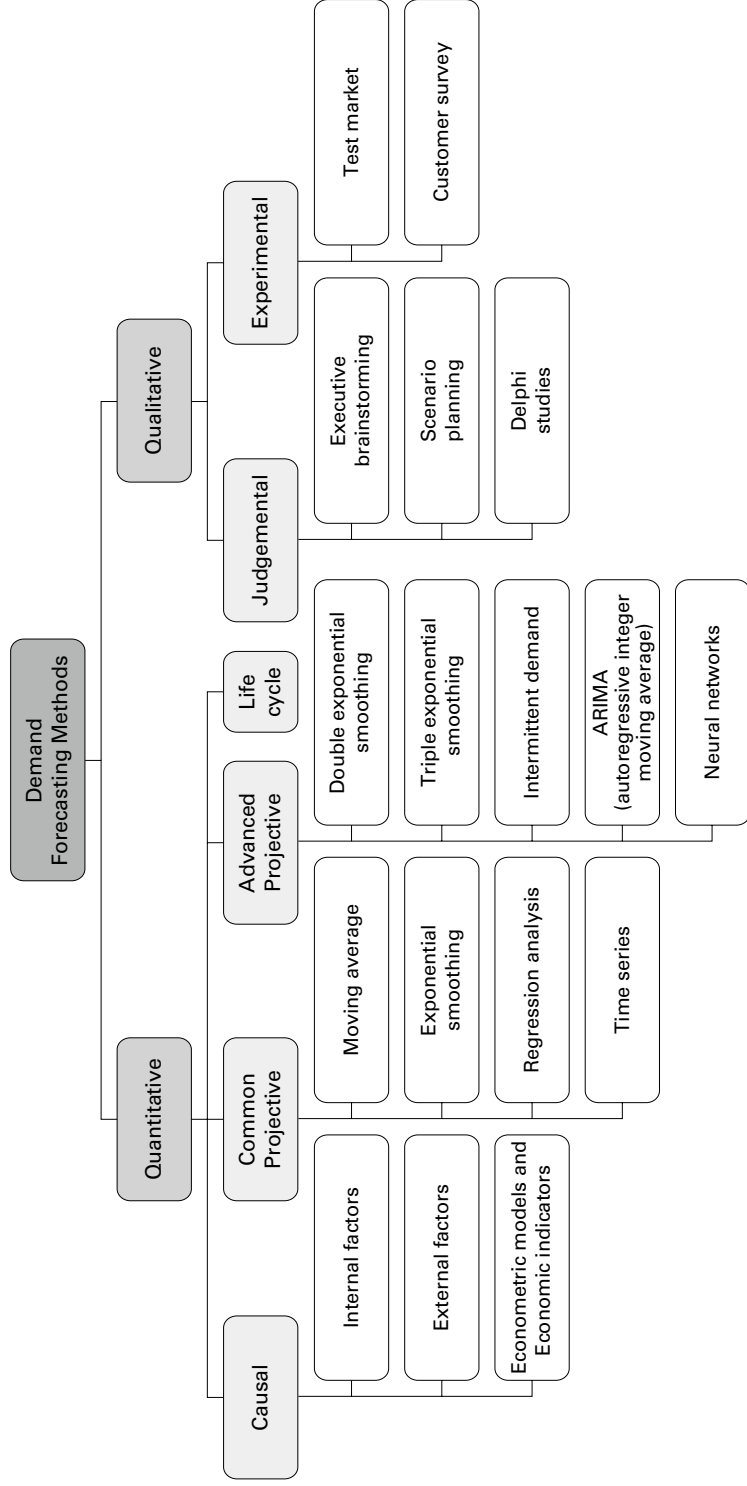
Experimental methods

Experimental methods are used when there is no information available on which a forecast can be based: again, this is likely to apply to new products. Companies may set up a group of existing customers and determine from them what the likely demand might be. Results are then extrapolated to a larger population and a forecast is produced. Sometimes companies use a small geographic area as a 'test market' to identify likely demand and then extrapolate this to the full market area. As well as test marketing, methods might also include customer questionnaires and consumer panels.

Quantitative forecasting methods

There are a number of different methods that are used for quantitative forecasting, as Figure 17.1 illustrates. These vary dramatically from some fairly simple, but very

Figure 17.1 Different demand forecasting methods



useful, approaches to some that are extremely complicated. The next several sections will describe some of the key methods listed in Figure 17.1.

Causal methods

Causal methods are used where the demand for a product is dependent on a number of other factors. Very often they are used in conjunction with another quantitative forecasting method because they enable the forecast to be adjusted more accurately with respect to certain other factors that have an influence on demand. These factors may be internal or external to the company. *Internal* factors are generally under the control of the company and include aspects such as promotions and price. *External* factors are likely to be out of the control of the company and may be directly business-related (competitors' plans, legislation) or indirectly related (seasonality, weather, the state of the economic cycle).

Classic causal methods of forecasting include the use of economic indicators (gross domestic product, interest rates) to gauge causal trends in demand for products and services, enabling forecasts to be adjusted accordingly. A more sophisticated approach is that of econometric modelling whereby a variety of economic variables are taken together and are used in mathematical models to forecast the underlying demand for products and services.

Common projective forecasting methods

In this section, some of the more common and most straightforward methods of forecasting are described. The basic methods are the moving average (and the weighted moving average) and exponential smoothing. These approaches use past demand data to estimate what demand is likely to be in the future. This can then become the basis for determining what stock levels are required to meet these forecast customer demands. In addition, the process of regression analysis is explained whereby the demand trend for a product can be estimated through the means of 'fitting' a line to a series of historic data points. These methods attempt to predict future demand based on historic data, but for many products there are additional factors that can also have an important influence on the accuracy of these predictions. These factors include trends over time, seasonality, general cyclical behaviour and random fluctuations. Time series analysis is often used to enable factors such as these to be taken into account and this is reviewed in the final part of this section.

Moving average/weighted moving average

The simplest method is the moving average, which takes an average of actual demand for a certain number of previous periods and uses this average as the forecast of

demand for the next period. Such a system is able to respond to trends and is suitable for some products, but is not effective if the product has seasonal demand or random demand variations (see time series later in this section).

The formula is as follows:

$$F_t = \frac{A_{t-1} + A_{t-2} + A_{t-3} + \dots + A_{t-n}}{n}$$

where:

F_t = the forecast demand

n = the number of periods to be averaged

A_{t-n} = actual demand in the past up to 'n' periods

An additional problem with this method is that it ignores the age of the observations, as all are treated equally in the process of determining the forecast demand level. It takes no account of changes over time, which is not really representative of demand in most logistics systems – because things do tend to change over time. This problem can be reduced by use of the weighted moving average, which puts more emphasis on the use of the most recent data, so reflecting actual demand more accurately.

The formula is as follows:

$$F_t = \frac{w_1 A_{t-1} + w_2 A_{t-2} + w_3 A_{t-3} + \dots + w_n A_{t-n}}{n}$$

where:

w = a weighting factor

Exponential smoothing

A more sophisticated version of this method of forecasting is known as exponential smoothing. This also gives recent weeks far more weighting in the forecast, but each forecast is in fact a weighted average of all prior observations. The weighting process declines exponentially with the increasing age of the observations, thus both emphasizing the importance of the most recent weeks and taking account of the value of the earlier data. The formula for exponential smoothing is as follows:

$$F_t = aY_{t-1} + (1 - a)F_{t-1}$$

where:

F_t = the forecast demand

Y_{t-1} = previous actual demand

F_{t-1} = previous forecast demand

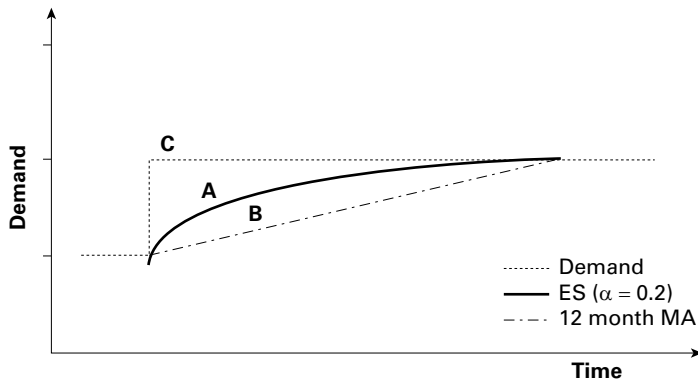
a = an exponential smoothing factor (the smoothing constant)

The exponential smoothing approach can also include a consideration of the forecast error to improve the accuracy of the forecast – that is, the difference between the forecast and the actual demand for the previous period.

Forecasting methods such as exponential smoothing tend to give a much faster response to any change in demand trends than do methods such as the moving average.

Figure 17.2 provides an example of some of these different approaches. The dash-dotted line (C) represents actual demand, the dash-dot line (B) represents a forecast using the moving average method and the single line (A) represents a forecast using exponential smoothing. It can be seen that the single line (exponential smoothing) responds more quickly to the demand change than does the dash-dot line (moving average).

Figure 17.2 The moving average (MA) method (B) and the exponential smoothing (ES) method (A) of forecasting shown working in response to a step change in demand (C)



Regression analysis

Another method used is regression analysis, where a line of 'best fit' is statistically derived to identify any correlation of the product demand with other key factors and from this a trend line can be determined. Using the least squares method, a straight line is fitted around a scatter of data points. A correlation coefficient can be derived to indicate how well the regression line fits the data, as the larger the scatter of points around the line, the less strong is the relationship. This type of analysis works around the assumption that demand is normally distributed, but this may not necessarily be the case as aspects such as customer behaviour, price changes, weather changes, etc may distort this type of relationship. Regression analysis is also not a good method for taking account of seasonal fluctuations and cyclical factors.

'Time series' models

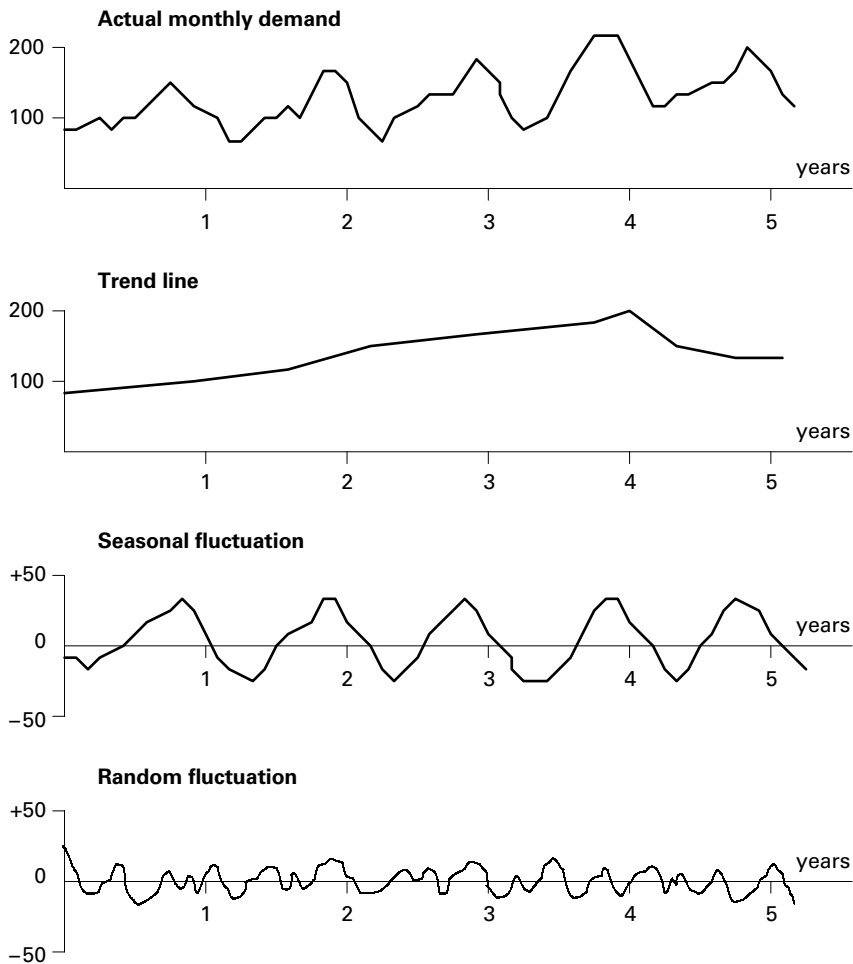
These projective forecasting techniques use historic demand data to identify any trends in demand and project these into the future. Unlike causal techniques they take no account of judgement or opinion. So, although based on actual past demand, they take no direct account of future events that may affect the level of demand. There are several different projective forecasting methods available, and it is important to select the most appropriate alternative for whatever type of demand is to be measured.

An additional point that needs to be emphasized is that there are different ways in which the demand for a product can vary over time. Some of these factors cannot be taken into account by just using the forecasting methods described so far. They need to be understood and data need to be adjusted before accurate forecasting can take place. These different elements of demand have been recognized and are taken into account by the use of 'time series' analysis. This is illustrated in Figure 17.3, where it can be seen from the graphs that the overall demand pattern can be divided into the following:

- *A trend line over several months or years:* in the graph, the trend is upward until the end of year 4, and then downward. It is this trend that can be forecast by using methods such as exponential smoothing.
- *A seasonal fluctuation:* this is roughly the same – year in, year out. In the graph, there is high demand in mid-year and low demand in the early part of the year. A classic example in the UK for many products is the high demand that occurs at Christmas.
- *Random fluctuations that can occur at any time:* these can be totally random but they may be causal and thus identified by using some of the qualitative methods described earlier. The classic example is – if it rains, umbrella sales increase!

Thus, a number of different approaches can be used and linked together to provide the most accurate forecasting of demand for any given product or group of products and allow for appropriate inventory levels to be identified and fixed. Each of the key elements should be taken into account by a good forecasting system and its associated stock control system:

- the trend, by setting inventory levels and replenishment cycles using an appropriate forecasting system
- seasonality, by adjusting inventory levels on a timely basis via seasonal analysis
- random, by providing sufficient safety stock

Figure 17.3 Elements of a demand pattern

Advanced projective forecasting methods

There are a number of more advanced projective methods of forecasting that can be used. They are fairly sophisticated but are very relevant under certain circumstances. They include techniques such as:

- Double exponential smoothing, which smooths random variation and trend, e.g. Holt-Winters method.
- Triple exponential smoothing, which smooths random variation, trend and seasonality, e.g. Winters method.
- Croston's exponential smoothing, which is used where there is intermittent demand. This involves simple exponential smoothing on the non-zero data and a

separate application of exponential smoothing to the times between non-zero data.

- Autoregressive integer moving average (ARIMA), which is fitted to time series data to help in understanding the data and to predict future points in the series, e.g. Box-Jenkins.
- Artificial intelligence (AI), where there is automated learning from past experience. Demand sensing, for example, uses current information to determine how the supply chain should react, employing pattern recognition technology to analyse real-time demand signals and create forecasts that are automatically input into supply chain planning systems. Thus, real-time data, algorithms and automation are combined to actively sense demand changes and quickly respond. These are digital supply chain planning platforms that are powered by AI and machine learning (ML) in particular.

Life cycle forecasting

Life cycle forecasting is relevant as it recognizes the key factor that over the life cycle of a product the characteristics of demand can and do change quite dramatically and that this affects the inventory and replenishment requirements for the product. For many high-technology products, for example, this is particularly important because the length of product life can be very restricted as new, more up-to-date products come into the marketplace and supersede them. It is essential, for example, that inventory levels are not held at very high levels in order to avoid high and costly wastage due to product obsolescence.

There are four stages to the product life cycle – introductory, growth, maturity and decline – all of which have relevance to logistics, including implications for inventory holding and replenishment. The product life cycle was discussed in the final sections of Chapter 6 (see particularly Figure 6.4).

Key implications for logistics and particularly for inventory include:

- setting suitable initial stock levels at the introductory stage
- the importance of stock availability at the introductory stage
- the danger of overstocking if a product doesn't take off
- the danger of losing business if a product is understocked at the early stages
- the need for cost-effective logistics and inventory levels at the growth stage
- care not to overstock in the maturity stage due to competitive and substitute products competing in the market
- avoiding obsolescence costs by minimizing stock in the decline phase

Alternative forecasting and modelling approaches that can be used to assist in life cycle inventory planning include input–output models, simulation models and life cycle models.

Accuracy and level of forecasting

Another important aspect of forecasting is measuring how accurate the forecast is. In this regard, there are various measures. For example, bias can be measured (e.g. the forecast always tends to be too high or too low) and error can be measured. Measures include:

- MAD: mean absolute deviation
- MSE: mean square error
- MPE: mean percentage error
- MAPE: mean absolute percentage error

Another point about forecasting is that where there are numerous combinations of options for an item (e.g. a car can have various body colours, trim colours, automatic or manual gearbox, air conditioning, etc) then it may be best to forecast at car type level and then split by percentages (based on historic demand, for example) for each of these options. This is often preferable to regarding each possible combination as an SKU and trying to forecast at SKU level.

Product groups or product lines may be categorized by demand pattern in order to determine the most suitable forecasting algorithm. One common method is to show a chart with demand volatility on one axis and demand frequency (i.e. interval between demands) on the other. All SKUs are then plotted on this chart. Often, a 2×2 matrix is then used to identify, say, four different algorithms.

An approach to demand forecasting

It is sensible to adopt a very methodical approach to demand forecasting. To achieve this, it is recommended that a number of key steps are used. These can be summarized as follows:

- 1 Plan. Ensure from the outset that there is a clear plan for identifying and using the most appropriate factors and methods of forecasting. Understand the key characteristics of the products in question and the data that is available. Consider the different quantitative and qualitative methods that can be used and select those that are relevant. If necessary and feasible, use a combination of different methods. Identify ways of double-checking that the eventual results are meaningful – it is unsafe merely to accept the results of a mechanical analytical process.

Forecasting at individual SKU level is a typical ‘bottom-up’ approach, so check results with suitable ‘top-down’ information.

- 2 Check. Take care to review the base data for accuracy and anomalies. Poor data that is analysed will produce poor and worthless results. Where necessary, ‘clean’ the data and take out any abnormalities.
- 3 Categorize. A typical range of company products can and do display very different characteristics. Thus, it is usually necessary to identify key differences at the outset and group together products with similar characteristics. It is likely to be valid to use different forecasting methods for these product groups. Use techniques such as Pareto analysis to help identify some of the major differences: high versus low demand, high versus low value, established products versus new products, etc.
- 4 Metrics. Use statistical techniques to aid the understanding of output and results (standard deviation, mean absolute deviation, etc). There may be a number of relevant issues that can impact on the interpretation of results: the size of the sample, the extent of the time periods available.
- 5 Control. Any forecasting system that is adopted needs to be carefully controlled and monitored because changes occur regularly: popular products go out of fashion and technical products become obsolete. Control should be by exception, with tracking systems incorporated to identify rogue products that do not fit the expected pattern of demand and to highlight any other major discrepancies and changes.

Inventory planning for manufacturing

MRP I and II

Key developments in inventory planning are aimed at solving some of the problems encountered by the use of the more traditional approaches to stock replenishment. They are based on the concept of *materials requirements planning* (MRP), which is a computerized system for forecasting materials requirements based on a company’s master production schedule and bill of material for each product. This has subsequently been developed into *manufacturing resource planning* (MRP II), which is a broader-based system, used to calculate the time-phased requirements for components and materials with respect to production schedules, taking into account replenishment lead times, etc. This approach enables inventory levels to be significantly reduced, and service levels, in terms of shorter production lead times, to be improved. MRP systems are now quite well established, as are other related techniques such as ‘just-in-time’ (JIT) or kanban systems (see Chapter 13).

DRP, ERP and SCP

The obvious advantages of MRP and JIT systems to manufacturing have led to the further development of associated techniques for distribution – *distribution requirements planning* (DRP). DRP systems are designed to take forecast demand and reflect this through the distribution system on a time-phased requirements basis. DRP thus acts by pulling the product through the distribution system once demand has been identified. It is particularly useful for multi-echelon distribution structures to counter the problems of requirements occurring as large chunks of demand (see the Forrester effect, described in Chapter 15).

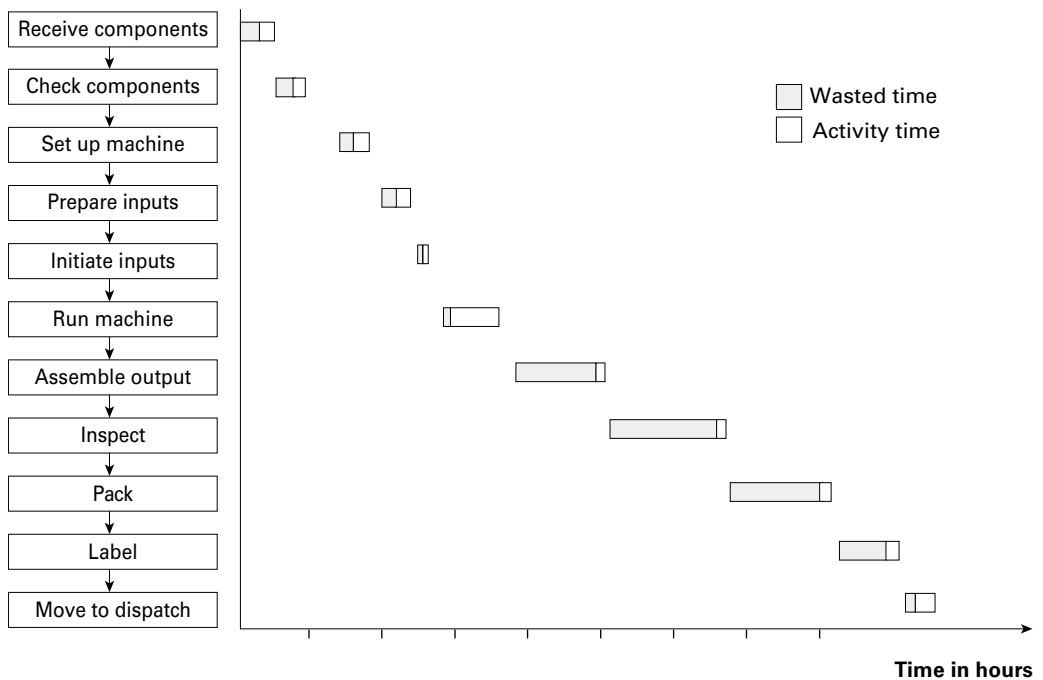
The most recent systems adopt an even broader planning approach. These are time-phased and enable planning across a whole business and even across complete supply chains. They are known, respectively, as *enterprise resource planning* (ERP) and *supply chain planning* (SCP).

These systems are also discussed in Chapters 13 and 40.

Time compression

The concept of *time compression* is an important approach in the planning of manufacturing inventory requirements, or perhaps it should be termed as the planned reduction in manufacturing and WIP inventory. The opportunities for such reductions have been illustrated in Chapter 16 in the discussion on analysing time and inventory, where the use of supply chain mapping enables the identification of feasible time and inventory savings. Time compression techniques provide the means for achieving these improvements. Factors that need to be considered when planning a time compression study include:

- The need to take a complete supply chain perspective when planning: beware sub-optimization.
- The need to undertake appropriate analysis: as with many logistics studies, much time and effort has to be invested in the data collection, validation and analysis stages.
- The identification of unnecessary inventory and unnecessary steps in key processes: this is where savings and improvements of real value can be found.
- Working towards customer service requirements as well as cost minimization when planning for production.
- Designing products to be compatible with supply chain requirements: it can be very difficult to achieve this in some companies that have a strong, traditional manufacturing base.

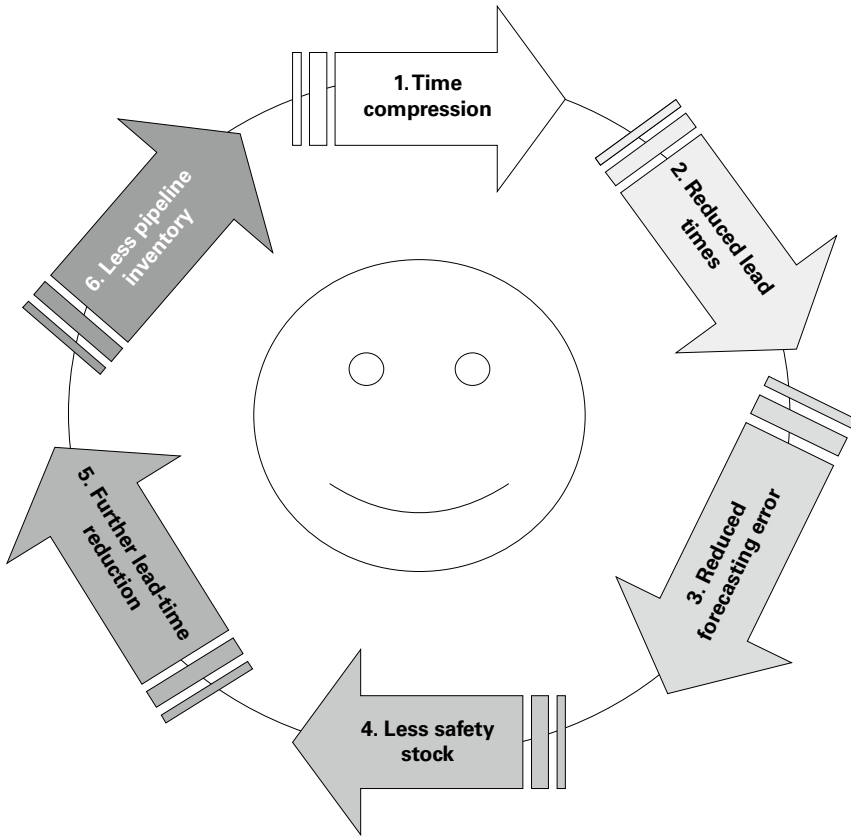
Figure 17.4 Time-based process mapping

- Designing production processes to be compatible with supply chain requirements: the ability to postpone processes until later in the supply chain can lead to significant inventory reduction.

Time compression can be a relatively simple exercise to undertake but the benefits can be quite considerable. A typical approach could be as follows:

- Supply chain mapping can be used as the starting point to help identify the major opportunities for time and inventory saving.
- The next stage is then to 'walk the process', taking care to follow and record every detailed step in the process.
- Each activity is then measured according to the total time, including both 'value-added' time and 'wasted' time (see Figure 17.4).
- The process is then reassessed or re-engineered to eliminate as much wasted time as is possible.

Time, and thus inventory, is taken out of the system and in this way overall cost is reduced. Time compression is a technique that provides a means to identifying and improving processes that can lead to a number of potential benefits. It is a way of creating a 'virtuous circle' of improvement that can include shorter lead times, better forecasting and reduced inventory, as illustrated in Figure 17.5.

Figure 17.5 The virtuous circle of time compression

Inventory planning for retailing

In recent years, power within most supply chains for consumer products has lain very firmly in the hands of retailers rather than manufacturers. This has applied to all but the strongest brand names. The development of internet and home shopping has had little if any impact in changing this. Many retailers have tended to outsource their distribution and logistics activities but, although this continues to be the case, retailers are now taking a much closer interest in the impact that an effective logistics operation can have on their overall service offering – and consequent company profitability. This applies to distribution and also particularly to inventory management policy and practice.

Inventory management at distribution centre (DC) level for both retail national distribution centres (NDCs) and retail regional distribution centres (RDCs) poses

similar problems to those experienced by manufacturers. At the retail store, however, inventory requirements can be quite different, depending on the product availability strategy and the merchandising policies that are used. New types of inventory management systems have been developed to cater specifically for these different requirements. Some of these approaches have significant similarities, but the overall aim is to promote the greater visibility of information within the supply chain, to enable inventory to be reduced and to enhance customer service in terms of product availability. The main planning techniques are as follows.

Vendor-managed inventory (VMI)/co-managed inventory (CMI)

Vendor-managed inventory is where the manufacturer is given the responsibility for monitoring and controlling inventory levels at the retailer's DC and in some instances at the retail store level as well. Specific inventory targets are agreed, and it is the responsibility of the manufacturer to ensure that suitable inventory is always available. Such arrangements depend on accurate and timely information, and suitable computerized systems have become available in recent years. The main advantage for retailers lies in the reduction of operating costs and also the delay in payment for the products in question. For manufacturers, it is suggested that running a VMI system for a retailer provides the opportunity to develop a much closer, and hopefully more binding, relationship with the retailer as well as giving a much better visibility of real demand. This can make the planning of production much easier and can lead to significant reductions in inventory holding right through the supply chain. However, it can also make it more difficult for the retailer to change suppliers. Co-managed inventory (CMI) is similar to VMI but with CMI the inventory replenishment order is confirmed by the retailer.

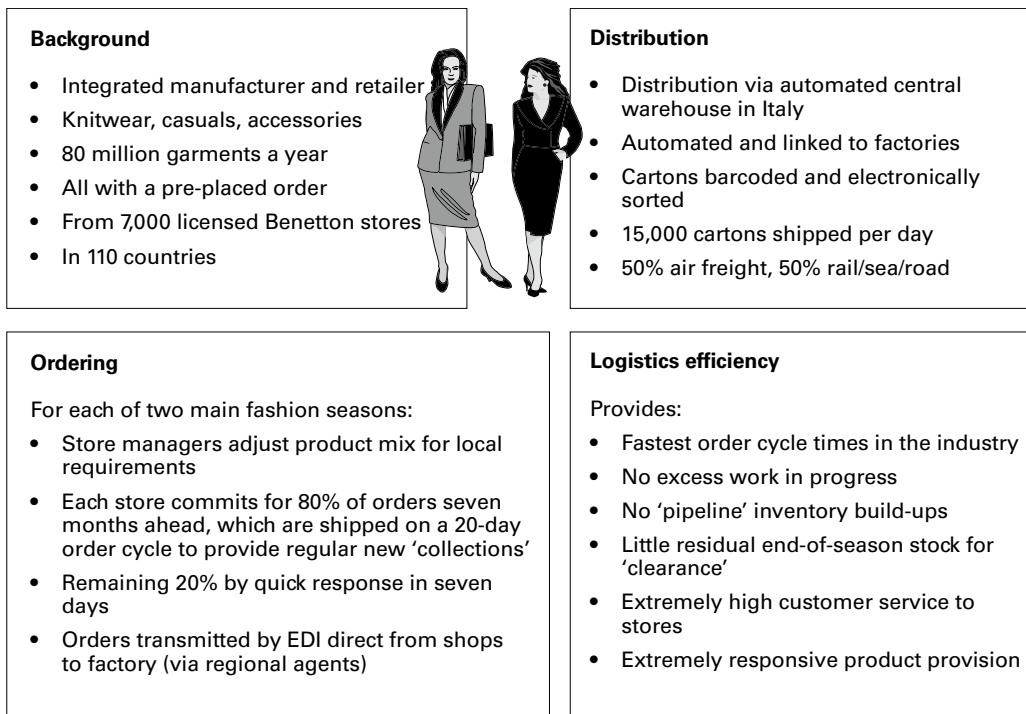
Continuous replenishment programme (CRP)

The aim with CRP is to develop free-flowing order fulfilment and delivery systems, so that pipeline inventories can be substantially reduced. Such systems use up-to-the-minute point-of-sale information (via electronic point-of-sale – EPOS – systems) to identify real-time demand and to pull product through directly from the supplier, through the DC and on to the retail outlet. CRP systems are thus able to synchronize this flow of product by focusing on end user requirements via the use of real-time demand, linked to flow-through distribution systems that allow for cross-docking, store-ready packaging and automated handling. Once again, pipeline inventory is kept to a minimum or completely eliminated.

Quick response (QR)

A further development of the JIT approach is that of quick response (QR). Here the aim is to link the manufacturer more closely to the actual demand at the retail level. There are strong similarities with continuous replenishment systems, but with QR the emphasis is on time compression and the opportunity for the manufacturer to redesign production operations to allow for a 'little and often' approach to resupply. Short production changeovers and small batch sizes enable the manufacturer to respond to changes in demand in a very short timescale. A classic example is the Benetton operation, particularly in its initial composition. This demonstrated most of the key characteristics of a QR system. It has allowed the company to offer an extremely responsive supply to its retail outlets and to reflect the fast-changing nature of the fashion industry. Figure 17.6 provides more information.

Figure 17.6 The Benetton Group: initial quick response system



Efficient consumer response (ECR)

This is another concept that uses the most recent advances in information technology to allow a streamlined approach to the supply of products to retail stores. ECR

was originally set up and run in the United States with the aim of improving service and reducing costs in the grocery industry by focusing on the efficiency of the supply chain as a whole rather than on individual components in individual companies. The goal of ECR is therefore to develop a customer-driven system that works across the supply chain. One original definition is still very applicable today: ECR consists of:

A seamless flow of information and products involving manufacturers and retailers working together in joint planning and demand forecasting. Both sides might take on functions traditionally handled by the other if they can do it better and at a lower cost.

ECR combines a number of different concepts and strategies. The basic tenets of ECR are:

- a heavy use of electronic data interchange (EDI) for exchanging information with suppliers
- an extremely efficient supply chain using cross-docking and direct store deliveries, thus keeping inventory holding to a minimum
- the use of sales-based ordering, notably through continuous replenishment programmes (CRP)
- much greater cooperation with suppliers, using where appropriate, co-managed inventory (CMI) or full vendor-managed inventory (VMI)

There are four key strategies in the use of ECR. These are store replenishment, store assortment (ensuring the right mix of products in the store to maximize consumer satisfaction), promotion and new product introduction. It is, however, the first two of these – speedier replenishment and better store assortment – where the greatest benefits are to be found in both cost reduction and service improvement. Some of the key factors and their associated benefits include:

- automated systems that reduce labour and administrative costs
- sharing information, which leads to more timely deliveries and falling inventory levels at the store
- cross-docking, which reduces inventory levels at the DC
- concentrating on fewer suppliers, which reduces transaction and administration costs
- offering the right products to the right customers, which increases volume sales and economies of scale
- more timely, more accurate information, which means that customer needs are more fully addressed
- the ability to tailor the products and services on offer in the store, which allows a company to take account of local preferences

- rapid replenishment, which can reduce stockouts, and means that customers seeking a particular product or brand will not leave empty-handed

A common approach for the implementation of ECR by a retailer is to focus on the consumer and then to develop a particular IT strategy and capability. This is likely to include the use of EDI, EPOS, computer ordering, computer routeing, etc. It is important to create a climate for change and to re-engineer existing business practices, as they are unlikely to be adequate for the successful implementation of ECR. The next requirement is to develop a responsive replenishment strategy jointly with key suppliers for key products. Finally, a workable flow-through distribution operation must be planned and implemented. A typical flow-through operation is likely to involve:

- *Pre-distribution identification*: vendors pick, sort and pre-label final orders using barcodes.
- *Automated cross-docking*: this will require conveyors, diversion lines and barcode readers.
- *A disciplined appointment-scheduling procedure*: inbound receipt scheduling will need to match available labour and minimize vehicle waiting.
- *New facility design*: this should ideally include shipping doors around the circumference of the building. The use of conveyors will eliminate put-away and picking.
- *Floor-ready merchandise*: suppliers should provide tags and labelling to reduce DC and retail store work and handling.

Category management (CM)

This has been developed to provide greater support for product and inventory control and management. It is essentially a means of categorizing products into 'families' that have very similar characteristics in terms of their selling profile. Thus, SKUs from very different product groups may be categorized together and their inventory holding planned in the same way because they have the same order or usage patterns. Typical examples of these categories are:

- *Vital and expensive*: products that require close control and monitoring. Supply sources need to be reliable, and delivery performance must be consistently good. A continuous stock review policy should be applied to products in this category.
- *Desirable and expensive*: inventory should be held at minimum levels and a continuous stock review policy should be applied.

- *Vital and inexpensive*: these should be stocked at maximum levels, and a reliable source of supply should be substantiated. Delivery performance should be carefully monitored. A weekly periodic stock review policy should be used.
- *Desirable and cheap*: hold maximum stock levels and use a monthly periodic stock review policy. Keep order frequency to a minimum number of times per year.
- *Common usage spares*: hold stocks at reasonable levels and use a monthly periodic stock review policy.

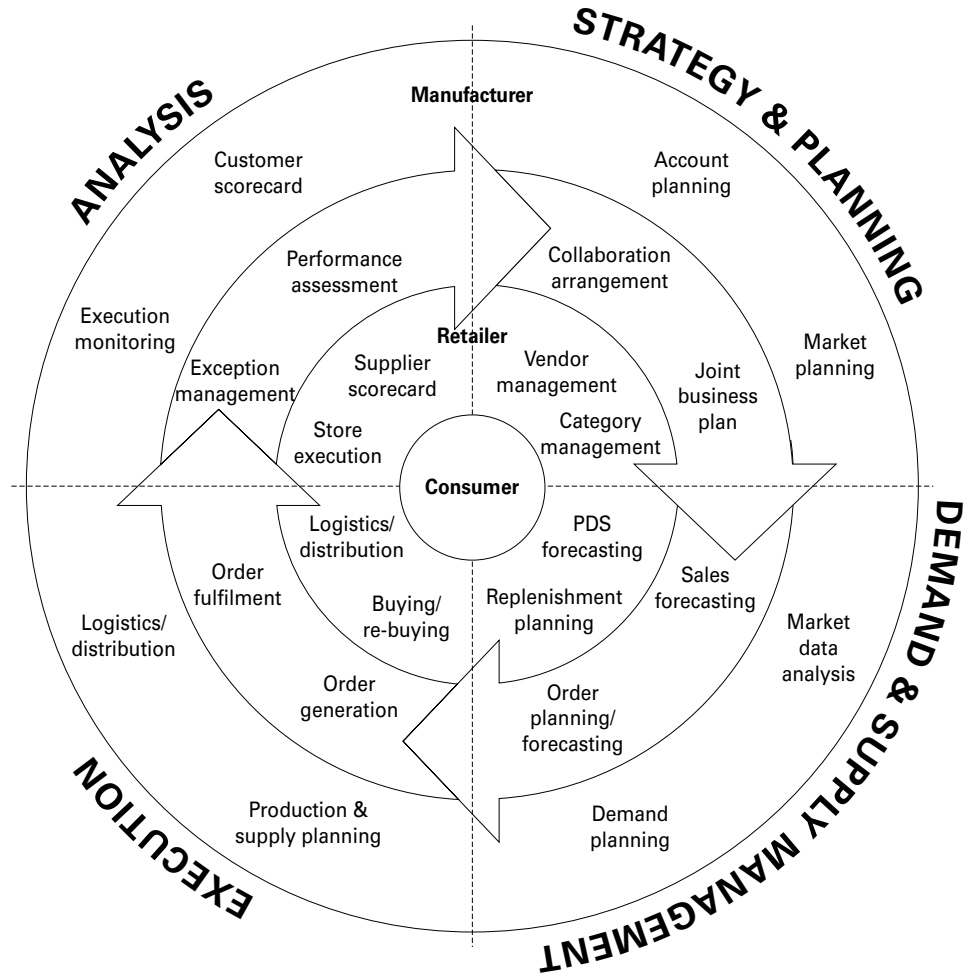
Note that this approach takes account of the important factor that product requirements can vary considerably between one product and another. Inventory planning using category management caters for this. Companies that do not recognize this and adopt a ‘one-size-fits-all’ approach to inventory planning are likely to suffer either high-cost or low-availability issues for some of their portfolio of products.

Inventory planning for the supply chain

Some of the inventory-planning techniques previously described in the manufacturing and retailing sections of this chapter have reflected the advantages of being able to take a broader, supply chain view of demand and inventory requirements. This section briefly describes some additional approaches that use this as their central proposition, but which do not have a specific leaning towards either manufacturing or retailing.

Collaborative planning, forecasting and replenishment (CPFR)

Collaborative inventory management has been developed as a long-term approach to minimizing the type of demand amplification illustrated by the Forrester effect (see Chapter 15, Figure 15.6). This requires end-to-end coordination of activities across the different echelons of the supply chain and combines multiple trading partners in the planning and fulfilment of customer demand. Sales and marketing best practice (e.g. category management) is linked to supply chain planning and operational processes to increase product availability at the same time as minimizing inventory and logistics costs. A general framework is used to help the retailer/buyer and manufacturer/seller to work together to satisfy the demand of the customer. This is known as collaborative planning, forecasting and replenishment (CPFR) and, as Figure 17.7 demonstrates, there are four main areas for collaboration:

Figure 17.7 CPFR model

- *strategy and planning*: identifying and agreeing the overall rules for the collaboration, including product mix and placement, and event plans
- *demand and supply management*: the forecasting of consumer demand derived from point-of-sale information and replenishment requirements
- *execution*: the placing of orders, delivery shipments, restocking of products on shelves, etc – these are all of the events in the ‘order to cash’ cycle
- *analysis*: monitoring of exception orders, calculating key performance indicators (KPIs) and assessing continuous improvement opportunities

Supply chain inventory optimization

Inventory optimization is a scientific approach to determine the ideal inventory levels across a complete supply chain, that is, across different company thresholds. The aim is to identify the most effective inventory locations and stock levels for the supply chain as a whole. For example, traditionally, where a product moves from one company to another within a supply chain there is often evidence of two large adjacent stock builds: where the goods leave the supplier and where they arrive at the customer. This is due to a variety of factors, such as unreliable supply, a lack of confidence, uneven demand patterns and poor information on the real demand requirements for the finished product. An inventory-optimization approach can reduce these unnecessary inventory levels without damaging service levels.

This type of approach has become feasible because of the extent of data that is now available and the ability of computer systems to analyse such large quantities of data. This multi-echelon software can optimize inventory levels across the whole supply chain, taking into account the multiple stages in the supply chain, different types of inventory and time-phased demand. This type of modelling is, generally, undertaken at SKU level and the results can reflect the different inventory requirements for products at the various stages of the supply chain and the demand for the same SKU in different geographic locations.

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PART FOUR

Warehousing and storage

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Principles of warehousing

18

Introduction

Warehouses are crucial components of most modern supply chains. They are likely to be involved in various stages of the sourcing, production and distribution of goods, from the handling of raw materials and work-in-progress through to finished products. As the dispatch point serving the next customer in the chain, they are critical to the provision of high customer service levels. Furthermore, owing to the extensive land and buildings occupied, the number of staff involved and the nature of the, often highly automated, equipment required, warehouses are one of the most costly elements in many supply chains. Their successful planning and management is therefore critical in terms of both service and cost.

The nature of warehouses within supply chains may vary tremendously, and there are many different types of classification that can be adopted, for example, by:

- *stage in the supply chain*: materials, work-in-progress, finished goods or returned goods
- *geographic area*: for example, a global warehouse may serve the whole world, a regional warehouse may serve a number of countries, a national warehouse may serve just one country, or a local warehouse may serve a specific region of a country
- *customer type*: for example, a distribution centre for serving stores or an e-fulfilment centre for internet customers
- *product type*: for example, small parts, large assemblies (e.g. car bodies), frozen food, perishables, security items and hazardous goods
- *function*: for example, inventory holding or sortation (e.g. as a 'hub' of a parcel carrier)
- *ownership*: owned by the user (e.g. the manufacturer or retailer) or by a third-party logistics company
- *company usage*: for example, a dedicated warehouse for one company, or a shared-user warehouse handling the supply chains for a number of companies

- *area*: ranging from 100 square metres or less to well over 100,000 square metres
- *height*: ranging from warehouses about 3 metres high through to ‘high-bay’ warehouses that may be over 45 metres in height
- *equipment*: from a largely manual operation to a highly automated warehouse

The role of warehouses

The prime objective of most warehouses is to facilitate the storage and movement of goods through the supply chain to the end consumer. While there are many techniques used to reduce the need to hold inventory, such as flexible manufacturing systems and just-in-time (JIT), it is often necessary to accumulate goods in warehouses, particularly where the following two conditions apply:

- *The demand for the product is continual.* In some industries, such as fashion, a particular style may be manufactured on a one-off basis. Under these circumstances, the goods can be ‘pushed’ through the supply chain to the stores where they are sold, and there is therefore no need to hold inventory in warehouses. However, most goods are offered for sale on a continual basis and therefore they need to be ‘pulled’ through the supply chain based on customer demand.
- *The supply lead time is greater than the demand lead time.* Where goods are ‘pulled’ through the supply chain, this can only be achieved without inventory where the supply can take place within the lead time offered to the customer. For example, if goods are offered to customers on a next-day-delivery lead time, it is often the case that materials cannot be sourced, goods manufactured and transport undertaken within this timescale. In this situation, the goods must be supplied from inventory.

Inventory is therefore often essential to smooth variations between supply and demand. In addition, even when the full cost of inventory is taken into account (see Chapter 15), it may be more cost-effective to build up inventory so as to reduce costs elsewhere in the supply chain. Examples of this may be to enable manufacturing economies of scale, to obtain purchasing discounts for large quantity orders, to build seasonal stock in advance, and to cover for production shutdowns. Also, inventory may be held just in case specific undesired events occur in the future, as with humanitarian aid supplies (e.g. tents and blankets), pandemic preparations (e.g. personal protective equipment: PPE) and power station spares (e.g. steam turbine rotors).

Where inventory is required, then the decision needs to be taken as to the optimum point to hold it in the supply chain. This may be related to the ‘decoupling point’ concept explained in Chapter 16, whereby strategic inventory is held to enable ‘lean’ manufacturing or supply to be undertaken upstream in the supply chain, while

an 'agile' response may be given to volatile downstream marketplaces. Holding inventory upstream enables the form and location of goods to be postponed as long as possible, thus reducing inventories, while holding the inventory downstream is often necessary to be able to respond rapidly to customer demands.

The combination of global supply chains (which tend to have long lead times and be liable to disruption) and increasingly volatile markets has resulted in substantial strategic inventory holdings becoming necessary. This trend has been further compounded by product range proliferation, resulting in inventories of many different product lines being required. Thus, although great steps have been taken to improve supply chain management, particularly as regards the minimization of inventory, in many companies the levels of inventory have remained static or increased.

The holding of inventory is just one of a variety of roles that a warehouse may perform. Thus, with the increasing emphasis on the movement of goods through the supply chain, many of the roles may be related to the speed of movement as well as to inventory holding. The following list highlights some of the common roles performed:

- *Inventory holding point.* This is commonly associated with the decoupling point concept as mentioned above, the holding of critical parts in case of breakdown or acting as a repository (e.g. for archive records or personal effects).
- *Consolidation centre.* Customers may order a number of product lines rather than just one, and would often prefer these to be delivered together. The warehouse may perform the function of bringing these together, either from its own inventory holdings or from elsewhere in the supply chain.
- *Cross-dock centre.* If goods are brought from elsewhere in the supply chain (e.g. directly from manufacturers or from other warehouses) specifically to fulfil a customer order, then they are likely to be cross-docked. This means that the goods are transferred directly from the incoming vehicle to the outgoing vehicle via the goods-in and -out bays, without being placed into storage.
- *Sortation centre.* This is basically a cross-dock centre, but this term tends to be used for parcel carrier depots, where goods are brought to the warehouse specifically for the purposes of sorting the goods to a specific region or customer. A similar operation occurs in the case of fashion goods being 'pushed' out to stores, whereby goods are brought to a warehouse solely for the purpose of sorting into vehicle loads.
- *Assembly facility.* This is often useful in postponing production as far as possible down the supply chain in order to minimize inventories. The warehouse may thus be used as the final assembly point for the product, involving activities such as kitting, testing, cutting and labelling.

- *Trans-shipment depot.* This is commonly used to serve outlying regions of a country. In a typical scenario, orders would be picked at a national distribution centre and transported to a 'stockless' trans-shipment depot, where the goods are sorted to smaller vehicle loads for immediate delivery to customers.
- *Returned goods centre.* This is typically for returned goods (particularly in the case of internet shopping) but may also be used for goods at end-of-life (e.g. to recover precious metals from electronic goods) or for the recycling of packaging and transit assets (such as trays).

Warehouses often fulfil a mix of these different roles, and it is important to be clear as to the precise roles being performed. There is now a wide range of names given to warehouses, and many of these names reflect the different roles that they perform. Some of these names include: supplier consolidation centre, JIT sequencing centre, customer service centre, fulfilment factory, e-fulfilment centre and 'dark store'.

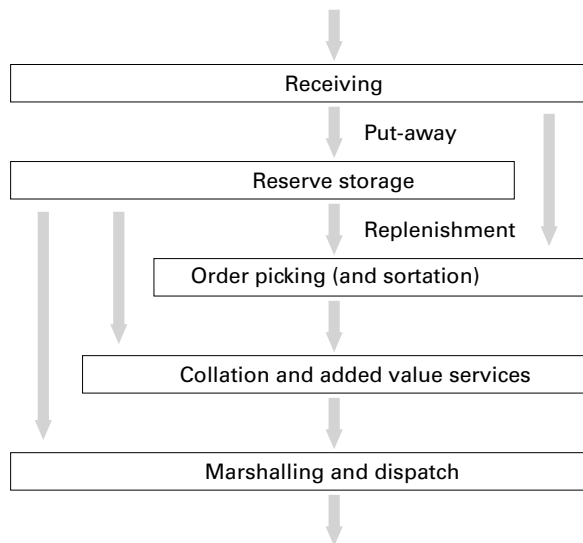
There is sometimes a distinction made between 'warehouses' and 'distribution centres'. In this book, 'warehouse' is used as a generic term to cover all of the roles listed above in all stages of the supply chain while 'distribution centre' is taken to mean warehouses within the downstream supply chain (i.e. after manufacturing).

Warehouse operations

Every warehouse should be designed to meet the specific requirements of the supply chain of which it is a part. Nevertheless, there are certain operations that are common to most warehouses. These tend to apply whether the warehouse is manual by nature with fairly basic equipment or whether it is highly automated with sophisticated storage and handling systems. For an inventory-holding warehouse, typical warehouse functions and material flows are shown in Figure 18.1.

These functions are as follows:

- *Receiving.* This typically involves the physical unloading of incoming transport, checking against what is expected and recording the incoming goods into the computer system. It can also include such activities as unpacking and repackaging in a format suitable for the subsequent warehouse operations. Quality control checks may be undertaken as part of this activity. From here, the goods are then put away in the warehouse, either to reserve storage or directly to a picking location.
- *Reserve storage.* Goods are normally taken to the reserve storage area, which holds the bulk of warehouse inventory in identifiable locations. When required, the goods are taken from reserve storage either directly to marshalling (if, for example, a full pallet is required by a customer) or to replenish a picking location.

Figure 18.1 Typical warehouse functions in a stockholding warehouse

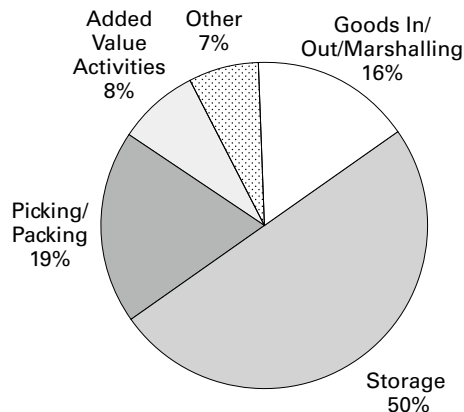
- *Order picking.* When an order is received from a customer, goods need to be retrieved from the warehouse in the correct quantity and in time to meet the required service level. An order will frequently contain a number of order lines, each requesting a specific quantity of an individual product line. If the order line is for a full unit load (e.g. pallet) then this can be retrieved directly from the reserve storage area. However, if the order line is for less than a unit load (e.g. a number of cases or items) then the goods will normally be retrieved from the picking location. If only small quantities of a product are stored in a warehouse, then the reserve and picking stock may be combined, and goods picked from this consolidated area. Order picking is a key warehouse operation, both in terms of cost and service, as a significant proportion of the warehouse staff is normally required for this function and it is critical to achieving high levels of order accuracy.
- *Sortation.* For small sizes of order, it is sometimes appropriate to batch a number of orders together and treat them as 'one' order for picking purposes. In this case, the picked batch will have to be sorted down to individual orders before dispatch.
- *Collation, added-value services and packing.* Goods need to be collated into complete customer orders ready for dispatch. Unless the goods are picked directly into the dispatch containers (e.g. directly into roll-cages or into cartons), they will be assembled or packed together after picking. For example, the goods may be passed to a packing station where they are packed into a carton. These may in

turn be stretch- or shrink-wrapped on to a wooden pallet ready for transit. This process may also involve final production postponement activities and value-added services, such as kitting, labelling, print-on-demand (for books) and 3D printing.

- *Marshalling and dispatch.* Goods are marshalled together to form vehicle loads in the dispatch area and are then loaded on to outbound vehicles for onward dispatch to the next 'node' in the supply chain (e.g. to a trans-shipment depot or to a freight forwarder's depot for groupage/consolidation). Although inherently a dispatch area, returned goods for recycling, refurbishment or disposal may be received back in this area, in the receiving area or in a specialist returned goods area (or to a separate returns warehouse).

The typical split of floor areas used for these functions is shown in Figure 18.2. Storage generally takes up the largest proportion of the warehouse area, and frequently uses a greater height section of the building (i.e. storage being undertaken in 'high-bay' buildings and other activities in 'low-bay' buildings). The percentage figures on picking and packing are shown together, as sometimes these activities are combined. These two activities typically take up a smaller but important floor area, as do the goods receiving, marshalling and dispatch activities. It is interesting that added-value services often take up little space, but this is frequently because they are an integral part of the picking and packing activities (e.g. price ticketing may be undertaken at the same time as packing).

Figure 18.2 Floor area usage



SOURCE Baker and Perotti, 2008

As mentioned earlier, the holding of inventory is not the only role of a warehouse. Some warehouses act as cross-dock or trans-shipment points and, in these situations, there is no reserve storage function. Such warehouses include parcel sortation

centres, fashion garment sortation centres (where garments may be imported already destined for particular shops) and perishable goods centres (where perishable food items may be immediately sorted to their destinations). A simplified material flow is typical of such warehouses, involving just three main areas:

- *Receiving.* Goods may be received in a condition ready for immediate dispatch to the customer or may require labelling or some other form of activity.
- *Sortation.* The goods then need to be sorted to their destinations. This may be undertaken manually or by the use of high-speed sortation equipment. In the case of the latter, the incoming goods may be already barcode-labelled by the sender so that they can be put directly on to the sortation machine and automatically sorted into specific customer orders or destinations.
- *Marshalling and dispatch.* The goods are then marshalled into vehicle loads and loaded on to the vehicles. In the case of parcels, the warehouse may be equipped with boom conveyors that extend directly into the vehicles.

It should be noted that many warehouses act both as a stockholding and cross-docking point. For example, a regional distribution centre for a food retailer may pick some goods from inventory and combine these with cross-docked perishable items and then dispatch all of these goods to the retail store in the same vehicle.

Costs

As noted in Chapter 1, warehousing typically accounts for about 20 to 25 per cent of logistics costs, while the carrying costs for the inventory within them account for a further 20 to 25 per cent. Together, these represent a very significant sum for many companies.

The detailed breakdown of warehouse costs varies by the nature of the operation, but typical figures from past studies of ‘conventional’ warehouse operations (e.g. adjustable pallet racking served by reach trucks with case picking at ground level) are as follows:

- staff: 45–50 per cent, with half of this often represented by order picking and packing staff
- building: 25 per cent, including rent or depreciation on the building
- building services: 15 per cent, including heat, light, power, building maintenance, insurance and rates
- equipment: 10–15 per cent, including rental or depreciation, equipment maintenance and running costs
- information technology: 5–10 per cent, including systems and data terminals

These figures demonstrate the importance of the effective use of both building space and staff in the design and operation of warehouses. In terms of staffing, the efficiency of the order-picking operation is particularly significant.

It should be noted that for warehouses that are highly automated (e.g. with automated storage and retrieval systems, conveyors, sorters, autonomous mobile robots and robotic picking equipment) the equipment costs would be substantially higher than shown above. Similarly, information systems may involve very complex functionality (e.g. advanced algorithms, artificial intelligence, and communications systems) and therefore may also represent a very significant proportion of costs.

Packaging and unit loads

Most goods that pass through a warehouse are packaged. This may be, for example, to contain the product, protect or preserve it, improve its appearance, provide information or facilitate storage and handling. Frequently, this packaging is at a number of different levels, such as directly enclosing the product (i.e. primary packaging), containing a number of primary packages (i.e. secondary packaging), or some form of outer packaging (normally to facilitate transport and handling).

The nature of packaging is very important for warehousing operations, particularly as customers may require the goods at any of these levels. Thus, some customer orders may be for individual items (e.g. loose or in their primary packaging), for cases of goods (e.g. containing a number of items) or at some greater quantity (e.g. a full pallet load of goods). In the case of internet fulfilment operations, a very large packing operation is often required to pack multiple individual items in cartons or smaller packages. The warehouse operation must be designed so that any of the order quantities that are offered to customers can be picked, packed and dispatched cost-effectively.

Most supply chains are structured around the unit load concept, whereby goods are transported, stored and handled in standard modules. This may occur at different levels, for example with goods being placed in cartons, which are placed on pallets, which in turn may be loaded in ISO containers for export shipping. The use of such unit loads enables transport, storage and handling systems to be designed around modules of common dimensions. In warehousing, some of the most frequently used unit loads are as follows:

- *Pallets.* These are the most common form of unit loads stored in warehouses. They are basically raised flat platforms, on which goods can be placed, and into which truck forks can be inserted to lift and move them. The entry for the forks can be on all four sides, known as four-way entry pallets, or just on two sides, known as two-way entry pallets. Most are made of wood, although some are constructed of plastic or fibreboard. The type of material determines, for example: their durability,

weight and rigidity; to what extent they are reusable or repairable; and whether they are subject to international transport regulations (due to possible pests in wooden pallets). Goods are often secured onto pallets by means of tape, strapping, stretch-wrapping (where a plastic film is wound around the pallet, manually or automatically) or shrink-wrapping (where plastic film is heated and then shrinks to the contours of the goods). There are various standard sizes of pallets in different parts of the world and for use in different industries. These variations can cause problems both in terms of international transport and in the design of racking equipment to hold various size pallets that may occur in a particular warehouse. In continental Europe the most common type is the Europallet (1,200 mm × 800 mm), whereas in the UK the standard size is slightly larger (1,200 mm × 1,000 mm), similar in size to that in the United States (48 in × 40 in, i.e. 1,219 mm × 1,016 mm). There are a number of pallet pools in operation that facilitate the exchange of pallets between companies and reduce the need for repositioning. Other types of unit load may also be covered by these pools.

- *Cage and box pallets.* These are used to contain irregular-sized goods that may otherwise fall off a standard pallet. They have solid or mesh sides and may be constructed of, for example, steel or plastic. They can be picked up by a fork-lift truck and can often be stacked on top of each other.
- *Stillage.* This is a generic term that is often, but not always, applied to steel unit loads, as in the case of steel cage pallets mentioned above. They can normally be lifted from beneath by a fork-lift truck and they either contain the goods by means of mesh (or solid) sides or act as a frame, for example, with posts on each corner. Specialist stillages are used for holding such goods as tyres, long pipes, casks of beer and sheets of glass.
- *Roll-cages.* These are normally constructed of steel and often comprise mesh bottom, sides and shelves. Wheels are fitted to each corner so that the roll-cages can be pushed. Alternatively, forks can be inserted under the base so that they can be moved by a pallet truck. They are commonly used in retail distribution both for order picking and for delivery to shops.
- *Tote bins.* Plastic tote bins are used in many warehouses for the storage and handling of small items. They vary in size but a typical bin may be 600 mm long × 400 mm wide × 300 mm high. They may be open top or have a closable lid, and can hold a number of items or boxes within them. In industrial contexts, they may be made of steel.
- *Dollies.* These comprise bases fitted with wheels, on which plastic trays and tote bins may be stacked. Again, these are common in retail distribution.
- *Intermediate bulk containers (IBCs).* These are normally used for storing and transporting liquids and solid particulate products in unit loads of about one or two tonnes. They thus offer an alternative to bulk handling for such products.

IBCs may be rigid (e.g. stainless steel containers for holding liquids) or may be flexible (e.g. bulk bags for granules). Depending on their nature, they may be lifted by fork-lift truck either from the bottom or from straps on the top. Some can be block stacked, one on top of the other.

The most significant unit load in warehousing is the wooden pallet, and storage/handling systems specifically designed for this type of load are examined in Chapter 19. Systems for non-palletized loads are then covered in Chapter 20.

Storage and handling systems (palletized)

19

Introduction

The wooden pallet is the most common unit load used in warehouses. It is a convenient-sized load for moving goods around the warehouse and for the storage of goods. The goods often arrive already on pallets, but even where this is not the case, as occurs frequently with loose-loaded ISO shipping containers, then the goods may be palletized at the goods receiving area ready for put-away to storage. The use of wooden pallets enables standard storage and handling equipment to be used, irrespective of the nature of the goods on the pallet. The exact nature of the equipment will be determined by such factors as the throughput levels, inventory holdings and the requirements of the wider supply chain. The various types of storage and handling equipment available for palletized goods are explored in this chapter.

Pallet moving equipment

There is a wide range of equipment available for moving pallets around a warehouse, from simple manual aids to sophisticated computer-controlled equipment. Some of the most common types are as follows:

- *Hand pallet truck.* This is a truck with two forks that will fit into the slots of a pallet. The forks can be raised slightly by a simple pump action to lift a pallet off the floor. The truck can then be pulled manually and the pallet deposited at the required floor location in the warehouse. It is useful for infrequent movements over short distances.
- *Powered pallet truck.* This is similar to the above, except that it is battery-powered. The trucks may be pedestrian-controlled or may have a platform or a seat for the operator to stand or sit on.

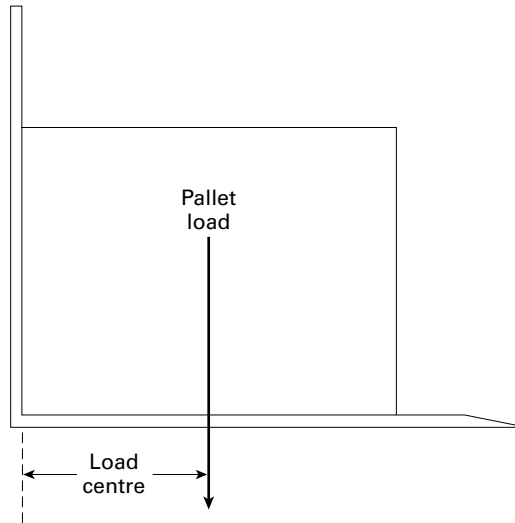
- *Tugs and tractors.* For long horizontal movements, a tug may be used, towing a number of trailers loaded with pallets. This reduces the number of journeys that need to be performed. Tugs may be manually driven or robotic (see below).
- *Conveyors.* There are a number of possible conveyor types, with the simplest being gravity roller conveyors. These conveyors comprise a series of rollers inclined at a slight angle. When the pallet is positioned on the conveyor, it rolls forward to an end stop (or to the pallet in front). Braking rollers may be fitted to slow the momentum of the pallet down the slope. For longer and more controlled movement, powered roller conveyors are often used. Chain conveyors, comprising two parallel chains running in tracks, are often used for short transfers between roller conveyors and as a diversion mechanism from one conveyor to another. Turntables may be incorporated for 90-degree turns, and lift mechanisms may be used for vertical movement between conveyors at different levels. Further details of conveyors may be found in Chapter 20.
- *Transfer carts.* Another alternative is for pallet transfer carts to run on tracks located on, or just above, the floor in a similar fashion as on a railway track. The carts are fitted with a powered transverse conveyor on top for moving the pallets on and off. The tracks can form a barrier to truck and pedestrian movement and therefore need to be designed so as not to interfere with such flows.
- *Monorails.* Pallets may be transported by means of ‘carriers’ suspended from a monorail – normally one, or sometimes two, pallets per carrier.
- *Automated guided vehicles (AGVs).* These are battery-powered computer-controlled trucks and hence do not require a driver. In warehouses, they are normally used for moving pallets but can be used for a variety of unit loads or goods (e.g. paper reels). Typical applications are for the horizontal movement of pallets from the goods receiving area to the reserve storage system, or from the latter to the marshalling area. They normally have a short transverse conveyor on top and can thus transfer the pallet from and to a standing conveyor at each end of the journey. Data may be transmitted to the AGVs by infrared or radio frequency signals, while guidance of the trucks may be by a variety of means. A common method is a wire-guidance system, whereby a wire is buried in the warehouse floor and sensors in the AGV can follow the magnetic field generated by the electric current flowing through the wire and steer the AGV accordingly. Other systems include magnets buried in the warehouse floor, optical guidance by strips or painted lines and radio beacons. Many modern systems use laser guidance. For this type of system, retroreflective strips are placed on walls and equipment around the warehouse and these are detected by a laser scanner on the AGV, using light detecting and ranging (LiDAR) technology. This basically measures the time it takes for a pulsed laser to travel to and from a reflector (or other surface) in order to measure distance. Based on predetermined routes on a digital map, the

AGV can then guide itself through the warehouse. The vehicles have obstacle detectors (e.g. sound, infrared, laser and/or bumper) on board so that they stop if they detect a person, truck or other obstacle in their path. A less common form of AGV runs on tracks laid on the floor and is therefore similar to the transfer carts described above.

- *Autonomous mobile robots (AMRs) for pallet movement.* These are similar in many respects to AGVs but, whereas AGVs are ‘guided’ by a central computer system, AMRs are ‘autonomous’, as the names suggest. AMRs are instructed to take a pallet from one location to another but take decisions autonomously as to how to navigate their way. Input from various sensors, such as cameras and lasers, using LiDAR technology, are used by the AMR to determine its exact position in the warehouse. This is typically undertaken using simultaneous localization and mapping (SLAM), which can create a map of an unknown environment and simultaneously recognize its position on that map. In this way, AMRs can refer to a digital map of the warehouse and find their way around obstacles or congested areas, employing algorithms and artificial intelligence (AI). The digital map can initially be created by walking the AMR around the warehouse during commissioning. The AMRs can incorporate various sensors and safety features (such as laser scanners) so that they can work in the same aisles as trucks and personnel. An AMR used for tote bin transport is shown in Figure 20.3 in the following chapter.
- *Lift trucks.* In general, the above types of equipment are used solely for horizontal movement. For placing pallets into storage positions, some form of lifting mechanism is required. Lift trucks are commonly used both for horizontal movement and vertical stacking, and these trucks are described in the following section.

Pallet stacking equipment

The effective storage of goods in a warehouse normally involves the stacking of pallets, either one pallet on top of another or, more commonly, the placing of pallets into some form of racking. In order to achieve this, the truck must be capable of lifting a defined load. Manufacturers normally define the maximum load that can be lifted (e.g. one or two tonnes) at a specified load centre (e.g. 500 or 600 millimetres). The load centre represents the centre of gravity of the load at a specified distance from the heel of the forks. It is thus normally equivalent to the centre of the load being lifted (see Figure 19.1). If a load with a greater load centre is lifted then the maximum weight that can be carried must be ‘derated’ in accordance with the manufacturer’s specifications.

Figure 19.1 Fork-lift truck load centre

A lift height will also be specified by the manufacturer and this is the height to which the forks can be raised carrying a specified load. The maximum permitted load may reduce at greater heights. The vertical mast of the fork-lift truck may be simplex, duplex, triplex or quad. This refers to the number of vertical columns in the mast. A simplex mast is a single mast that does not move, duplex has a second mast that elevates vertically from that, triplex has a third mast that elevates above the second mast, etc. Thus, a simplex mast would need to be at least the total height of the specified lift, whereas a triplex mast would be much lower when closed but would be able to reach to that height when the three columns are extended. Another consideration is the 'free-lift' height of the mast. This is the height that the forks can be raised before the mast starts to extend upwards. This is important for stacking in low enclosed spaces such as when loading or unloading shipping containers. Fork truck masts also incorporate a tilt facility: forward tilt of about 5 degrees for picking up and setting down loads, and backward tilt of about 5 to 12 degrees for keeping the load stable while travelling, lifting and lowering.

As with pallet movement equipment, there is a wide range of lifting trucks available. Some of the more common ones are discussed in the following sections.

Stacker trucks

These are probably the least expensive fork-lift trucks available and tend to be used for infrequent lifting or in confined spaces. The trucks are battery-powered and variations include pedestrian-operated, ride-on, stand-in and seated. They tend to be lightweight in nature (although 2,000 and 3,000 kilogramme stacker trucks

can be found) and tend to be limited in height, up to about a 6 metre lift height. The front wheels are normally in front of the load to provide stability but this means that, when stacking, the bottom pallet must be supported on a beam, so that the front legs can extend underneath. This front-wheel configuration is suited to open-base pallets (e.g. Europallets) but is not suited to perimeter-based pallets (e.g. as are typical in UK pallet pools). The difference being that perimeter-based pallets have wood all the way round the edge at the lower level and therefore the front wheels would need to go over these, preventing the pallet from being raised by the forks (or in fact splitting the pallet open if the forks were raised). There are also straddle stackers where the front legs are set further apart so that the legs can extend either side of a ground floor pallet, thus overcoming this constraint. Counterbalanced stackers are available and these tend to be pedestrian-operated versions of counterbalanced trucks (see below).

Counterbalanced fork-lift trucks

These are very common and versatile trucks found in a wide variety of warehouses. They can be used for loading and unloading vehicles, as well as moving goods around the warehouse and lifting goods into pallet racking. There are two front wheels and one or two rear wheels, the latter being used for steering. They may have pneumatic tyres for working in yards outside or solid/cushion tyres that are more suitable for inside warehouses.

The load is carried forward of the front wheels and therefore the weight of the load needs to be counterbalanced by a steel or iron casting and/or by the weight of the battery or engine itself (see Figure 19.2). This configuration results in the truck being fairly long and therefore requiring a wide aisle (about 3.5 metres) in which to work. Thus, although counterbalanced fork-lift trucks are very versatile, they do require considerable aisle space within warehouses. They are built to a wide range of specifications, typically from 1,000 kilogrammes payload upwards. Lift heights for warehouse trucks are normally up to about 8 metres (i.e. the height of the forks above the ground when raised), although some can lift higher.

Figure 19.2 Electric counterbalanced fork-lift truck loading pallet into shelved cantilever racking



SOURCE Linde

Note that certain mechanisms are available to facilitate the handling of pallets by fork-lift trucks. These include side shift, which enables the forks to be shifted laterally by about 75 millimetres at right angles to the direction of truck travel so as to facilitate the accurate positioning of loads, for example during loading pallets into ISO shipping containers. A further mechanism allows for the two forks to be spread into a total of four forks so that two pallets can be moved at a time. This may be used, for example, for the rapid side-unloading of vehicles at goods receiving.

Although most fork-lift trucks have rear-wheel steering, there are some trucks that are articulated so that the truck body ‘bends’ in the middle during turning. These trucks can be used for loading and unloading vehicles and are designed to operate in aisles of as little as 1.7 to 1.8 metres. They are therefore proving popular in some specific situations, particularly where this type of versatility is required and where there is a need for some pallet racking in confined spaces.

Instead of having a mast there are some counterbalanced fork-lift trucks that have a telescopic boom that extends from alongside the driver. These telescopic fork-lift trucks are typically used at construction sites and on farms but can also be useful for loading trucks and rail wagons as they can extend far enough to load from one side, thus saving warehouse yard space.

Alternative fuel types are discussed later in this chapter.

Reach trucks

Reach trucks are commonly used in warehouses as they are able to operate in narrower aisles than counterbalanced fork-lift trucks. This is because they can carry most of the load within the wheelbase. They have outriggers with the front wheels positioned at the ends of these (see Figure 19.3). The mast can reach forward along these outriggers to position a pallet in front of the front wheels, either on the ground or at height. Alternatively, particularly in the United States, the mast may be fixed and a scissor mechanism enables the forks to reach forward. As the mast or scissor mechanism is only extended when picking up or positioning pallets, this provides greater stability when the truck is moving and also enables the truck to operate in much narrower aisles, typically in a 2.7 or 2.8 metre aisle compared to the 3.5 metre aisle required for a counterbalanced fork-lift truck.

As reach trucks are designed to operate within the warehouse, they are normally battery-powered. They can have a maximum lift height of about 13 metres (i.e. the height of the forks above the ground).

Figure 19.3 Reach truck working in aisle of adjustable pallet racking



SOURCE Linde

Autonomous lift trucks

These lift trucks are a type of autonomous mobile robot (AMR) and are specifically designed for stacking pallets. They are therefore basically driverless counterbalanced, reach or narrow-aisle trucks and operate in a similar way. The navigation systems are as described earlier for AMRs and they normally incorporate camera and other technology for the accurate positioning of pallets into pallet racking.

Other stacking equipment

There is a range of other specialist pallet stacking equipment for use with specific storage types. These include double-reach trucks, narrow-aisle trucks and stacker cranes. Each of these is described with the appropriate storage system later in this chapter.

Alternative fuels for warehouse trucks

A number of different fuels are available for warehouse trucks. These include:

- *Diesel*. This fuel emits carbon dioxide and harmful particulates and is therefore normally used for trucks operating in warehouse yards rather than within warehouse buildings. These trucks can be powerful and are useful for operating on gradients and handling heavy loads.
- *Liquefied petroleum gas (LPG)*. Cylinders hold propane and butane in liquid form at high pressure. These cylinders need to be changed when the fuel is exhausted. The trucks are quieter and more environmentally friendly than diesel trucks but they still emit carbon dioxide as they are burning a fossil fuel. They are used outside and inside warehouses but should always be employed in well ventilated areas. For example, they are commonly used for the side-unloading of vehicles under a canopy outside a warehouse and then bringing goods through level-intake doors into an adjacent warehouse receiving area.
- *Compressed natural gas (CNG)*. CNG can be produced on site from natural gas and the truck cylinders, holding compressed gas, can then be refuelled within a few minutes at refuelling points. Again, this fuel is more environmentally friendly than diesel but still involves burning a fossil fuel (unless the gas is produced from biomass).
- *Lead-acid batteries*. Battery trucks are very commonly used for internal warehouse operations. They produce zero carbon emissions; the carbon footprint being dependent on how the electricity is generated, either from the mains network or, for example, by means of on-site wind or solar power. They can normally operate about an eight-hour shift before the battery needs recharging. Facilities are

therefore needed in the warehouse for charging and for changing batteries (i.e. for loading a spare battery into the truck in the case of multi-shift operations). The charging area needs to be specially ventilated as hydrogen gas, which is explosive, is produced during this process. Technology such as regenerative braking and lowering of loads extends the charge cycle of batteries by returning power to the battery during these activities.

- *Lithium-ion batteries.* This technology is more recent than lead-acid batteries and offers higher energy density, meaning that batteries can be smaller and/or more powerful. The batteries are more expensive but they have a longer life and require less maintenance. Lithium-ion batteries can be charged rapidly without ventilation so that the need for specialist battery-charging and -changing facilities can be avoided. Rapid opportunity charging can therefore be undertaken, for example during driver breaks. Lithium-ion batteries can thus be used in 24/7 operations without any need for changing batteries.
- *Hydrogen fuel cells.* Hydrogen can be supplied to warehouse sites either as hydrogen gas or as liquid hydrogen under pressure, normally by specialist road tankers. Some warehouse sites generate their own hydrogen. Electricity is required to manufacture the hydrogen and therefore the carbon emissions depend on the source of this power, as with electric batteries. The hydrogen cells themselves produce zero carbon emissions as hydrogen combines with oxygen when it burns to produce water vapour. The cells can be refuelled in a few minutes at a refuelling point within the warehouse.

More details of these and other fuel technologies are provided in Chapter 42.

Palletized storage systems and equipment

There are many storage systems available for palletized goods, ranging from simple block stacking to advanced computer-controlled systems. As well as representing a range of technologies, these systems offer various compromises between the very dense storage of pallets with limited accessibility to each pallet and, at the other extreme, individual accessibility to every pallet but taking up a large amount of warehouse space. These alternative systems are described below.

Block stacking

This is the simplest form of storage with pallets being placed one on top of another. It is very cheap as there is no need for any racking equipment. However, the height of the stack is limited by the crushability and stability of the loads. Crushability is important not only because of possible damage to the goods at the bottom of the

stack but also because any crushing of the lower loads may present a risk of the stack toppling over. Pallet posts or collars (e.g. wooden boards that go around the pallet) may be used to prevent crushing, but these of course have a cost and need time to be inserted and dismantled.

Block stacks are normally arranged in rows of a fixed depth (e.g. two, three, four or more deep) running 90 degrees to the aisle. The first pallet is placed on the floor at the back of the row and the next pallet placed on top. The third pallet would be placed on top of these or, if the stack were only two high, then it would be placed on the ground in front of these. In this way, the row is filled up to a specified depth and height of pallets. The pallets are extracted in reverse sequence and therefore this is a 'last-in first-out' (LIFO) system.

As the lift trucks must be able to drive between the rows and access the back of any row, then the rows of pallets must be positioned slightly apart (typically about 100 millimetres between each row). Also, about 50 millimetres is normally planned as the gap between pallets in the same row, to allow for the possible overhang of goods over the edge of the pallet and for some leeway in operation. Typically, block stacking is carried out by counterbalanced fork-lift trucks.

To avoid double-handling, rows should only contain one stock-keeping unit (SKU). Once filled, the row should then be completely emptied before any other pallets are placed there, as otherwise the back pallets will become 'trapped' and may stay there for a very long time. In practice, more than one row is normally allocated to an SKU so that one row can be filled with new pallets arriving while another row is being emptied. As a result, many rows are likely to be only partially full at any moment in time and this is often referred to as 'honeycombing'. Typically, only 70 per cent of pallet positions are utilized due to honeycombing. For example, if three rows are used for a particular SKU, then one may be used for receiving goods (and will be on average half-full), one may be full with stock, and one may be used for dispatching goods (and thus be on average half-empty). In such a situation, only about two-thirds of the locations would be occupied by pallets. Similarly, if four rows are used for an SKU, then about three-quarters of the locations are likely to be occupied on average. Thus, if a block stack area is required to store 1,000 pallets then about 1,430 pallet locations may need to be provided (i.e. $1,000/0.7$), depending on the number of rows per SKU.

For easy and safe fork-lift truck driving, the front-to-back depth of any row should not normally exceed six pallets in from the truck access aisle, which means blocks of a maximum 12 deep, back-to-back. In practice, layouts may well incorporate rows of different depths to accommodate SKUs with different inventory levels. Thus, in a four-high block store, for example, SKUs with a typical inventory level of 48 pallets may be stored in three 6-deep rows, while SKUs with a typical inventory of 24 pallets may be stored in three 3-deep rows (at 67 per cent location utilization).

Block stacking is suitable for that part of the product range where there are few product lines, each with a high inventory level, and where very strict first-in first-out (FIFO) movement of inventory is not required. The advantages are good use of area (although not necessarily of building height), flexibility to change the layout of the blocks, quick access to inventory for rapid throughput operations, and low capital cost (as no racking is needed).

Drive-in and drive-through racking

In order to overcome the problem of crushability, drive-in racking may be used. With this type of racking, metal uprights are positioned on each side of every row in a block stack area and horizontal metal flanges extend along these uprights at right angles to the aisle in order to support the upper pallets. Fork-lift trucks drive between the columns into each row in order to position the pallets either on the floor or on the metal flanges. Operationally, the racked area is used in the same way as block storage, with the same benefits and drawbacks, except that the rack height is not limited by the crushability of the product. It is thus a last-in first-out (LIFO) system and suffers from low location utilization (again about 70 per cent). However, it is a dense storage system and is suitable where there are high numbers of pallets per SKU.

Driver strain can be an issue as the fork-lift trucks need to travel down between the column uprights into the rows and must carry the pallets at the height at which they will be positioned (i.e. just above the metal flanges on which they are placed). Although the racks may be used for fast-moving goods (as these generally have many pallets per SKU), travel speed within the racks tends to be relatively slow.

The pallets are positioned onto the cantilevered metal flanges at the appropriate height on each side of the row. The pallets therefore need to be of a high quality in order to support the weight of the goods without cracking in the centre. If the goods are fairly light and can be block stacked two high, then pairs of pallets may be positioned on the flanges.

Drive-in racks are generally built up to about 10 or 11 metres in height and to about six pallets deep, although they can be much deeper. As with block stacks, they may be positioned back-to-back, with access to separate rows from each side. Where fork-lift trucks can pass completely through the rack into another aisle then this is known as drive-through racking. This is less common than drive-in racking and tends to be used in staging areas (e.g. goods being marshalled ready for dispatch), rather than for storage.

Satellite, or shuttle, racking

This type of racking is similar in appearance to drive-in racking, with pallets resting on flanges on two edges. However, in order to avoid the need for lift trucks to enter the racking, battery-powered satellites are used. These are also known as radio shuttles or pallet moles. A space of about 200 millimetres in height is allowed under each level of racking for the satellite to pass. The truck first of all positions the satellite at the entrance to the pallet lane (i.e. a specific level of a row in the 'block stack') that is to be used. The truck then brings a pallet and places it in the end position of the pallet lane. On receipt of a radio signal from a remote device operated by the truck driver, the satellite lifts the pallet slightly and moves it into the racking to the furthest location in that lane that is available. The truck then brings the next pallet and the satellite moves that pallet into the racking, and so forth. The satellite can operate while the truck is fetching more pallets or performing other duties. This type of racking can be constructed so that pallets may be 10 deep or more into the racks. If the pallets are retrieved from the same end then this is a LIFO system. However, if aisles are placed at either end, then the satellite can bring goods to the far end so as to operate a 'first-in first-out' (FIFO) system. This may be a distinct advantage in many circumstances, although there would be a loss of some storage space to allow for aisles at each end of the racking.

This form of racking provides dense storage suitable for product lines where there are sufficient numbers of pallets per SKU to warrant a whole lane (or three to four lanes in the case of single-aisle systems, so as to provide some stock rotation). Unlike drive-in racking, the lanes above and below each other may contain different SKUs, as they are each operated independently. This type of racking does not require so many pallets per SKU as drive-in racking or block stacking and is therefore more flexible in this respect. Thus, whereas 24 or 48 pallets per SKU were discussed as being suitable for block stacking, only about 10 pallets per SKU may be required for FIFO satellite racking. One disadvantage is the possible loss of one pallet in height (depending on exact building dimensions) owing to the need for space beneath each pallet level for the satellite to operate.

Push-back racking

Push-back racking is another form of dense storage system and also has the advantage that each level in the 'block stack' can be accessed individually. Push-back racking is typically constructed between three and six pallets deep. The fork-lift truck stays in the aisle and positions a pallet onto a wheeled frame at the appropriate height in the rack. The next pallet of that SKU is then lifted in front of the first pallet and is used to push the latter back into the rack. This second pallet is then placed onto a wheeled frame of its own. The procedure is then repeated with a third pallet

being used to push the first two further back and so on. When a pallet is required, the last pallet is then extracted and the earlier pallets roll back down under gravity to the front of the racking. It is thus a LIFO system. The frames nest into each other as they return to the front of the rack. An alternative system is to use rollers, instead of frames, in a similar fashion.

As each level (i.e. 'lane') can be accessed independently, there is no need for the whole row to be of the same SKU, as with block storage and drive-in racking. It is therefore suited to SKUs with lower levels of inventory, e.g. SKUs with eight pallets of inventory could be stored in three 4-deep lanes so as to maintain stock rotation.

Adjustable pallet racking (APR): reach truck operation

Adjustable pallet racking (APR) is the most common form of racking and is widely used in warehouses, factories and workshops. Pallets are placed single-deep onto horizontal beams, running parallel to the aisles, which are fixed to vertical frames (see Figure 19.3). The uprights of the frames are bolted to the floor, whereas the beams can be moved to different heights on the frames (hence the name 'adjustable'). However, in practice, beams are only moved infrequently as the integrity of the structure needs to be recalculated each time and the racking needs to be emptied of pallets. APR is normally laid out with a single rack against a wall and then double racks accessed from aisles on each side, finishing with another single rack against the opposite wall. Where there are cross aisles running at 90 degrees to the access aisles, then the APR is often continued over the cross aisles so that the lift trucks pass underneath. This provides additional storage space. Typically, two pallets of 1,000 × 1,200 millimetres dimension are stored per bay (i.e. between rack uprights), while three Europallets, with the 800 millimetre dimension facing the aisle, are stored in a single bay.

The main advantage of single-deep APR is that each individual pallet can be accessed directly. It is therefore suitable where there are few pallets per SKU and where FIFO is critical to an operation. Individual access also means that no 'honeycombing' is experienced and therefore pallet location utilizations of 90 to 95 per cent can be achieved before operational difficulties start to occur. As there are only two pallets between aisles, floor utilization is very poor compared to the denser storage systems described so far in this chapter.

APR may be served by counterbalanced fork-lift trucks. However, because of the very wide aisles needed for such trucks, reach trucks are commonly used. The racking is very versatile and can be configured to accept different kinds of loads (e.g. drums or paper reels) and thus trucks with specialist attachments may also be used within such racking systems. Additional features can easily be added, such as shelving for cartons or awkward size loads and protective mesh for retaining any goods that could fall behind the racks.

Double-deep racking

This is a variation on single-deep adjustable pallet racking with the racking being constructed two pallet positions deep from the aisles. A typical layout would therefore be two pallets deep against a wall, then an aisle, and then four pallets before the next aisle – with pallets being accessed two-deep from each side. This provides denser storage than single-deep APR, although not as dense as block stacking, drive-in racking, satellite racking or push-back racking.

Double-deep racking does not provide immediate access to each individual pallet and therefore is not suitable for strict FIFO storage. However, it is well suited to products with a minimum of four or five pallets per SKU (i.e. to allow rotation of the two-deep lanes, while providing reasonable location utilization). Pallet position utilization in double-deep racking tends to be higher than with the denser storage systems but not as high as single-deep racking – a figure of 85 per cent is typical for double-deep applications.

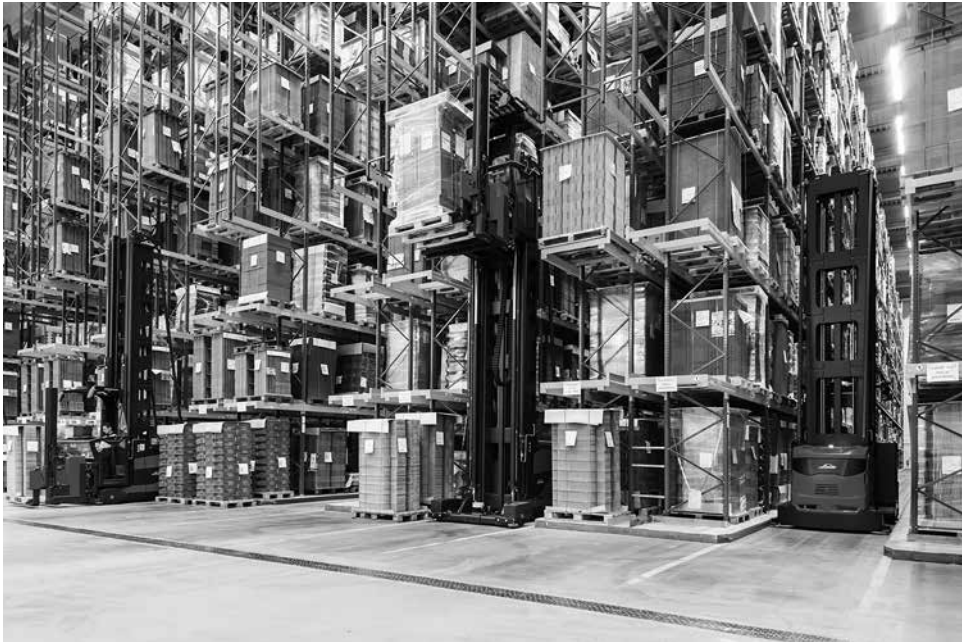
Specialist reach trucks are required to serve double-deep racking as the forks must extend far enough to reach the rear pallet. This is achieved either by having telescopic forks or by a scissor mechanism that extends outwards. In either case, the load centre is moved much further away from the reach truck and therefore a higher specification truck is needed. In order to minimize the extension in front of the forward wheels, it is normal for the ground pallet position to be raised onto a beam (rather than the ground pallet sitting on the floor as with single-deep racking). This enables the front wheels of the reach truck to move under the first pallet and thus be nearer to the back pallet positions. A potential disadvantage of having to place an additional beam at low height is that this may result in a warehouse building only being able to accommodate one pallet height less than single-deep racking. If this occurs (which is dependent on the exact clear operating height of the building) then a whole pallet level may be lost with double-deep racking, thus largely eliminating its denser footprint advantage as compared to single-deep racking.

Narrow-aisle racking

Narrow-aisle racking is basically the same as described earlier under APR but the racks are set out in much narrower aisles than those required for reach truck operations. Narrow-aisle racking typically has aisles of 1.8 metres or less and therefore must be served by specialist narrow-aisle trucks, also known as turret trucks and, frequently, as very narrow-aisle (VNA) trucks. These trucks have forks that extend from the side so there is no need for the truck to turn in the aisle (see Figure 19.4). The forks are located on rotating heads or on shuttle mechanisms, so that pallets can be extracted from either side of the aisle. Narrow-aisle trucks can have a lift height of about 14 metres (i.e. the maximum height of the forks above the ground), which

is greater than reach trucks. The greater height and the denser footprint (due to the narrow aisles) mean that more pallets may be stored per square metre than in a wide-aisle reach truck operation. Narrow-aisle racking is therefore a very common rack system for the main storage modules of large warehouses.

Figure 19.4 Narrow-aisle trucks



SOURCE Linde

Owing to the greater height, the warehouse floor needs to be strong and very flat. The construction process is therefore more expensive, as well as the narrow-aisle trucks being significantly more costly than reach trucks. Due to their larger size, narrow-aisle trucks are normally confined to the storage cell and are not used for moving pallets around the warehouse. The trucks are guided within the aisles, either by horizontal wheels (mounted against a rail at floor level or against the first beam) or more commonly by a wire-guidance system (comprising a wire buried in the floor and sensors in the truck, as explained earlier for automated guided vehicles). Pick-up and deposit (P&D) stations are positioned at the end of each aisle (at ground and higher levels) so that pallets can be left there by the narrow-aisle truck and picked up by reach or counterbalanced trucks for onward movement. When narrow-aisle trucks have finished working in an aisle they can be steered by the driver into another aisle. Owing to their size, they normally require wide transverse aisles for this manoeuvre (i.e. about 4.5 metres), although there are some articulated narrow-aisle trucks designed to minimize this distance.

It is also possible to locate 'bus-bars' at first beam level in the racking so that narrow-aisle trucks can charge their batteries while they are in the aisles. This avoids the need for battery-changing or -charging in multi-shift operations.

For pallet-in/pallet-out operations, the driver normally stays in a seat at low level and therefore requires some assistance in locating the upper pallets. This may be by means of an automatic height selector or by camera image. If case or item picking is required from the pallets at high level, then the driver's cab elevates with the forks so that picking can be undertaken directly onto a pallet positioned on the forks. Some trucks are designed for both purposes and are known as 'combi-trucks'.

Various forms of semi-automation are available such as controlling simultaneous lateral and vertical movements within an aisle, taking the forks quickly and economically to the next location required. The driver can then regain control to put away or extract the pallet. Similarly, trucks may be steered automatically between aisles using, for example, laser guidance systems. Auto-fencing is another useful feature whereby lift heights can be restricted in areas where there is an overhead obstruction and speeds can be limited where there are pedestrian or transverse aisles. The trucks can also be completely driverless using technology described earlier under autonomous mobile robots (AMRs) and autonomous lift trucks.

In addition, there are articulated fork-lift trucks (described earlier in this chapter) that can operate within narrow aisles. These trucks have the forks at the front (like counterbalanced fork-lift trucks) but can turn in narrow aisles, so as to position pallets in the racking, by the truck articulating in the centre.

Powered mobile racking

Most rack systems are a trade-off between storage density and accessibility to individual pallets. However, powered mobile storage meets both of these objectives. This is achieved by basically constructing single-deep adjustable racking onto powered base frames. These frames take the whole weight of the double runs of racking between aisles and move on wheels along rail lines embedded into the warehouse floor. The frames are electrically operated so that an aisle can be created at any point between the double runs of racking. In this way, the other racks are parked in a condensed area while access can be obtained to any pallet in the aisle that has been created. The frames may be moved by means of buttons at the ends of the racks, by controls mounted on fork-lift trucks or from a central console. Safety features include photoelectric cells and 'trip' mechanisms that stop the racks if there is any obstruction.

The main operational disadvantage is that powered mobile racking is slow in operation and only one fork-lift truck can normally gain access at a time. Also, the racking is costly and needs strong floor foundations. However, it is well suited to very slow-moving goods that have only one or two pallets per SKU. As individual

access is provided, pallet location utilization is similar to conventional APR: i.e. 90 to 95 per cent. Powered mobile racking is commonly used in cold stores where storage costs are high and where a high density of product helps to maintain the low temperatures required for frozen goods.

Pallet live storage

Pallet live storage provides dense storage while maintaining 'first-in, first-out' stock rotation. Under this system, the first pallet is placed on an inclined roller conveyor. The pallet rolls forward and is then brought to a halt at the far end of the conveyor by an automatic braking system. The next pallet is then placed on the conveyor and this rolls down until it reaches the first pallet, and so on. When the first pallet is extracted, the other pallets all roll forward one position. The inclined roller conveyors are placed in parallel rows and one above the other, forming a very dense storage system, with an aisle for replenishment at one end and an aisle for retrieving pallets at the other end.

Each inclined conveyor should contain the same SKU and therefore this type of racking is suited to fast-moving products where there are numerous pallets per SKU (depending on the length of the conveyors). The pallets should be within a reasonable weight range of each other as the inclines and braking systems need to be calibrated for the pallet weight range of each application. The pallet location utilization rates are variable depending on the type of application. For example, if the system is used as the sole storage medium for a particular product range then only about 70 per cent of the locations may be utilized (as inventory will vary for each SKU on a day-by-day basis). On the other hand, if the pallet live storage is used for staging fast-moving products just before dispatch then location utilization can be maintained fairly high, as the variation in SKU inventories will be accommodated in the bulk store.

Short ground-level runs of pallet live storage (e.g. two pallets long) are often used for case picking of fast-moving goods. These may be laid out on the warehouse floor or on mezzanine floors. Sometimes ground-level runs are positioned under longer runs of pallet live storage inclined in the opposite direction. In this type of layout, replenishment can take place by reach trucks retrieving pallets from the upper levels and placing them directly into the ground-level runs below. Case picking can then take place by pedestrian pickers at the end of the ground-level runs under the upper runs of racking.

Automated storage and retrieval systems (AS/RSs)

In concept, most AS/RSs are similar to single-deep or double-deep installations described above except that, instead of a reach or narrow-aisle truck, computer-

controlled cranes run up and down the aisles, putting away and extracting pallets (see Figure 19.5). These cranes are electrically powered and run on rails, positioned on the floor, and are guided by a further rail above the top rack. The cranes comprise one or two tall masts with a handling mechanism that includes forks that extend from the sides of the crane to pick up pallets on either side. Sometimes, pallets are placed on bars (often known as ‘top hats’) above the beams so that cranes can insert platens underneath the wood to lift them. This is because it can be difficult to ensure that forks will always fit exactly into the holes in pallets, particularly owing to the flexing of the crane masts in high installations.

AS/RSs typically operate in ‘high bay’ warehouses, which may be up to about 45 metres in height. The cranes operate in aisles of only 1.5 metres or so wide, and therefore these systems provide excellent floor utilizations, combined with good access to pallets. AS/RSs are therefore particularly common where land prices are high. The pallet racks have to be strong, not only because of the height but also because they often form the structure of the building itself. Cladding may be fixed to the outermost racks to form a complete ‘rack-clad’ building.

Figure 19.5 AS/RS crane



SOURCE ©SSI Schaefer

Pallets are normally fed to and from the cranes by means of short conveyors located at one end of each aisle. These may in turn be fed by longer conveyors, by AGVs or by fork-lift trucks. Before being placed into the AS/RS installation, pallets are checked to ensure that nothing will cause any obstruction within the system. This is normally undertaken by pallet profilers, whereby pallets are moved under a structure containing photoelectric cells that check, for example, to ensure that no cartons have become dislodged in transit and that there is no loose shrink wrap. Otherwise, the pallet could become jammed within the AS/RS, and maintenance personnel may need to enter the installation and manhandle the offending case or shrink wrap. The whole AS/RS installation is controlled by an equipment control system (ECS) and this contains diagnostic equipment to identify the exact nature of any problem. Instructions to extract a particular pallet are normally given by the warehouse management system (WMS) to the ECS, which then takes over to control the in-feed, out-feed and crane mechanisms.

In fast-moving operations, there may be one crane per aisle, with both in-feed and out-feed typically taking place at the same end of the aisle. In slower-moving operations, there may be fewer cranes than aisles and, in this situation, cranes may be moved between aisles at the far end by means of a transfer car (which accepts the crane from its rails, then carries it to the next aisle where it needs to work and releases it into the rails for that aisle).

An alternative method is to curve the rails at the end of the aisle so that the cranes can run down the transverse aisle. These have point mechanisms that the cranes can alter to proceed down the appropriate rack aisle.

There is a wide range of designs for AS/RSs but these may generally be classified as follows:

- *Single-deep*. This has similar characteristics to those described for APR and narrow-aisle, in that there are two rows of pallet racking back-to-back between the aisles. The stacker cranes access one deep on either side.
- *Double-deep*. Again, the characteristics are similar to double-deep conventional racking. In this case, there are four rows of pallet racking between the aisles, and the stacker cranes are specifically designed to reach two-deep into the racks. Normally, they access one pallet at a time (as with double-deep reach trucks), but some AS/RSs have double-width aisles and can access two pallets at a time. The latter increases throughput rates but uses more space.
- *High-density crane systems*. In this type of system, each stacker crane has an on-board satellite that can move away from the crane in rails underneath the pallet lanes, and deposit a pallet into the racks or bring a pallet back to the crane (similar to satellite racking, described earlier). The pallet racks may be installed, for example 10 deep, so that the satellite can fill 10 pallets into a lane of racking. There would thus be 20 pallets back-to-back between the aisles. This is a very

dense storage system, but operates on a last-in first-out (LIFO) basis for each lane of 10 pallets. Alternative systems include the use of flow racks, which may be gravity or powered, with stacker cranes putting in at one end and extracting pallets from the other, so as to maintain a FIFO system.

- *High-density carrier systems.* These are similar in concept to the crane systems described above except that each level within in an aisle is served by a carrier (sometimes called a shuttle or cart). Pallets are lifted to the appropriate level by a lift at the end of the aisle and are then collected by the pallet carrier. These transport the pallet along the aisle and then deep into the rows of racks in a similar way to the satellites mentioned above. These systems are suitable for higher throughput operations as many carriers can work simultaneously at different levels within an aisle, rather than being dependent on a single crane. They are also suitable for lower height warehouses and for retrofitting existing buildings of varying heights. As with high-density crane systems they are suited to operations where there are many pallets per SKU, as the rows should contain the same SKU and may be anywhere up to about 20 pallets deep.

AS/RSs tend to make very good use of land area, because of their height and narrow aisles, and can be designed for high levels of throughput. However, they have a high capital cost and are therefore best suited to large installations that need to operate for most hours of the day (e.g. approaching seven-day-week, 24-hour operations). During non-working or off-peak hours, the equipment needs to be maintained. Also, during these periods, the AS/RS can be set to work automatically on 'housekeeping' duties to reposition the pallets in the optimum locations (e.g. fast-moving SKUs may have had to be put away at the far end of the aisles during congested periods and can later be moved nearer the in-feed/out-feed end).

Comparison of different types of palletized storage equipment

A comparison of space utilization can be calculated for each type of storage system based on such factors as the handling equipment characteristics, available warehouse height and pallet dimensions. An example for pallets with base dimensions of 1,000×1,200 millimetres is shown in Table 19.1.

The left side of this table gives the assumed height in number of pallets high (which will vary by application), the floor utilization (i.e. the percentage of floor area occupied by the pallets themselves within the storage module, excluding transverse aisles) and the number of pallet spaces that can be provided per square metre of floor area. In this example, it can be noted that block stacking offers very good floor area utilization; however, the achievable height may be limited by the crushability and

Table 19.1 Space utilization examples

Storage Type	Assumed Height	Floor Utilization	Pallets Spaces per m ²	Location Utilization Factor	Pallet Stored per m ²
Block stack (4-deep)	3 pallets	62%	1.5	70%	1.1
APR (reach truck)	5 pallets	36%	1.5	95%	1.4
Double-deep	5 pallets	47%	2.0	85%	1.7
Narrow-aisle	7 pallets	44%	2.6	95%	2.5
AS/RS (single-deep)	10 pallets	48%	4.0	95%	3.8

nature of the pallet loads. Similarly, narrow-aisle storage may provide more pallet spaces per square metre than double-deep storage because of the height that can be achieved. AS/RS can be constructed much higher than conventional systems, so the number of pallet spaces per square metre can be far greater (even more than that shown in the example for higher installations).

The last two columns show the location utilization factor for each storage system (i.e. the percentage of pallet spaces that would normally be filled) and, based on that factor, the actual number of pallets that can be expected to be stored per square metre. It should be noted that some storage methods are able to work at much greater location utilization factors than other systems. For example, it was mentioned earlier in this chapter that block storage may require up to about one-third of the spaces to be empty so that the operation can work effectively, while APR may work effectively with only 5 to 10 per cent of the locations empty. The number of pallet spaces per square metre should therefore be downrated by this factor to calculate the actual number of pallets per square metre that can be stored while maintaining an effective operation.

In addition to space, there are other factors that need to be taken into account. One method is to draw up a storage attributes matrix, such as that shown in Table 19.2 (which represents a very subjective view by one author). This method helps to identify which storage systems are best able to meet the specific requirements of an individual warehouse operation.

A further tool to help identify the appropriate pallet storage system is to develop a decision tree such as the example given in Figure 23.4, in the chapter on warehouse design.

Each storage type has specific characteristics that are suited to different operational circumstances and therefore account needs to be taken of such factors as the wider supply chain objectives, the throughput parameters, the cost profiles for that geographic location, the local planning regulations and the availability of staff. There are often compromises to be made between these factors. For example, rack types

Table 19.2 Palletized storage attributes matrix

Storage Type	Access to Each Pallet	FIFO	Low Rack Cost	Suitable for Ground Case Picking	Operating Speed
Block storage	1	1	5	1	4
Drive-in	1	1	2	1	3
Satellite	1	1 (SA) 5 (DA)	1	1	3
Push-back	2	1	1	1	3
APR (with reach truck)	5	5	3	5	4
Double-deep	2	1	3	2	3
Narrow-aisle	5	5	3	2	4–5
Powered mobile	5	5	1	1	1
Pallet live	1	5	1	5	5
AS/RS – single-deep	5	5	3	1	5
AS/RS – double-deep	2	1	3	1	5
AS/RS – high-density	1	1	3	1	3

Key: scale from 5 (= favourable attribute) to 1 (= unfavourable attribute)

SA: single aisle

DA: dual aisle (ie one aisle at each end of racking)

such as drive-in racking that offer dense storage do not give good access to pallets, whereas types such as single-deep APR that offer individual access to pallets often provide poor space utilization. On the other hand, where a system offers both excellent space utilization and individual access, as with powered mobile racking, then speed of throughput is compromised. Thus, a trade-off often must be made between these factors when deciding on the use of any storage and handling system.

Rack safety

Safety is of paramount importance for all racking systems, as any rack collapse can have very serious consequences. Safe working loads (i.e. in terms of weight) need to be displayed and adhered to. A single upright failure can lead to a ‘domino’ effect of collapses across an entire warehouse. Metal barriers are therefore often installed to protect uprights at the ends of aisles from truck collisions. Regular inspections need to be undertaken by a competent person and records kept. Any damaged metalwork requires immediate attention. Normally, racks need to be emptied of products while a new upright is fitted. However, there are now systems that use a jack to support the

weight of the rack structure while the damaged section of the upright is cut away and a new lower part of the upright is installed. In some rack systems this may take the form of a sacrificial leg that is designed into the upright for this purpose.

Guidelines for the positioning and installation of rack components are given by codes of practice issued by regional and national associations, such as the Fédération Européenne de la Manutention (FEM, 2021) for Europe and the Storage Equipment Manufacturers' Association (SEMA, 2021) for the United Kingdom in particular.

Another feature common to all racking systems is the consideration of fire suppression. Fire officers and/or insurance companies may require overhead sprinklers at ceiling level or may require sprinklers to extend down into the racking (e.g. at every level or every second level of racking). These are known as 'in-rack' sprinklers. In such cases, height calculations need to allow for space to be provided so that the water can be sprayed out over the goods from the sprinkler heads.

Storage and handling systems (non-palletized)

20

Introduction

Although pallets are very widely used in warehouse operations, there are many types of product that are not suitable for palletization, because they may be too small, too large or too long, or because they require lifting from the top. These products may include, for example, nuts and bolts, electronic items, paper reels, machinery, steel bars, carpets, drums and hanging garments.

Indeed, across different industries, about half of the goods in warehouses are stored in units other than pallets. The most common of these is as cases of product (e.g. cardboard boxes with product inside). These may just be placed directly on shelving, rather than on pallets. Another common form is in tote bins (e.g. plastic, fibreboard or metal boxes), normally used for holding a number of individual items or small cartons of product. This chapter examines the various storage and handling systems that may be applied to all goods not stored on pallets.

Small-item storage systems

There is a range of equipment designed for the storage of small items. Some of these are used in combination, and therefore standard sizes and modularity are important. Whatever system is used, it is important that there is a specified location, or locations, for every SKU.

Shelving, bins and drawer units

Probably the most common form of storage for cases and individual items is shelving. These are modular units that may be bought to many different specifications,

but typically comprise solid metal shelves about 1,000 millimetres long and 300 to 600 millimetres or more deep and arranged with one shelf above the other up to a total height of about 2,000 millimetres. The shelves are normally set out in long rows accessible by aisles, in a similar way to single-deep pallet racking. Each bay of shelving is supported by a steel frame and normally has solid sides. Each shelf can normally support about 200 kilogrammes of product, although various specifications are available.

Sub-dividers can be used so that a number of specific locations can be established to hold several different SKUs on one shelf. Similarly, drawer units can be incorporated (or can be stand-alone) in order to store small items. Another option for small items is to place them in small plastic, metal or fibreboard bins. These may be located on the shelving or on louvred panels at the end of each run of shelving.

For longer items, long-span shelving may be used, with spans of up to about 2,500 millimetres. Alternatively, cantilever shelving can be adopted. This type of shelving is supported from the central upright and therefore there are no vertical panels to impede the positioning of long items.

Shelving is typically located on the floor and accessed by pedestrians. This may be free-standing shelving (often accessed by pedestrians pushing trolleys) or may be fitted into the ground level locations of adjustable pallet racking (often accessed with trolleys or with low-level order-picking trucks). In the case of free-standing shelving, the height of a building may be utilized by having two or more levels of shelving on *mezzanine floors*. These floors may be shelf-supported (i.e. the shelving structure supports the floor above) or may be free-standing (i.e. shelving can be erected and dismantled below and above the floor without affecting the floor structure). The latter is more expensive but more flexible. Goods are normally transferred between ground and mezzanine levels by means of:

- conventional lifts (e.g. for pedestrians with hand-pallet trucks)
- pallet lifts (e.g. as an integral part of a conveyor system)
- vertical reciprocating conveyors
- inclined conveyors and spiral conveyors
- gravity chutes (for downward movement only)
- pallet gates (i.e. openings on the side of mezzanine floors to enable a lift truck to place a pallet, with a safety-gate mechanism that can be lifted so that the pallet can then be taken away by hand-pallet truck on the mezzanine floor)

Shelving can also be constructed to high levels (e.g. within, or in a similar way to, pallet racking) and be accessed by means of high-level narrow-aisle picking trucks or high-level fixed-path picking trucks running on rails (see Chapter 21). This may be most suitable where a large range of slow-moving goods are stored, with small quantities held for each SKU.

Mobile shelving

Normal shelving is fairly space intensive as aisles are required for pedestrian access between each double run of shelving. Where access is only occasionally required (e.g. with archive material) then an alternative is mobile shelving, which runs on rails. In concept, this is the same as powered mobile racking, with only one aisle needed for multiple runs of shelving. The aisle may be created in different positions by turning a wheel located at the end of each run of shelving or the system may be electrically activated, by means of push-buttons.

Suspended compartments

Vertical columns of small flexible compartments may be suspended from a track system, incorporated into, for example, the ground level locations of adjustable pallet racking. The front columns may be moved to one side in order to gain access to the rear columns. In this way, small quantities of many different SKUs may be stored in a single pallet rack bay.

Carton live storage

Carton live storage (sometimes referred to as flow racks) is similar in concept to pallet live storage. Cartons (or suitable products) are positioned on inclined rollers and roll forward until they reach the stop point at the lower end. This type of storage is generally suitable for product in cartons or in tote bins as these have smooth bases that will run along the rollers. Carton live storage provides a first-in first-out storage system, as the first carton or tote placed into the system is the first to be extracted. The system is often used in order-picking areas (see Chapter 21) as picking can be separated from the replenishment operation and as a good depth of stock can be kept in a very condensed pick face (as product extends back away from the pick face rather than along it) – hence a large number of different SKUs can be positioned in a small run of aisle, thus reducing the walking time of the pickers.

As with shelving, carton live storage can be built in to pallet racking (e.g. at ground level for picking purposes).

Carousels and lift modules

Carousels may be vertical or horizontal in nature. Vertical carousels (sometimes also known as paternosters) hold products on shelves within a steel-clad box. The shelves are suspended between two chains that are rotated in a vertical direction by electric motors. They are normally computer-controlled, bringing the appropriate shelf to an access point for the operator by the shortest possible route. In this way, the product

is always presented at the ideal ergonomic height for picking. Products may be placed directly onto the shelves (with different SKUs normally separated by dividers), into tote bins resting on the shelves or in drawer units fitted into the shelves. As the vertical carousels may be quite high (e.g. up to 12 metres or more), they can make good use of floor space and may thus hold a very large number of parts in a small area. The whole steel cabinet may be climate-controlled (e.g. for chilled goods) and is especially suitable for goods requiring high security. Many carousels have twin motors so that product can still be accessed if one motor fails.

Horizontal carousels are similar in concept except that they move bays of shelving on a chain in a horizontal direction. Often the bays are suspended from an overhead chain. Horizontal carousels tend to be used for slightly larger items than vertical carousels (e.g. medium to large cartons) and are suitable for low-headroom situations. They may of course also be placed on mezzanine floors so that banks of horizontal carousels can be installed at different levels.

An alternative concept is that of vertical lift modules. These look similar to vertical carousels from the outside but move shelves (often called units) independently so that product can be delivered to the operator in any order, rather than in shelf order. Also, multiple access points can be fitted (e.g. on different floors or side-by-side) so that more than one operator can access from the same range of products, or so that replenishment can occur at the same time as picking. There are also horizontal lift modules available for low-headroom situations.

Miniload

A miniload is basically an AS/RS for small items (see Figure 20.1). A computer-controlled crane operates along a central aisle and can access cartons or tote bins from shelving or racking on either side. The cranes may be designed to transport more than one carton or tote bin at a time, in order to improve access rates. Thus, for example, a crane may pick up two tote bins from an in-feed conveyor, put one away and then put the other away in a nearby location, before proceeding to extract any tote bins required. Attachments are available to pick up cartons of varying dimensions.

In setting up miniload systems, different heights, lengths of racking runs and crane speeds may be chosen depending on whether the goods are fast-, medium- or slow-moving (i.e. their Pareto group, as described in more detail in Chapter 23). The Pareto group is a key factor in any miniload system design as this determines the number of bins or cartons that need to be accessed per hour. Where access is limited by a single crane per aisle, miniloads tend to be used for very wide product ranges of slow-moving goods. For higher throughput situations, alternative types of storage system are available that can access bins simultaneously at each level. Thus, instead of a single crane in each aisle, there may be numerous 'shuttles' (or 'robots') working

Figure 20.1 Miniload crane tote storage system**SOURCE** TGW

independently at different levels within an aisle, bringing the goods to a vertical lift at the end (see Figure 20.2). These shuttles can access tote bins or cartons two or more deep if double-deep or multi-deep storage is required. In some systems, the shuttles may also be able to transfer between the different levels (using the lifts) and between the aisles (using transverse aisles next to the lifts). Also, to balance workload it is possible in some systems for the tote bins (or cartons) to be transferred by a shuttle ready for pick up in the adjoining aisle. In addition, there are free roaming shuttle systems whereby the shuttles (or ‘robots’) can move up the racking vertically, as well as horizontally, and move around the warehouse floor, in the same way as an autonomous mobile robot (AMR), to take the goods directly to a picking station.

Miniloards may also be used for buffer storage to sequence goods ready for packing or dispatch (see Chapter 22, ‘Dispatch processes’).

Multi-level grid systems

These systems are normally based on a multi-level grid frame in which tote bins can be inserted and extracted from the top. Robots run along the top of the grid lowering and lifting specific tote bins as required. The robots run on wheels and can access the top of any column in the grid. They normally communicate by radio frequency and

Figure 20.2 Miniload storage system with shuttles at each level

SOURCE Vanderlande

recharge their batteries as they work. If the required tote bin is buried beneath other bins then these are removed first by the robot and relocated into another column in the grid. Fast-moving goods should therefore be located near the top of the grid and slow movers further down. The robots can reposition bins into their best locations when they are not putting away or extracting bins required for the warehouse operations. Extracted bins are normally transferred to pick stations at the side of the grid for manual (or robotic arm) picking and then each bin is returned to storage after individual items or small cartons have been picked from it. This system has the advantage of providing a very dense storage area for small parts but it can involve considerable double-handling of bins to access the lower levels and therefore throughput capacity needs to be planned carefully in advance, preferably by computer modelling (e.g. simulation). This type of system is modular so that the grid can be extended and more robots can be added to accommodate changes in storage and throughput levels over time.

Long loads storage and handling systems

Long loads (such as steel rods, carpets and wooden boards) are problematic in terms of storage, as most racking systems cannot accept them (because of the rack uprights).

In addition, conventional handling equipment cannot move them effectively as very wide aisles would be needed to turn the loads. Specialist storage and handling equipment is therefore often used.

Storage methods include:

- *Block storage.* Wooden boards, for example, are often strapped into unit loads and block-stored in yards, with pieces of wood inserted between the loads so that they can be lifted from underneath.
- *Cantilever racking.* Cantilever racking comprises central steel uprights with bottom arms extending out towards the aisles to provide stability (see Figure 19.2). Further arms are then fitted at different levels, cantilevered from the central upright. In this way, long loads can be placed onto the arms without any interference from uprights near the aisle. For loads that could roll off, such as steel tubes, the arms are tilted slightly upwards and fitted with stop bars.
- *Vertical storage.* Long items may be stored vertically in 'A-frame' storage modules (where long items are inclined slightly towards the centre of the storage modules in a back-to-back fashion) or in 'toast-rack' storage modules (where items such as boards are stored vertically as toasted bread would be at a breakfast table).
- *Pigeonhole racking.* This type of racking comprises long 'pigeonholes' at various levels extending away from the aisle. They are often used for loads needing support, such as carpets, and may be loaded by trucks with boom attachments (that fit into the centre of the rolled carpets). Alternatively, a fork-lift truck attachment with rollers may be used for transferring long loads into the pigeon holes.

The handling of long loads is generally undertaken by:

- *Side-loaders.* These are basically flat-bed trucks with the driver positioned in a cab on one side. The mast is positioned halfway along the truck on the same side as the driver but can move to the other side for picking up and placing loads. Forks are fitted to the mast in the same way as a normal lift truck except that they extend from the side of the truck. Long loads can thus be lifted from block stacks or cantilever racking at the side of the truck and can then be moved lengthwise along the aisle. As there is no need to turn long loads in the aisles, the latter do not need to be as wide as for counterbalanced fork-lift trucks, although transverse aisles must be wide to allow for turning with the long loads. Side-loaders are frequently used for outdoor operations such as timber yards. Narrow-aisle side-loaders are available for indoor operations.
- *Multi-directional trucks.* On a conventional reach truck, the front wheels always face forward, and steering is from the rear wheels. The multi-directional truck has an additional option of being able to turn the front wheels. A similar type of truck

is the four-way truck, which can turn the front wheels through 90 degrees and lock them in this mode. These trucks can therefore act as side-loaders, but with narrower transverse aisles. This is especially useful in warehouses where part of the inventory range consists of long loads. For access to, say, cantilever storage, very wide rack and transverse aisles would be necessary if this option were not available.

- *Articulated long load trucks.* These are similar in design to the articulated trucks described in the section on ‘Counterbalanced fork-lift trucks’ in Chapter 19. However, the front wheels can turn a full 360 degrees so that the truck can proceed forwards with the load aligned alongside the driver. Long loads are thus transported lengthwise down aisles as with the two truck types described above.
- *AS/RS.* Stacker cranes may be used to move long loads into and out of cantilever racking.

Fork-lift truck attachments and overhead cranes may also be used for long loads and these are discussed in the two sections that follow.

Truck attachments

For larger items, it may be possible to handle the goods by means of attachments fitted to fork-lift trucks. These attachments may be used for block-stacking the goods or they may be used in conjunction with accessories fitted to adjustable pallet racking. For example, channel supports are available for storing post pallets on adjustable pallet racking (APR). Similarly, drum and reel supports are also available.

If attachments are used, then the weight of the attachment needs to be taken into account when specifying the payload capacity of the truck. In addition, many attachments result in the load centre being moved further away from the heel of the forks, resulting in further ‘deration’ of the weight that can safely be carried by the truck.

Some common truck attachments are as follows:

- *Clamps.* Various types of clamp attachments are available for such purposes as picking up bales, drums and home appliances. The clamps are operated hydraulically and can be set for different pressures, so as to prevent damage to goods. For goods that could be easily damaged the clamps may be rubber coated.
- *Rotating heads.* These can be used to move goods from the vertical to the horizontal position, for example, in the case of drums or reels that may be required to be placed in either orientation. Similar clamps are used in food processing and other industries for rotating buckets and thus dumping loads.
- *Load push-pull.* Unit loads may be placed on card or plastic slip-sheets so that the lip of these sheets can be gripped by the push/pull attachment and the load thus

dragged back onto the platens (i.e. wide forks) of the lift truck. The gripping mechanism is on a scissor back-plate that can move along the platen. This back-plate thus extends forward when retrieving a load and then moves back to the mast of the lift truck for transporting it. The use of these sheets saves space in shipping containers, avoids the cost of one-way pallets, and overcomes restrictions on the import of wood (imposed due to the possible spread of pests and diseases). Each party in the supply chain needs a similar attachment on its lift truck if the use of pallets is to be completely avoided.

- *Booms.* There are various boom attachments available for placing along the centre of items such as carpets and horizontal reels. The booms are inserted by the truck into the centre of the roll to lift and position it, for example, into pigeonhole racking.
- *Multi-forks.* These are frequently used where unit loads are made from the items themselves. For example, bricks may be strapped together leaving a number of slots within the lower layers for such attachments to fit into.
- *Drum tines.* These are horizontal bars that are used for lifting a number of horizontally oriented drums at once.

Cranes

Cranes are used particularly for moving very heavy loads (such as metal bars) within a predetermined area, but may also be used for lighter loads, for example where items are too heavy with respect to manual handling guidelines.

Equipment types include:

- *Jib cranes.* These are used for moving loads within a restricted area, such as in the vicinity of a workstation. They comprise an arm that pivots around a central upright (or wall mounting). An electric hoist moves along the jib so that loads can be lifted and moved anywhere within the radius of the jib arm.
- *Overhead travelling cranes.* These are often used in workshops to move heavy loads anywhere within the building unit. They normally comprise one or two beams that span the distance between rails fitted high on two walls of the building. Each end of the beam(s) rests on an end carriage that runs on the rails. A trolley with a hoist travels along the beam(s).
- *Gantry cranes.* These are similar to overhead travelling cranes but have uprights and run on rails fixed to the ground. They are therefore commonly used for outdoor applications; for example, in metal stockyards. Some gantry cranes are rubber tyred and these can be driven anywhere in a yard.

Most cranes are electrically-powered and are controlled by a fixed-wire pendant push-button control, by infrared control, by radio control or by an operator in a cabin fitted to the bridge. Safety and control features include load weight sensor displays, servo motors, anti-sway software, 'creep' speed, 'weightless' function for final manual positioning and sensors to prevent lowering the load near a machine or heavily on to the floor.

A range of attachments may be used, including hooks, magnets and mechanical or robotic clamps.

Conveyors

Conveyor systems are used for moving goods between fixed points, for holding goods as short-term buffer (i.e. accumulation) and for sortation.

Both gravity and powered conveyors may be used for the movement of goods. Types of gravity conveyors include chutes, skate-wheel conveyors and roller conveyors. These types of gravity conveyors are normally used for moving goods short distances; for example, chutes may be used for transferring goods down from a mezzanine floor while mobile skate-wheel conveyors may be used for vehicle loading and unloading. Powered conveyors are normally used for longer distances, and types include:

- *Roller conveyors.* These comprise a series of rollers and are frequently used for such unit loads as tote bins and pallets. Where accumulation is required (e.g. waiting for the next operation to take place), the unit loads may be held by the conveyor with minimum pressure, zero pressure or avoiding contact between the loads – the latter by using sensors and electronic controls.
- *Belt conveyors.* Belt conveyors consist of a continuous belt running on supporting rollers and are generally used for lighter loads (e.g. cartons) than roller conveyors.
- *Slat conveyors.* These are fitted with horizontal cross-slats and can be used for heavy and awkward loads. This type of conveyor is often used for baggage at airports.
- *Chain conveyors.* These carry loads on chains running in tracks parallel to the direction of travel and may be used for heavy loads or as transfer mechanisms between sections of roller conveyor.
- *Overhead conveyors.* An overhead conveyor consists of a continuous chain running in an overhead track, with loads on carriers suspended from the chain. Applications include order picking in warehouses with a wide range of SKUs (e.g. mail order companies).

Conveyor systems may be suitable where some of the following characteristics apply:

- high throughput
- fixed routes
- continuous (or intermittent, but frequent) movements
- uneven floors or split-level operations

The possible disadvantages of conveyor systems include:

- high capital cost
- obstruction to pedestrian and truck traffic
- inflexibility (i.e. cannot be moved readily) for future change

Conveyors are widely used for the movement of pallets, cartons, tote bins and other loads within warehouses, as well as being an integral part of order-picking and packing operations. In the latter activities, conveyors may have a specific application as a means of sortation (e.g. to bring all goods together for a particular order ready for packing, or to sort by vehicle load), and this aspect is covered in Chapter 21.

Automated guided vehicles and autonomous mobile robots

As well as being used for the movement of pallets (as described in Chapter 19), AGVs and AMRs may be used for transporting cartons and tote bins (see Figure 20.3), plus large loads such as car bodies and paper reels. In the latter case, instead of being fitted with roller conveyors to move the load, they may have ‘cradled’ belt conveyors to hold the reels and to move the reels on and off.

In addition to wheeled AMRs, similar platforms may be used based on magnetic levitation (maglev) technology. This type of system relies on magnetic fields to repel the platforms from tiles in the floor so that the platforms are suspended in the air and can thus move freely.

Hanging garment storage and handling systems

These are specialist systems for storing and handling garments on hangers, as shown in Figure 20.4. It is possible for garments to be transported in a hanging condition all the way from garment manufacturers in source countries such as in the Far East through to shops in, for example, the United States or Europe. Road vehicles and ISO shipping containers can be fitted with hanging rails, and warehouses can employ

Figure 20.3 Autonomous mobile robots (AMRs) used for transporting tote bins



SOURCE Knapp

Figure 20.4 Hanging garment system that can also be used as a pocket sorter (described in Chapter 21)



SOURCE Vanderlande

hanging garment systems for storage and for sortation to the individual shops. These systems may be manual in nature or may be highly automated, with garments being put away to reserve storage rails and then order-picked to customer orders automatically under computer control. These activities are based on overhead conveyor systems, as described above, controlling the hanging garments either singly or in batches. The individual garments may be identified by, for example, barcodes, vision systems or radio frequency identification (RFID) tags and, based on this information, the garments may be sorted at the rate of several thousand per hour. Such systems can be combined with pocket sorters (see Chapter 21) so that hanging and flat-pack garments can be handled together.

Order picking and packing

21

Introduction

Order picking represents a key objective of most warehouses: to extract from inventory the particular goods required by customers and, normally, bring them together to form a single shipment – accurately, on time and in good condition. This activity is critical in that it directly impacts on customer service, as well as being very costly. Order picking typically accounts for about 50 per cent of the direct labour costs of a warehouse.

Customers may require goods in pallet, case or unit quantities. In the case of pallet quantities, goods can be extracted from the reserve storage areas and brought directly to the marshalling area by the types of equipment described earlier (e.g. by a reach truck or a combination of stacker crane and conveyor). This chapter is therefore chiefly concerned with case and unit picking operations. For example, cases may be picked from pallets held in ground-floor locations for specific customer orders or individual units may be picked from plastic tote bins held on shelving. These would then typically be sorted into customer orders, packed (if necessary) and moved to the marshalling area to form vehicle loads ready for dispatch.

Order picking concepts

There are three main picking concepts that may be applied. These are:

- *Pick-to-order*. This is basically where a picker takes one order and travels through the whole warehouse (e.g. on foot or on a truck) until the entire order is picked. For example, in retail food distribution centres it is quite common for order pickers to take one or more roll-cage pallets and fill these with goods just for one store. The pickers may do this for goods located across the entire warehouse or just for their particular zone (see ‘zone picking’ below). Another type of pick-to-order is where pickers have separate compartments or containers for a number of orders on their trolley or roll-cage pallet. They may then pick-to-order for a

number of orders simultaneously, placing goods for each customer into a specific compartment.

- *Batch picking.* The main disadvantage of a pick-to-order regime is that pickers typically walk the entire pick face for a single order. In situations where a typical order may only have a few order lines (i.e. only a few different SKUs being ordered) and where the product range is very large, then this would be very inefficient. It is therefore common, particularly for small orders, to batch these together and pick the total requirement of all the orders for each SKU on a single picking round. This method can achieve great benefits in terms of picking time, but of course the goods then need to be sorted at the end of the picking run into the different customer orders. This sortation may be undertaken either manually or using automated sortation equipment.
- *Pick-by-line or pick-to-zero.* Under this concept, the exact numbers of cases or items are presented for picking. For example, they may be brought forward from the reserve storage area or they may be specifically ordered from suppliers for cross-docking. In both instances, the unit load of one product line is picked to waiting customer orders (hence pick-by-line) and the picking continues until that line is exhausted (hence pick-to-zero).

There are a number of factors that need to be considered in determining which of the above concepts to use; for example, the product range, the size of order, the picking equipment, and the size of unit load or container into which orders are being picked.

In some situations it may be appropriate to make use of a combination of two or more of the above picking regimes within one picking system. A typical warehouse order will require just one or two slow-moving products, but a large quantity of fast-moving popular products. In this situation the picking area may be laid out with popular products near the dispatch area to minimize movement, with the less popular products, which require fewer picking visits, further away. If pick-to-order is used, the slow-moving products could add significantly to the distance travelled by the pickers. In this situation, the possibility of pick-to-order for the most popular products could be considered, with batch picking being used for the less popular slow-moving products.

Zone picking

This is where the warehouse is split into different zones with specific order pickers dedicated to each zone. On receipt of a customer order, the warehouse management system (WMS) would typically examine each order line (i.e. SKU) on the order and identify in which zone the picking face for that SKU is located. The WMS would then

issue separate picking instructions to each zone. When the goods have been picked, they would of course all need to be collated together ready for packing (if necessary) and dispatch.

This method may be appropriate where different equipment is used for picking different types of product, where a single order would be too great a quantity for one picker to pick, or where the dispatch times mean that all the order lines must be picked quickly. It is also used where there are different physical zones for products, for example where products are separated for reasons of security, hazard or temperature regime.

Another approach to this concept is to pass a receptacle (e.g. a tote bin on a conveyor) from one zone to another. A picker would just pick the items required for an order from that zone and then pass the receptacle to the next zone. This would continue until the order is complete. This method can lead to work imbalances between zones so that on occasions some pickers have nothing to do while others are overloaded. There are several ways to overcome this, such as varying the boundary between zones. For example, a picker may push a roll-cage pallet around a pick face and then pass it to the next picker when they meet rather than at a fixed point. Another method is to replicate pick faces for fast-moving items in a number of zones and these fast movers are allocated for picking at a zone whenever the WMS calculates that the order picking load on that zone is light. This would vary wave by wave (see following section).

Zone picking may occur with either pick-to-order or batch picking (or, indeed, pick-by-line) techniques.

Wave and waveless picking

Orders may be released in waves (for example, hourly or each morning and afternoon) in order to control the flow of goods in terms of replenishment, picking, packing, marshalling and dispatch. The timing of the waves is determined by the outgoing vehicle schedule, so that orders are released to allow enough time to meet this schedule. Note that orders may not be released at the same time to each zone. For example, some zones may require a long time for order picking whereas a small range of high-security items may be picked just before dispatch. The use of waves allows for close management control of operations such as sorting and marshalling, which may be limited in terms of how many orders can be handled at the same time.

However, there are certain drawbacks to wave picking, particularly in the case of omnichannel fulfilment where flexibility and very short order cycle times are required. Together with the complex mix of automated equipment, robotics and labour in such facilities, it is very difficult for planned waves to ‘push’ work through effectively, as some warehouse zones may be waiting for the next batch of orders. The term ‘waveless’ picking is now used to describe more of a ‘pull’ approach whereby

decisions are taken in real time depending on the exact resources available and the urgency of particular orders. Under this type of system there is continuous order releasing, typically driven by optimization software based on the workloads of the various replenishment, picking, sortation, packing and marshalling operations.

Order picking equipment

There is a very wide range of order picking equipment available, from simple trolleys that may be pushed around by pickers to much more advanced equipment such as fully automated dispensers and robotics. The different equipment types may be classified under five main categories: picker to goods, goods to picker, goods to robot, robot to goods and automated systems.

Picker to goods

This category involves the order picker travelling to the goods in order to pick them. As with all picking categories, consideration needs to be given as to what storage equipment the picker is picking from (e.g. shelving, carton live storage or pallet locations), what equipment the picker is picking to (e.g. trolley or powered pallet truck) and what the picker is picking into or on to (e.g. wooden pallet or roll-cage pallet). The following is a list of common picking equipment types, based chiefly on what the picker is picking to:

- *Trolleys and roll-cage pallets.* With this method, the picker pushes a trolley (or roll-cage pallet) around the picking area and selects goods from, for example, shelving, ground-floor pallet rack positions or pallets set out in rows on the floor. A trolley (also often known as a pick cart) normally has a shelf, or shelves, on which to place the goods or it may be in the form of a frame for holding plastic tote bins or cartons. Roll-cage pallets are normally taller and have wire mesh on three sides, with or without a mesh door on the fourth side. Roll-cage pallets may form a common unit load for both picking and transport, and are often used, for example, in the food retail industry for this purpose. The roll-cage pallets may therefore be moved directly to the marshalling area after picking ready for loading on to the vehicles. This type of picking is normally conducted at ground level or on mezzanine floors. Although these are manual methods, high pick rates can be achieved in appropriate circumstances and the whole picking operation can be very effective. In some warehouses, ladders may also be used particularly for locating slow-moving lines at high levels. However, there are health and safety issues concerning the use of ladders and therefore it is often best to avoid, if possible, warehouse designs that involve their use.

- *Powered order picking trucks.* These are electrically-powered trucks that have forks, often carrying two wooden pallets or three roll-cage pallets, on to which picked goods may be placed. They are often also known as low-level order picking trucks (LLOPs). It is common to use these for picking from ground-floor pallet locations, either from pallets placed in rows in a forward pick area or from the ground level of wide-aisle adjustable pallet racking (see Figure 21.1). The ground-floor pallet positions normally comprise pallets resting on the ground but these positions may be fitted with shelving to hold cartons where a whole pallet is not required in the pick face. Pull-out units can be fitted so that pallets or carton shelving can be pulled out into the aisle by the order picker to facilitate access to the goods, particularly where the beams are too low for the picker to reach easily underneath. Some trucks are fitted with a step or elevating platform and are therefore also suitable for picking from the pallets placed on the first beam level of racking.

Figure 21.1 Order picking onto a low-level order picking truck (LLOP)



SOURCE Linde

- *Collaborative autonomous mobile robots (AMRs).* These are often known as ‘cobots’ (short for collaborative robots). Instead of picking staff having to push a trolley or get on and off a powered order picking truck, a cobot can travel autonomously to pick locations, using the type of navigation technology described in Chapter 19 under ‘AMRs for pallet movement’. The cobot can thus lead an

order picker on the optimum pick route so that the picker can spend his/her time picking the actual goods rather than also having to drive or push a truck or cart. The cobot can have a display (e.g. to instruct the picker how many items to pick and show photographs of the required items), a barcode scanner, lights to shine on the pick location and LED lights next to the receptacles so that the picker knows exactly where to put the items. When the pallets or receptacles (e.g. cartons or tote bins) on the cobot are full, the cobot can then transport these to the dispatch area and a new cobot meets the picker, so that the picker can continue picking without interruption.

- *Monorail picking systems.* A further alternative is to place a picking receptacle, such as a pallet or roll-cage, on a carrier suspended from a monorail system. The receptacle (e.g. pallet) could be taken to different parts of the warehouse in the exact sequence that would, for example, make up a stable load or make best use of the pallet space available. The pallet would thus not necessarily follow a normal picking route. It may in fact visit the zone a picker is responsible for two or more times in the pick sequence. As the pallet is being moved by an automated monorail system, this would not adversely affect the walk distances, and hence the productivity, of the pickers. In addition, the monorail system can aid the picker by, for example, automatically lighting the pick location and showing on a screen exactly where the picked carton should be placed on the pallet. The carriers can also incorporate automated weighing equipment so that pickers could be notified of any discrepancy between the expected and actual weight of the picked goods at the time of picking. Special compartments on the carriers can be used for taking empty pallets, shrink wrap and other packaging from the pick area.
- *Free-path high-level picking trucks.* Goods may be picked from upper levels of racking, or from high-level shelving, by means of free-path high-level picking trucks. These trucks have an elevating cab position so that the picker is lifted to the ideal height for picking. These typically operate in narrow-aisle environments, but some are also designed to operate in reach truck, or wider aisles. Some narrow-aisle trucks can operate for both pallet put-away and retrieval as well as for order picking. There are other specialist designs, for example trucks with two masts that raise a platform so that two pickers can operate at high levels and pick large items such as sofas. High-level picking is suitable where, for example, goods may need to be picked from any pallet in the warehouse (e.g. where there is typically only one or two pallets per SKU). However, picking rates are lower than for ground-level picking and pick effectiveness may be further restricted by only one truck at a time being able to pick in a narrow aisle.
- *Fixed-path high-level picking trucks.* These are similar to free-path trucks, except that they run on a bottom rail and are also guided by a top rail – thus being similar to an AS/RS crane operation. These tend to be faster in operation than

free-path trucks. They are suitable, for example, for picking from high-level shelving where a multitude of SKUs may be stored in small quantities. They may be manually operated or be directed by computer.

- *Conveyors.* A number of picking operations make use of conveyors. For example, pedestrian pickers may select the required items from flow racks, shelving or pallet locations and place them on to conveyors to be taken away for subsequent picking, packing or collation into customer orders. Zone picking is often used in these operations so that an order picker would just pick items from a specified section of flow rack, shelf or pallet locations. In the case of 'pick-to-tote' or 'pick-to-carton' systems, the goods are placed in plastic tote bins or cartons on the conveyor which then takes them to the next zone for further picking. In 'pick-to-belt' systems, the goods are placed directly onto the conveyor belt and transported to packing or collation.
- *Dynamic pick face.* Frequently, orders are not received at one time for the full range of goods held in a warehouse. Thus, pickers are travelling past many SKUs that are not required by any order at that time. The basis of a dynamic pick face is that only those goods that are required, for example in that picking wave, are placed in the picking aisles. This results in a condensed pick face and thus reduced travelling time. Miniload systems may be used to extract the required tote bins and bring them forward to a pick face ready for picking. The picking may then be undertaken manually, for example from the product tote bins brought forward by the miniload to 'order tote bins' on a conveyor. Another approach is to use a 'shelf modules-to-picker system' (see page 326) using AMRs to transport shelf units of required SKUs to form a 'pick wall'. Dynamic pick faces are normally used for the slower-moving lines that are ordered infrequently, as the fast-moving lines tend to be required for every picking wave and are thus allocated permanent picking locations. Note that dynamic pick faces can be assembled using conventional means by, for example, reach trucks bringing pallets forward to the pick area.

It is not uncommon for travel time (i.e. the time taken for a picker to move from one pick location to another) to take up 50 per cent or more of the picker's time. The next largest element is often the actual picking of the goods, and a third element is carrying out the information requirements (e.g. ticking a paper pick list, placing a label on the goods, and barcode scanning activities).

Goods to picker

It is inefficient for a picker to travel the whole length of a pick face if a relatively small proportion of the total product range is to be picked during that pick run. Various types of equipment have therefore been devised to bring goods to the

picker rather than the other way round. These goods-to-picker systems are normally computer-controlled so that the precise SKUs are presented to the picker in the required sequence.

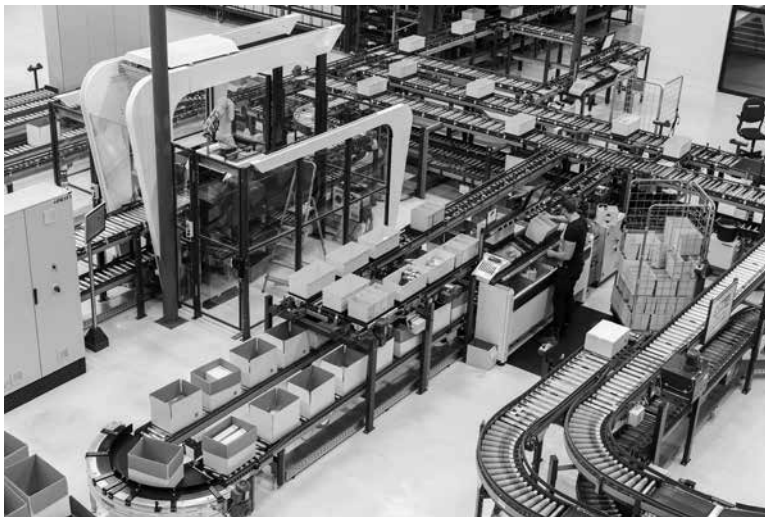
There is a wide range of equipment but some of the main types are as follows:

- *Horizontal and vertical carousels.* These are often arranged in modules of two or three carousels so that the picker can pick from one carousel while the other(s) is, or are, rotating. It should be noted that goods are presented at the ideal picking height for the picker in the case of vertical carousels (see Chapter 20 for detailed descriptions of carousels).
- *Miniloads.* These may be used for full carton picking or for presenting cartons, or tote bins, to an individual picker at the end of a miniload aisle. Any remaining goods are then returned to the miniload storage (see Chapter 20 for further details). Where more pickers are required then a totes-to-picker system is used, as described below.
- *Totes-to-picker systems.* Tote bins (or cartons) are transported to pick stations which are typically designed ergonomically for high picking performance with minimum bending and twisting and with technology aids such as pick-by-light and put-to-light (see page 338). The tote bins are normally presented at the pick station so that the picker can take the required number of items and place them in a tote bin (or carton) on a conveyor below (see Figure 21.2). There are normally a number of tote bins at a low level in front of the picker so that a number of customer orders can be picked simultaneously. The original tote bin on the upper conveyor is then either forwarded automatically to another picker requiring that SKU or returned to storage. The 'order tote bin' at the lower level is transported (often by conveyor) to the packing or collation area when that order is complete. The original tote bins may be extracted from a variety of storage systems (described in Chapter 20) and by various means, for example:
 - *Miniload (served by cranes):* tote bins may be extracted by miniload crane, placed on a conveyor and transported by complex conveyor systems to each of the pick stations in turn requiring that SKU. After picking, the tote bins, containing the remaining goods, are returned to the miniload in the same way.
 - *Miniload (served by shuttles):* where the miniload is served by shuttles at each level rather than by cranes, the tote bin would be extracted by a shuttle, lowered to ground level by lifts at the end of the aisles, and then placed on a conveyor system for transfer to the pick stations.
 - *Miniload (served by free-ranging robots):* in this case, the free-ranging robot is able to travel horizontally and vertically up the racking to access the tote bin, take it down to ground level and then travel autonomously on the warehouse

floor directly to a pick station. At the pick station the free-ranging robot could go up a slope to present the tote bin at the required picking level or do this by a self-contained scissor lift.

- *Multi-level grid systems*: tote bins extracted from a multi-level grid system (see Chapter 20) can be transported by conveyor to the required pick stations, as described under ‘miniload (served by cranes)’ above.
- *Shelving (served by autonomous mobile robots)*: autonomous mobile robots (AMRs) with self-contained scissor lifts (or similar) may be used to extract tote bins or cartons from the different heights of conventional shelving. These AMRs would travel to the appropriate location, lift the extraction tool to the required height and take the bin or carton out by using suction pads, by gripping the sides (and sometimes back) or by lifting it from underneath. The AMR may have space for a number of tote bins. When the AMR is full, it would transfer the tote bins on to a conveyor system or take directly to the pick stations.

Figure 21.2 Totes-to-picker system on the left and totes-to-robot system on the right



SOURCE Knapp

- *Pallet-to-picker system*. These may be based on AS/RS (see Chapter 19) and typically operate in a similar way to that described for miniloads above, except that pallets are presented to the picker. However, care has to be taken that throughput requirements can be met and that storage utilization is not adversely affected by the return of many part-empty pallets. The same type of operation can of course be performed using reach trucks from wide-aisle APR.

- *Shelf modules-to-picker systems.* A further system available is one that brings complete shelf modules (e.g. about 1 metre in length, comprising about two to five shelves) to the picker. This is undertaken by autonomous mobile robots (AMRs), in this case often known as robotic drive units, ‘bots’ or robotic butlers, that move to beneath the required shelf module and then raise this and transport it to the appropriate pick station. At the pick station, the picker extracts the required goods and places them into one of a number of cartons or tote bins each representing separate customer orders. The picker is thus presented with a continuous stream of shelf modules to pick from. At the same time, the picker could be directed to replenish the shelves with goods sent to him/her from the receiving area. If necessary, the shelf units are fitted with restraints across the front of each shelf so that items do not fall while the unit is being moved. Storage cubes, with soft flexible shelves, may also be used instead of rigid shelf modules. These typically have access for the picker on all four sides of the cube.

Goods to robot

Instead of bringing goods to human pickers, goods may be transported to *robotic pickers*, for example in a totes-to-picker system (see Figure 21.2). The robots need to recognize the different SKUs, observe their orientation in the pick bin and then decide what tools to use and how to pick them up. Such robots often have articulated robotic arms and use gripper or suction tools. They typically have vision (e.g. camera), audio and/or tactile systems to acquire information about the items. The robots may be taught the basic actions of how to pick up different items by means of virtual reality by a person using a teaching pendant. The robot maps the motion it must perform in different circumstances onto its neural network (which may be cloud-based and thus available to other robots). It will enhance its performance over time by means of machine learning, or more specifically deep learning, which are forms of artificial intelligence (AI). In this way, a static robotic picker can be used in place of a person at a picking station.

Robotic palletizers are often used at the end of production lines to build pallets of particular SKUs in designated patterns that maximize the pallet space and provide good stability during transit. The pallets are then normally taken (e.g. by conveyor) to the reserve storage area of a warehouse. Within the warehouse, robotic palletizers may be used in a similar way to build dispatch pallets of mixed SKUs (often called ‘rainbow pallets’) for a specific customer order. This operation has the added complexity of stacking different size cartons on to a pallet so as to maximize the cube of the pallet and avoiding the crushing of fragile items, while providing a stable load. Similar robotic arm equipment is used to stack tote boxes onto dollies (i.e. wheeled platforms) ready for dispatch to stores.

Robot to goods

Various technologies have been described above where ‘robots’ travel around the warehouse to pick up shelf units, tote bins and cartons and transport them to a pick area for picking by a human, or where they travel alongside a human picker as a collaborative robot (‘cobot’). However, by combining the navigation technologies described under ‘AMRs for pallet movement’ (in Chapter 19) and the robotic picking technologies described under ‘goods to robot’ above, *mobile piece-picking robots* can be used to travel autonomously to pick locations around a warehouse and pick the required items. These items may be placed onto a pallet or into a receptacle (such as a tote bin or carton) carried on the robotic picker and, when full, these are then taken to a conveyor, to packing or to a collation area. The mobile piece-picking robots could also work in conjunction with ‘cobots’, described earlier, which would undertake the transport of the pallet or receptacle so that the mobile piece-picking robot can continue picking. Mobile piece-picking robots often work in specific aisles away from people but, if it is possible to put in place sufficient safety systems (such as laser sensors), they could be used in proximity to human pickers.

Automated systems

The picking systems described so far all require a person or robot to pick the individual items that make up an order. However, there are non-robotic automated picking systems available that are suitable for certain applications. These are mechanical systems that perform specific operations in predictable circumstances and do not need to act autonomously to overcome unforeseen difficulties. These automated picking systems include:

- *Layer pickers.* Cases are normally stacked on to pallets in layers. In some industries, such as fast-moving consumer goods, price differentials are offered to customers based on whether they order in pallet, layer or case quantities. In such cases, it may be beneficial to automate the picking of layer quantities. Typically, a pallet is brought forward from the reserve pallet store (e.g. by AS/RS and conveyor) to a layer picking machine. This machine would lift off the top layer (e.g. by suction pads) and place it on to a pallet that is being assembled for the customer order. The product pallet would be returned to the reserve store and another pallet would be brought forward and the process repeated until the customer pallet is filled with all the layers required. The layer picking machine often has three sections: one for the product pallet; one for the customer pallet being assembled; and one for empty wooden pallets that will form the next customer pallets.
- *A-frame dispensers.* These typically comprise two lines of near-vertical magazines positioned over a conveyor in the shape of an ‘A’. Each magazine contains a single

SKU with the individual items or cartons stacked vertically. This equipment is well suited to small items of a regular shape or size (e.g. small pharmaceutical cartons, toothpaste in cartons, etc). The items may be dispensed automatically from the magazines into a tote bin as it passes on the conveyor below. This tote bin may represent a customer order and then be conveyed directly to packing. Alternatively, the items may be dispensed directly on to the conveyor. They may then either pass through a sorter for automatic sortation or a specified length of conveyor belt may be reserved by the computer system for an order and the relevant items dispensed on to this section of conveyor. At the end of the A-frame conveyor, the items are then tipped into a packing case or similar receptacle, often placed on a conveyor running at right angles to the A-frame conveyor. Although the picking is completely automatic, the replenishment operation, to refill the magazines, is manual. This type of equipment can achieve very high throughput rates.

- *Small-item dispensers.* These often operate on the same principle as miniloads. Small computer-controlled cranes with extraction devices (or robotic arms) retrieve trays containing small items, or grip items directly, and place into a picking box carried on the crane (see Figure 21.3).

Figure 21.3 Small-item dispenser



SOURCE Knapp

Order picking equipment choice

Decisions related to which order picking equipment should be chosen for a given situation depend on many factors, such as the scale of operation, the size of the items, the breadth of product range, the stockholding levels and the level of

throughput of each item. In fact, it is quite common to select a number of different types of order picking equipment each appropriate to specific SKU groupings based on these factors. For example, different order picking equipment may be appropriate for small fast-moving products as compared to large slow-moving products. A decision tree is therefore shown in Figure 21.4 to provide some assistance with these choices. It should not be followed rigidly but can help to narrow the choice down to a few feasible options which can then be analysed in more detail.

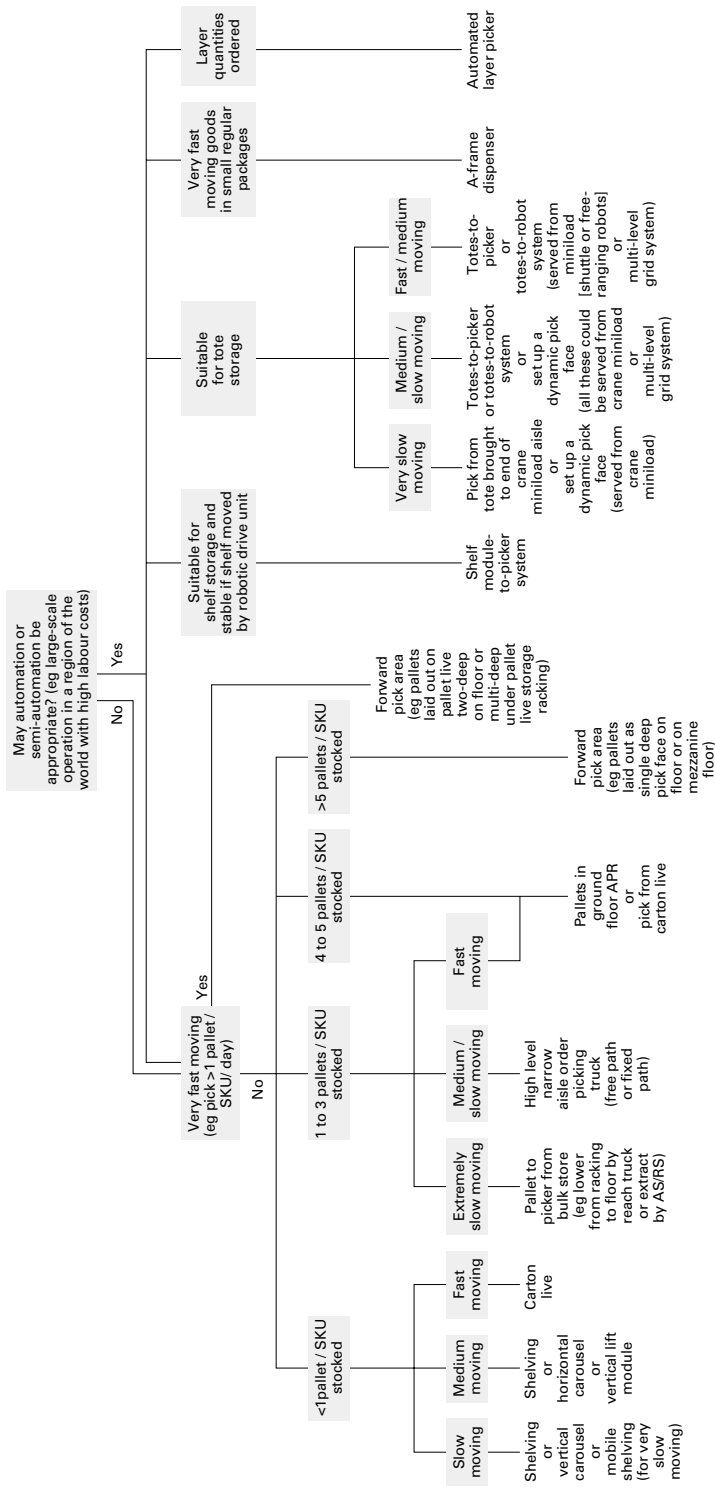
The first question on the decision tree refers to whether or not automation (including robotics) may be appropriate, as this can often be ruled out in regions of the world where labour costs are low. Large scale operations tend to favour automation, particularly 24/7 operations. However, even small-scale operations such as back-of-store (i.e. back-of-shop) or local fulfilment centres may be suited to *micro-fulfilment* solutions, such as goods-to-picker systems. If automation could be an appropriate solution then it is recommended that both conventional and automated options are compared, in which case both pathways should be followed on the decision tree. In addition, there are various semi-automation opportunities within the scope of conventional solutions. For example, order picking could be carried out from ground-floor pallet positions within adjustable pallet racking with picked items being loaded onto roll-cages that are pushed manually. Alternatively, pickers may use powered pallet trucks, cobots or carriers on monorail systems or pick directly on to conveyors.

It should be noted that the decision tree focuses on what storage medium the goods should be picked from and, as seen from the example just mentioned, there may be various options as to what mobile equipment may be used to load the picked items on to. Similarly, there may be an option as to whether a human or a robot should undertake the actual picking. When following the decision tree, it should be noted that decision points such as '1 to 3 pallets / SKU stocked' relate to individual SKUs within the SKU grouping being considered. Thus, equipment under this pathway may be appropriate for a SKU grouping of a thousand SKUs each of which has a stockholding of between one and three pallets.

Sortation

If goods have been batch picked, then they will need to be sorted into the relevant customer orders. This may be undertaken manually or by automated/robotic sortation equipment. Similarly, goods that have been zone picked will need to be brought together into the relevant orders. This may be a much simpler operation (i.e. depending on the number of zones) but may still be undertaken either manually or with the assistance of some form of automated sortation. Common forms of manual sortation include:

Figure 21.4 Decision tree for order picking equipment



- *Put to unit load.* Batch or zoned picked goods may be brought (e.g. by pick cart or conveyor) to a warehouse operative who may sort the items to nearby dispatch unit loads (e.g. cartons or roll-cage pallets). For example, a batch pick of six customer orders could be routed to an operative stationed at the end of a conveyor spur and he/she would place each item into one of six roll-cage pallets positioned within easy reach.
- *Put wall.* Batch or zoned picked goods could be brought to a 'wall' made up of shelving cubicles, with each cubicle representing a particular customer order. A warehouse operative would then place each item in the appropriate cubicle, possibly with the aid of put-to-light or voice technology (see later in this chapter). There can also be lights on the back of the pick wall to indicate when an order is complete. The finished orders would then be extracted from the back of the shelving, ready for packing or placing into a dispatch unit load (e.g. roll-cage pallet).

Sortation typically occurs immediately after picking so that items can be assembled into the appropriate orders ready for packing or dispatch. However, sortation may also occur after packing so that the packed goods can be assembled into vehicle loads (or into postcode areas ready for postal or express parcel deliveries). It should be noted that single-line orders (which are common in many e-fulfilment operations) should bypass sortation and be sent directly to packing.

Mechanized sortation can be undertaken as an integral part of conveyor systems. For example, a conveyor may sort to different packing stations by means of pop-up wheels that are raised when the required case goes past a conveyor spur. The wheels are then powered at that moment and the case is diverted down that spur.

However, for high-speed sortation, conveyors normally feed directly into specialist sorters. These are normally set out in a line or loop so that product (e.g. individual items or cases) move past numerous chutes until they reach the one that they are destined for (e.g. representing a particular store or vehicle load). Product is normally identified by means of an automatic recognition system (e.g. barcode scan or camera-based imaging) and diverted down that chute. Alternatively, there can be manual in-feed stations where a warehouse operative may scan one item from a particular SKU in a tote bin of batch picked goods and be advised on a screen how many items of that SKU to place on the conveyor at that point. This item-by-item in-feed task could also be undertaken by a robotic arm. If a particular item is not recognized on the sorter, for example because of a defaced barcode, then that item would be diverted down a reject spur for manual intervention. Sorters may also be used for cross-docking (see Chapter 22). They can achieve very high throughput rates. There are a number of sortation systems available including:

- *Sliding shoe sorters.* There are 'shoes' located at the edge of the conveyor. When the goods reach the appropriate destination point, the shoes slide across to divert

Figure 21.5 Sliding shoe sorter

SOURCE Vanderlande

the goods down that spur (see Figure 21.5). These are suitable for cartons and tote bins of regular shape and reasonable rigidity. Typical operating rates are about 6,000 or more sorts per hour.

- *Rotary arm sorters.* These are similar in principle to the above but have rotary arms at the edge of the conveyor which can rotate across the conveyor and push goods down the appropriate spur. Throughput rates are similar to the above.
- *Bomb-bay sorters.* These hold goods in receptacles that have opening bottoms releasing the goods in the same way as a 'bomb-bay' on an aeroplane. These are suitable for goods that may be dropped vertically, for example, small packages into mailbags for postcode sortation. An advantage of this type of sorter is that less space is needed as there are no chutes or conveyors to either side of the sorter. A typical throughput rate is about 6,000 to 10,000 sorts per hour.
- *Tilt-tray sorters.* Tilting conveyors are usually laid out in a horizontal circular configuration, with a series of tilting trays or slats fitted to a conveying chain, and capable of tipping loads off to left or right to branch conveyors or to off-take chutes. The slats can be tilted singly or in multiples according to the sizes of load being handled. Tilting conveyors are used for high-speed sortation operations, such as parcel distribution and for some cross-docking installations. The effectiveness and speed of these applications depend on information technology

and coding systems such as barcodes. Each load is identified as it enters the system, which then instructs the conveyor to discharge the load to its designated destination. Sorting rates typically quoted are between 15,000 and 20,000 units per hour per installation, but the rate is dependent on the size of installation, the number of in-feed points and the number of destination off-take chutes or conveyors. These sorters are suitable for a wide range of products with non-stick bases, although normally the items conveyed should be of a similar weight.

- *Push-tray sorters.* These are similar to the above but a bar comes across the tray to push the item down the required chute.
- *Cross-belt sorters.* These comprise a series of mini conveyor belts aligned at 90 degrees to the direction of travel. The appropriate mini conveyor belt starts up when the item reaches the required off-take destination point. This forms a positive movement and is therefore suitable for a wide range of items. Sort rates are similar to those of tilt-tray systems.
- *Pocket sorters.* Items are placed manually into pockets suspended from an overhead conveyor system (see Chapter 20, Figure 20.4). This can be undertaken at the pick location itself or at an in-feed station following picking. Each pocket is typically identified by radio frequency identification (RFID) and is then sorted automatically so that all pockets containing items for a specific order arrive at the packing station together. The system often incorporates an area of buffer storage where items are held awaiting all the other items to be picked for that order. This buffer storage of pockets can also be used to hold returned goods, particularly for fast-moving items that are returned in good condition and can therefore be resold immediately. In addition, this system can be integrated with hanging garments so that both hanging and flat-pack garments, as well as other types of goods of a similar size, can be handled on one system.
- *Autonomous mobile robot (AMR) sorters.* These act in a similar way to tilt-tray or cross-belt sorters except that instead of the trays or cross-belts being on a conveyor, they are fixed to individual AMRs. An AMR can therefore collect the goods from an induction station for example and then take the goods to the sortation area. It would then transfer the package down an appropriate chute or into a receptacle for the customer order or delivery zone.
- *Robotic put wall.* In such systems, goods may be batch picked and taken (e.g. by conveyor) to a robotic piece picker, which is surrounded by numerous locations on a circular wall. Each location represents a specific customer order. The robotic arm picks up each item and sorts to individual orders by placing each item in to the appropriate location, ready for taking away to packing or dispatch by a warehouse operative.

Many of the above sorter types can be stacked two or more high to make use of available warehouse height.

After goods have been brought together for an order, either by sortation after a batch pick or as part of a pick-to-order operation, then the order may need to be verified prior to dispatch. This is sometimes carried out manually as part of the packing operation (see ‘Packing and added-value services’ section later in this chapter) or it can be conducted automatically – for example, by order verifying equipment that can optically record information on all six sides of cartons (e.g. from barcodes or matrix codes), count the number of cartons, and/or read RFID tags as they pass along a conveyor (see Chapter 24 for more details of these types of technology).

Picking area layout

The layout of the picking area is critical to achieving high levels of productivity. One of the first decisions that needs to be taken is whether to have separate reserve inventory and picking locations for individual SKUs or to combine all the inventory into a single location. This will largely depend on the total amount of inventory for an SKU. For example, in the case of small electronic items the total inventory may fit in a small tote bin and therefore it would be sensible to have a single location, whereas there may be many pallets held of a particular retail food line and it would not be practicable to hold all of these pallets in picking positions.

The general principle is that picking stock should be concentrated into the smallest feasible area, so as to minimize picking travel time between the SKUs. Reserve inventory therefore needs to be held separately in many instances.

The separation of reserve and picking inventory may be vertical, e.g. pick from racking at ground-floor level with reserve stock on the higher racking levels, or horizontal, with reserve stock in one area and picking in another. In the latter instance, it is fairly common for picking activities to be conducted at multiple levels using mezzanine floors, so as to use the full height of the building.

Another approach is to construct ‘pick tunnels’ with, for example, two-deep pallet flow racks on either side (or a number of levels of carton flow racks) at ground level. Reserve stock is then stored above, extending over the pick aisle to form a tunnel. This reserve stock may extend three or four pallets deep from either side, and therefore satellite or push-back racking could be used, accessed from aisles adjacent to the pick aisle and then fed into the back of the flow racks. Frequently, a carton conveyor extends through the pick tunnel to take away the picked cartons for sortation.

Pick face size

Where inventory is split between picking and reserve locations, then a decision needs to be taken as to the amount of inventory to place in the pick location. This is a

trade-off, as having small pick locations would reduce the pickers' travelling time (and pick location equipment costs), while having larger locations would reduce the replenishment effort to maintain product in the pick locations. If all these costs are added together for different size pick locations, the total costs would typically form a U-shaped curve on a graph and the optimum size can be determined by the lowest point on this curve.

These costs will vary by equipment type and a common solution to minimizing the pickers' travelling time and, at the same time, reducing the replenishment workload is to use carton live storage, so that a good depth of inventory can be held within a small picking face. A similar total cost approach can be used in this instance to identify the optimum depth of carton live storage – as well as the number of lanes per SKU, as fast-moving lines may be allocated more than one lane of carton live storage.

Slotting

The 'slotting' of inventory is a term used for identifying which SKUs should be placed in each location. In picking, a very common approach is to use the Pareto principle: ranked by units sold or, more normally for picking, ranked by the number of order lines for an SKU during a set period. The most commonly ordered SKUs would therefore be placed in the locations that can be most readily accessed.

Another, more sophisticated, method is to consider the 'value' of a pick face run and to try to calculate how to make best use of the most valuable runs of shelving or racking (e.g. those nearest the start and finish of the pick runs). This is undertaken by calculating the 'cube per order index' (COI) of each SKU and then ranking these in order. The calculation is basically the ratio of an SKU's storage space requirement at the pick slot to the frequency of pick accessions. It thus allocates the most valuable space next to the start/finish points to the most frequently picked SKUs that use up the least space. A typical calculation would therefore be:

SKU 1 COI = 1 cubic metre of pick slot space: 100 pick accessions per day = 0.01

SKU 2 COI = 1 cubic metre of pick slot space: 20 pick accessions per day = 0.05

The lower the COI in this case, the better the space is used, and therefore SKU No 1 would be placed nearer the start/finish point. This formula may need to be adjusted for particular circumstances. For example, in some situations it may be more useful to compare pick accessions to the linear metres of shelving required for an SKU.

The most valuable picking area is often referred to as the 'golden zone'. This may be the area nearest the start and finish of the picking run, or locations at the ideal picking height (i.e. about waist height), or a combination of both. However, care

must be taken not to cause congestion by concentrating most of the pick activity in just one small area.

Other slotting approaches include location by:

- *Weight*, so that heavier items are placed at the bottom of the dispatch loads.
- *Store layout*, so that items in roll-cage pallets can be easily placed on to shelves when they arrive at the stores.
- *Products frequently purchased together*, so that walking between locations for such items can be minimized. The slotting can be determined by data analytics of past purchasing behaviour and/or the use of AI to identify and act on such behaviour as it changes over time.
- *Random slotting*. Under this approach goods are placed in locations wherever there is space. This is used with the objective of maximizing the cube utilization of the shelving space rather than minimizing the walking distance of the order pickers. It may be suitable in zone picking where a large number of small items are picked in a single picking run as the picker would have to walk past most of the pick face in any case.

Under the above approaches slotting can be determined by data analytics of the most frequently ordered items, of items frequently purchased together, etc. However, the results would change over time – for example, a fast-moving item may change to a slow-moving item very quickly where fashion is concerned. There is therefore a trade-off between the cost of reslotting items and the benefits achieved by minimizing pick times. Frequent data analysis can be undertaken to identify required changes and to calculate the optimum course of action. Similarly, AI can be used to monitor and act on changes in the demand for individual SKUs while balancing the benefits with the cost of reslotting, learning the best way to do this over time.

Pick routes

Another factor that affects picking productivity in picker-to-goods operations is the actual route taken around the pick face. For example, pickers could go up one side of an aisle and down the other side, or they could pick from both sides of the aisle on one trip. Specific route options include:

- Transversing the entire pick face in a ‘snake’ pattern, going up one aisle, down the next, etc picking from both sides.
- Approaching all aisles from the same end, travelling up the aisle until all goods are picked and then returning to the same end.
- Approaching the aisles from each end in turn, i.e. picking all goods as far as the mid-point of the aisle and then returning to the same end, doing the same in

the next aisle, etc, and then approaching all aisles up to the mid-point from the other end.

- A more sophisticated refinement of the above is to proceed down an aisle picking all required items until it would be shorter to approach from the far end than to proceed to the next item. That item would then be approached from the far end in the second part of the pick route.

Consideration should be given as to which pick route is appropriate for each operation and the warehouse management system (WMS) (see Chapter 24) then needs to be configured accordingly.

Information: alternative methods for order picking

Although travel time is normally the most significant element of overall picking time, the time taken for processing information also needs to be considered. This may comprise reading which location to go to, reading how many items to pick, confirming that the picker is at the right location and/or picking the correct goods, and advising the system of any shortages at the pick face. This information exchange is necessary for the picker to complete the task and also to ensure that the pick is completed accurately. The design of the information exchange therefore needs to achieve high productivity while ensuring high levels of accuracy. There are numerous alternative methods available, supported by varying levels of complexity in information systems:

- *Paper pick lists.* These are printed by the computer system and list all of the SKUs to be picked, together with their location and the number required. The system normally lists these in the sequence of the locations to be visited as per the pick route used. The picker proceeds to pick all the items, noting any discrepancies (e.g. owing to shortages at the pick face) on the paper pick list.
- *Pick-by-label.* With this method, the pick list comprises a series of gummed labels on a backing sheet, printed in the sequence that the items need to be picked. The picker sticks a label on to each item and returns any unused labels to the pick station in order to record any shortages at the pick face.
- *Barcodes.* Barcode scanning is the most common method to confirm pick accuracy. Barcodes may be placed at each location (e.g. on a shelf or on a beam in the case of racking) and the picker then scans this label to confirm that he/she is at the correct location prior to commencing a pick. If the individual products have barcodes, then the picker may be required to scan each label (or to scan the label on one item per SKU picked). This provides a more precise check than location

labels as it also identifies any replenishment mistakes (i.e. where incorrect goods have been placed in a pick location).

- *Radio data terminals.* These can provide online communication between designated warehouse workstations and warehouse management systems, and are therefore often used in order picking. The terminals may be truck-mounted, cart (or cobot) mounted, waist-mounted or fitted to the wrists of the pickers. They are often combined with barcode scanners. For example, a barcode scanner may be fitted as a ring on one or two fingers so that pickers can move goods with both hands free or it may be attached to the back of a glove. The radio data terminals may also show photographs of the items to be picked to help the picker identify the correct items.
- *Pick-by-light.* Normally, in these systems, every picking location is fitted with an LED (light-emitting diode) display panel, controlled by computer. A common application is for a plastic tote bin, representing a customer order, to be taken by conveyor to a specific zone of the warehouse. The barcode on the tote bin is read, and the appropriate LED panels illuminate, showing the quantities of items to be picked for all SKUs required for that order. Having picked the items, the picker presses a cancel button on each location and then uses the conveyor to pass the bin to the next zone. This process continues until order completion. This method can give high pick rates and very high levels of picking accuracy. A combination of pick-by-light and put-to-light is often used in totes-to-picker systems.
- *Put-to-light.* This is similar to pick-by-light, except that it is normally used in the sortation process. For example, a picker may undertake a batch pick and then return to an area of pigeonhole shelving (i.e. a 'put wall'), with each pigeonhole representing a customer order. On scanning a particular product, LED panels illuminate, showing the number of items required for each customer order. LED lights can also be fitted inside each 'cubby hole' to illuminate the relevant locations. An alternative scenario for put-to-light technology is where lights are fitted to picking trolleys holding multiple bins (each representing a customer order). When the picker arrives at a location and scans the location (or item) barcode, the lights on the trolley show how many of that item are required to be placed in each bin.
- *Radio frequency identification (RFID).* If cases or items are fitted with RFID tags, the accuracy of the pick can be confirmed by these tags being read at the time of picking (e.g. by using special gloves for reading tags or by placing a tag reader on the receptacle that the goods are being picked to). This technology is explained in more detail in Chapter 24.
- *Voice technology.* With this technology, the picker can hear voice instructions (in their own language) from the computer through a headset. The picker then selects the required items and speaks through a microphone to confirm the pick. Frequently, a check digit displayed at each location needs to be repeated by the

picker to ensure that the goods have been picked from the correct location. As with pick-by-light, this system completely frees the picker's hands and thus facilitates high pick rates. This technology offers improvements in productivity and shorter training times while maintaining high levels of accuracy.

- *Vision technology.* An alternative to voice technology is for order pickers to wear headsets or 'smart' glasses incorporating a heads-up display (similar to the displays used by fighter pilots, for example). This can provide basic information as to the next pick and can direct the picker to the exact location by means of arrows on the display. The confirmation of the pick can be by an integrated camera reading a product number, barcode or location number and/or by the picker interacting with the WMS by voice. The 'smart' glasses may also use augmented reality (AR), for example, to create 'virtual' put walls avoiding the need for labelling locations and put-to-light technology.

Further details of some of these technologies are provided in the section 'Data capture and transmission' in Chapter 24.

Picking productivity

As order picking can often account for 50 per cent of the staff in a warehouse, picking productivity is a very important component of overall efficiency. It may be measured in quantity terms (e.g. the number of cases or units picked per person per hour) or in terms of the number of locations visited (e.g. the number of SKUs or order lines picked per person per hour).

Comparing pick rates of different warehouses can provide some very diverse results with figures often varying by more than 100 per cent (e.g. 150 cases per person per hour in one warehouse and 350 cases per person per hour in another). This does not necessarily mean that one warehouse is more efficient than the other, as pick rates may vary according to many factors, such as:

- *operational requirement:* item size, number of items per order line, number of order lines per order, product range (i.e. number of SKUs), specific requirements (e.g. labelling, batch number checking), scale of operation
- *equipment:* pick method (e.g. picker to goods or goods to picker), pick height (e.g. ground-level or high-level picking), equipment type (e.g. trolley or electrically-powered order picking truck)
- *management:* motivation (e.g. employee satisfaction, job benefits, incentive schemes), work processes (e.g. batch picking, slotting and pick route methods),

workload balancing (e.g. between warehouse zones), replenishment and stock accuracy

- *information technology*: technology aids (e.g. pick-by-light, voice picking)

Pick rate should not be the sole measure of performance, and other key indicators to be monitored include accuracy of pick, completeness of order fill and timeliness of meeting dispatch deadlines.

Replenishment

Replenishment is the activity of transferring goods from reserve stock (or sometimes directly from goods-in) to the picking face. Both the efficiency and accuracy of picking are greatly affected by the replenishment operation. If picking stock has not been replenished to the pick face then an order requiring that SKU cannot be completed. The picker will have travelled to a pick slot unnecessarily and the customer will be dissatisfied (or the picker will need to return to the slot again once the goods have been replenished). Similarly, if goods have been replenished to the wrong pick slot then the customer is likely to receive the wrong goods (depending on the checking procedures in place).

Replenishment is often triggered when the pick face only has a certain quantity of goods left. However, with this type of system there is always the danger of the location being replenished too early (and thus the goods still in the pick face may need to be double-handled and put on top of the replenishment load) or, more seriously, the goods may arrive too late, with some pickers being unable to pick those goods. This uncertainty can be minimized by the use of real-time computer systems to issue replenishment instructions. In many operations the actual order quantities are in fact known a few hours ahead of picking and therefore a further method is to base the replenishments on the known order quantities for the next pick wave. With this approach, there should be no pick face stockouts occurring even when there is particularly heavy demand for an individual SKU. With waveless picking, the replenishment time may be reduced even further with pick locations being replenished immediately before picking or, in less busy times, when resources allow.

It is important to design the replenishment task not only so that it is effective but also so that it does not interfere with the picking task, otherwise the replenishment operatives may impede, and slow down, the order pickers. This applies particularly to high-throughput operations. Methods to overcome this problem include:

- Setting out separate replenishment and picking aisles. These may be laid out as alternate aisles with, for example, replenishers filling carton live storage from the

rear and pickers picking from the front. A similar layout is possible using ground-level pallet-live storage.

- Undertaking the replenishment and picking tasks at different times of day. For example, if picking is undertaken in the evening ready for next-day delivery then it may be possible to carry out most of the replenishment before the picking task begins. In the case of carousels it is essential that these tasks are undertaken at different times as the same access point is required for both tasks. Another example is where picking occurs from ground-level narrow-aisle racking (which is found in some operations as a result of severe space constraints). While this should be avoided if possible, where it does occur, then low-level order picking should not take place at the same time as narrow-aisle truck put-away and replenishment tasks (for health and safety reasons).
- Having multiple locations for fast-moving goods. With this method, replenishers and pickers are not operating at the same pick slot.

It should always be remembered that successful order picking is dependent on an effective replenishment operation.

Packing and added-value services

In parallel to order picking, some goods may be produced at the warehouse specifically for a customer order. Thus, 3D printing may be undertaken to fabricate either slow-moving or customized goods, from such materials as plastic, resin, metal and carbon fibre. A wide range of goods can be produced in this way, for example machine parts, smartphone cases, fashion accessories and medical goods. Similarly, slow-moving books may be printed-on-demand at the warehouse when specific customer orders are received. Other added-value services may also need to be undertaken, such as labelling, testing, kitting, final assembly or cutting.

After these activities, the goods will often need to be packed. However, in some instances, the goods will have been picked directly into the dispatch unit loads, such as roll-cages or pallets, and therefore in these circumstances there would be no specific packing activity.

Where goods are required to be delivered in cardboard cartons (e.g. by parcel carrier or postal service), then it may be possible to pick the items directly into the cartons. A typical example of this is where the WMS has details of the dimensions of all the items sold and can calculate in advance the size of carton that will be required. The appropriate size carton can therefore be erected (either manually or by machine) for that order and this could then be transferred to each relevant pick zone by conveyor (or by cobot) so that order pickers can pick directly into the dispatch carton.

The cartons can then be forwarded to packers for labelling and sealing, or this may be undertaken automatically by packing machines on the conveyor line.

Frequently, goods are picked in parallel in different zones of the warehouse and are then sorted in order to bring them together for packing. For example, items or tote bins may be conveyed to a sorter that brings the different goods together for a specific order. These will then be conveyed to an individual packing station. Sometimes picked tote bins or cartons are temporarily stored in a miniload and extracted in the required order combinations ready for packing. Alternatively, a number of small single-item orders may be picked together into one tote bin and this may be conveyed to a packing station for placing into a number of small packages. In large operations, there may be many packing stations fed by each conveyor.

The packing stations normally comprise a table on which to work, together with various items of equipment and materials, such as a computer screen that provides details of the order, a printer for labels, various sizes of cartons and envelopes, filling materials or air pillow machine (to avoid the movement of goods within the cartons), tape, adhesives, advertising leaflets and other sundries. There can be pick-by-light shelving within reach of the packers to advise which advertising leaflets, vouchers or other items to insert in each customer package. As people are working at the packing stations for long periods, these must be designed with ergonomics in mind, with tables at the correct heights, chairs and footrests (if seated), and with conveyors, equipment and materials all positioned to avoid twisting, overreaching, bending and awkward lifts. Packing benches may be electric height-adjustable with memory settings for each packer (depending on how tall they are) and for each depth of carton being packed.

Various forms of automated equipment are used for packing, such as print-and-apply labellers, laser-reactive markers (for printing directly on to cartons), closing machines, sealers and banding machines. These may be integrated into the conveyors so that these operations can take place, for example, immediately after manual packing. In-line weigh scales may be incorporated into the conveyors to check weights before and after packing (and thus act as a further check on picking accuracy). There are various specialist packing machines available, including automated small-item packing machines and 'on demand' or 'perfect fit' packing machines. The latter machines avoid the need to hold various sizes of cartons, as each carton is specifically constructed on the machine to fit each customer order. This approach also has the advantage of minimizing the cubic measurements of the cartons, thus reducing transport costs, as well as minimizing the use of void fill materials. Camera-based digital image technology can be used to check and record contents, estimate the amount of void fill materials required, confirm correct labelling, etc.

There are many environmental considerations in the selection of the most appropriate packing solutions, including the use of recycled and/or recyclable package

materials, the type of void fill materials used (e.g. plastic or cardboard), reusable dispatch unit loads (e.g. tote bins and roll-cages) and efficient transportation use (e.g. by minimizing the cube of packages and using collapsible containers).

After packing, the goods may be sent to another sorter in order to sort to post-code, individual carrier, geographic region or vehicle load. The goods are then ready for dispatch.

Receiving and dispatch

22

Introduction

Both the receiving and the dispatch areas of a warehouse are critical to its successful operation. Receiving is important, as it forms the basis for all the subsequent activities of the warehouse. For example, goods need to be passed through receiving rapidly so that they quickly become available for picking customer orders, and this must be carried out with a high degree of accuracy to ensure that the correct goods are received and located in their assigned locations. The dispatch activity is critical, as it is the customer-facing aspect of the warehouse and therefore it must operate effectively to ensure that all goods are dispatched to the customers on time. Operational failures in either of these areas will quickly result in service-level failures, which may be damaging to the company and may be costly to rectify.

Receiving processes

The receipt of goods into a warehouse needs to be a carefully planned activity. In most large warehouses, incoming vehicle loads are booked in advance so that the appropriate resources can be allocated to the activity. On arrival, drivers report to the gatehouse, where staff check the vehicle documentation and direct the driver where to go, either directly to an unloading bay or to a parking area.

The vehicle, or container, doors may be sealed, particularly in the case of imported goods. Where this occurs, the seal number needs to be checked against that advised by the sender so that it can be ascertained whether the doors have been opened during transit (and hence there may be the possibility of loss).

On unloading, the goods are normally checked to ensure that they are the correct items and of the required quantity and quality. This may be undertaken by cross-checking against purchase orders, but this can be very time-consuming. An alternative method is for the sender to transmit an advance shipping notice (ASN) by electronic data interchange (EDI) and for this to be related automatically to the

appropriate purchase order. The goods can then be checked specifically against the ASN for that vehicle. Often, suppliers are graded in terms of trustworthiness and this grading would determine the extent of checking. Thus, a complete check may be performed on a shipment from a new supplier and then smaller and smaller samples of goods could be checked in the future as the supplier proves their reliability in terms of quantity and quality. This is often reinforced by performance monitoring and sometimes by penalties on suppliers for non-conformance. For approved and trusted suppliers, it may be that the quantity and quality can be assumed to be correct as per the ASN, in which case the goods can be unloaded and transferred immediately to storage.

If goods are to be quarantined (e.g. stored until quality control results are available), then this can be undertaken by placing the goods into the normal reserve storage area and using the warehouse management system to ensure that the goods are not picked for any customer orders.

New stock-keeping units (SKUs) should have their details recorded on first arrival at the warehouse so that this information can be used for planning subsequent operations. For example, an item may be placed on a machine that can weigh and scan for each dimension (i.e. length, width and height) and take a photograph of the item if this is useful for the subsequent picking, packing and checking processes. Vision systems may be used to identify any anomalies such as crushed cartons.

Some packages may require some form of processing. This can include:

- applying barcode labels (e.g. attaching licence plate numbers (LPNs) to identify each pallet or sticking labels to each case)
- palletizing (e.g. for goods received loose as cartons, as is common in the case of containerized shipments)
- re-palletizing (e.g. if the pallets are of the wrong type or of poor quality)
- de-palletizing (e.g. placing into tote bins to be put away into miniload storage)

The unit loads then need to be checked, particularly if they are to be put away into an automated storage and retrieval system. For example, pallets may be weigh-checked on a conveyor and then passed through a dimension checking device, which would register any protrusions outside the permitted dimensions by means of photo-electric cells. Any pallets that do not conform (e.g. because the cartons have shifted in transit) are then sent to a reject spur on the conveyor for manual rectification.

When the goods are ready for placing into storage, they may be put away and the computer system advised of the location number or, more normally, the warehouse management system would identify the most appropriate location and issue a put-away instruction (e.g. on a paper put-away sheet or transmitted to a truck driver's radio data terminal). If goods are required immediately by customers (as in the case of new or out-of-stock lines) they may be directed from receiving to picking, packing or dispatch.

A key objective in designing the receiving process is to enable the goods to be put away to the required location in the warehouse with the minimum handling and minimum delay possible. This often requires close coordination with suppliers, in terms of procurement agreements and the timing of deliveries.

Dispatch processes

After order picking, the goods for a particular order need to be brought together and made ready for dispatch. This may involve added-value activities, such as labelling, tagging, testing and packing into cartons. Where production postponement (e.g. final assembly) is undertaken, these activities may be quite extensive.

The goods then need to be sorted to vehicle loads and placed in, or on to, unit loads ready for dispatch. This may be a conventional operation (e.g. loading into roll-cage pallets and then using a powered pallet truck to take the goods to the marshalling area) or it may be automated (e.g. using conveyor sortation and then robots to load tote bins onto dollies, i.e. wheeled platforms). In complex operations, it may be necessary to buffer goods in a miniload system, or similar, ready for release in the correct sequence for the building of dollies or other unit loads. In the case of goods being dispatched on pallets, robotic palletizers may be used particularly where mixed SKU (or 'rainbow') pallets are required. Then the whole pallet may be stretch-wrapped, or shrink-wrapped, so that the goods do not move during transit. The goods are then transported to the appropriate marshalling area, which will have been allocated based on the outgoing vehicle schedule. There may be one or more marshalling areas associated with each loading door. Particularly where large items are required for a customer order, the goods may in fact be brought together for a customer order for the first time directly in the marshalling area. The goods are then loaded onto the vehicle and secured.

Loading is often an activity that needs to take place within a short period of time (i.e. most of the vehicles may need to leave at about the same time of day). This can be alleviated by pre-loading drop trailers, or swap-bodies, during the hours leading up to the dispatch times. In this situation, the vehicle fleet is designed to have more articulated trailers than tractor units, and similarly more swap-bodies than vehicles. The extra trailers or swap-bodies can thus be pre-loaded while the vehicles are still delivering the previous loads.

If a customer plans to collect the goods, then the vehicle load will need to be assembled and held in the marshalling area, awaiting collection. Good coordination is necessary in such instances to avoid the load taking up valuable marshalling area space for longer than necessary.

In the case of temperature-controlled goods, it is important to consider how the dispatch activities are managed, particularly when loading vehicles that are

compartmentalized and thus capable of transporting goods at different temperatures. For example, loading the vehicles at three different loading docks (e.g. at ambient, chill and frozen temperatures) may be very time-consuming, while loading at a single loading dock will require close control to ensure that the temperature chain is maintained.

Cross-docking

Cross-docking is an activity whereby goods are received at a warehouse and dispatched without putting them away into storage. The goods may thus be transferred directly from the receiving bay to the dispatch bay. This normally involves some form of sortation. Goods for cross-docking need to arrive by a strict time schedule linked to the vehicle departure times. The outgoing vehicles may be taking a mix of cross-docked goods (e.g. fresh goods) and stocked goods (e.g. long-shelf-life items), and thus a great degree of coordination is required to ensure that the operation can occur smoothly. If sortation is required, then a pick-by-line technique may be used to pick individual products from incoming pallets and place them on outgoing customer pallets. This may be undertaken manually or by using automated sortation equipment.

There are a number of variations of cross-docking. For example, in some instances the goods may be pre-labelled for particular stores or customers, whereas in other situations the goods may just be sorted by product line, with or without a label being applied during the cross-docking operation.

Cross-docking has a number of advantages in that it facilitates the rapid flow of goods through the supply chain and can be used as a technique to reduce inventory levels. It is particularly common for fresh and short-shelf-life goods, as well as for goods that are pre-allocated and need to be 'pushed' out to stores, as in the fashion industry.

While there can be substantial benefits from cross-docking, it may not be suitable in every situation, for example:

- The introduction of cross-docking at a warehouse may just move inventory upstream in a supply chain, as suppliers may need to hold more inventory themselves to supply the warehouse on a just-in-time basis. A holistic view therefore needs to be taken to ensure that total inventory in the supply chain is reduced.
- Goods may be transported in less than pallet load quantities or less than vehicle load quantities, thus increasing transport costs.
- Considerable handling space may be required at the warehouse for the sortation activities.

- Close coordination is required with the suppliers (plus high levels of reliability), and this becomes increasingly complex with greater numbers of SKUs and suppliers.

For these reasons, it may not be beneficial to cross-dock in many situations, for example, where there are thousands of SKUs from hundreds of suppliers. A total supply chain view thus needs to be taken, as with all logistics decisions, to identify when cross-docking may be advantageous. In very general terms, it is often beneficial to cross-dock goods at warehouses up to and after the decoupling point (e.g. for the purposes of load consolidation) but to store goods at the decoupling point in order to provide the required cycle and safety inventory.

Returned goods

Goods may, of course, be returned to a warehouse for a variety of reasons such as:

- unwanted goods (e.g. clothing items that do not fit)
- incorrect goods originally dispatched (e.g. owing to an order picking error)
- damaged goods (e.g. owing to poor packing)
- recalled goods (e.g. where the manufacturer has found a fault and recalls goods back from customers)
- end of life goods (e.g. electrical and electronic items that require recovery and recycling under the European Community Waste Electrical and Electronic Equipment (WEEE) Directive)
- unit loads (e.g. pallets and roll-cages that need repair, and plastic trays that require washing before reuse)
- packaging (e.g. returned by stores)

In some industries, for example fashion sales via the internet or home catalogue, the proportion of goods being returned to the warehouse may be very high (e.g. 20 to 30 per cent or even more). The handling of returns must therefore be carried out effectively, with processes in place for deciding whether, for example, to return goods to original suppliers, repair or refurbish the goods, return to stock, sell through another channel or outlet store, sell to a merchant, pass to a charity, recycle or send to landfill/incineration. It is important that these decisions are taken quickly so that returned goods do not build up and take a lot of space in the warehouse. In addition, there may be considerable cash tied up in returned goods if they are not handled quickly. Some companies establish specific zones in warehouses to handle returned goods while others have set up specialist warehouses that act as returned goods centres. If the goods need to be returned to stock, then it may be advantageous to

establish a specific zone to which returned goods are transported and picked from or to place returned goods together in mixed SKU tote bins and transfer to miniload storage, ready for subsequent picking.

Receiving and dispatch equipment

The equipment types required for unloading and loading tend to be similar in nature for both receiving and dispatch, and these are therefore described together.

Common types of handling equipment include:

- *Boom conveyors.* Goods are frequently shipped in loose cartons in ISO containers to save on space in the container, to comply with wood regulations affecting pallets, and to save the cost of pallets that will not be returned. Similarly, packets are frequently transported loose to parcel carriers, as they will be individually sorted to destination on arrival at the parcel hub warehouse. In these instances, a boom conveyor may be used to extend into the vehicle or container. When unloading a vehicle or container, the warehouse staff just need to lift the goods on to the conveyor, which transports the goods off the vehicle and then can link to the warehouse conveyor system to take the goods to the appropriate area of the warehouse (see Figure 22.1). For loading, this process is reversed.

Figure 22.1 Telescopic boom conveyor



SOURCE Vanderlande

- *Pallet trucks.* Where loading and unloading takes place from the rear of the vehicle, then it is normal for a pallet truck (either hand or powered) to be used within the vehicle.
- *Fork-lift trucks.* For side-loading and -unloading (e.g. of curtain-sided vehicles), counterbalanced fork-lift trucks are normally used. These may be fitted with side-shifts so that pallets can be accurately positioned on the vehicle. Another form of attachment that is often used is one that enables two pallets (side by side) to be lifted at a time. Fork-lift trucks with telescopic booms (see Chapter 19) are also sometimes used so that vehicles can be loaded from just one side, thus saving on warehouse yard space. Conventional counterbalanced fork-lift trucks may also be used for end-loading and -unloading, particularly if pallets are stacked two high on a vehicle. In this case, trucks with a maximum free lift are required, so that the truck mast does not rise while inside the vehicle. Another common use is for slip-sheets to be used to separate unit loads in a container and special attachments can be fitted to fork-lift trucks to help load and unload these. Fork-lift trucks may be fitted with automated barcode scanners so that pallets can be identified to the warehouse management system without the need for the driver to leave the truck and scan the pallet barcode with a hand-held scanner.
- *Automated pallet loading/unloading systems.* There are automated systems available that can load or unload all the pallets on a vehicle simultaneously. These require special trailer units (e.g. fitted with rollers or tracks) which connect to a warehouse conveyor system at the loading bay. All of the pallets can then be loaded (or unloaded) together in one movement of the conveyor. Owing to the specialist nature of the trailers, these systems are best suited to shuttle journeys, for example between a manufacturing plant and its associated distribution centre. Similar systems are available for vans fitted with roller tracks so that the pallets can be loaded (e.g. at level intake bays) by fork-lift truck and then pushed into the van. Further pallets can be loaded depending on the platform length of the van. The roller tracks are then lowered to avoid movement during transit.
- *Automated and robotic case loading/unloading systems.* Cases are often loose loaded and unloaded into shipping containers in order to save space, avoid the cost of one-way pallets and protect the environment (as pests could be introduced into other countries unless the wooden pallets are properly treated). In such instances, loading and unloading both require considerable manual effort. There are machines that, for unloading for example, can extract groups of cartons (by clamps or suction) and stack these onto pallets for onward movement within the warehouse. The operator can drive the machine into a container as it is emptied so as to reach all the cases at the back of the container. Alternatively, the cases could be automatically placed onto a conveyor by such equipment. Similar systems using robots with vision systems, machine learning and robotic arms incorporating sensors and grippers are available.

- *Automated and robotic tote bin loaders.* This equipment is particularly applicable where goods are dispatched from a warehouse in tote bins; for example, in the case of stores being supplied with small items. Tote bins may be moved from picking, or packing, on conveyors and then brought to an automatic loading machine or robot for stacking on to pallets or dollies (i.e. wheeled platforms) ready for dispatch to the stores. The pallets or dollies are then moved (e.g. by powered pallet truck) to the marshalling area.
- *Pallet scissor lift tables.* Once the pallets have been unloaded, they may be brought to unpacking stations where, for example, goods may be extracted and placed into tote bins ready for storage in miniload systems. In order to present the goods at the correct height for this work, pallets may be placed on scissor lift tables, which would be at a low level for the start of the operation and then could gradually be lifted as the pallet is emptied (so that the operator does not need to stoop to pick up the lower items left on the pallet). This type of equipment is becoming more common with increased awareness of health and safety issues regarding manual handling.

The loading bays themselves are normally equipped with a number of features, including:

- *Dock levellers.* These are normally permanently fitted at each bay and form a gentle slope up or down to match the bed heights of each vehicle. A truck, such as a powered pallet truck, can then be driven directly on to the vehicle for end-loading or -unloading. As vehicle bed heights may vary considerably, the dock leveller needs to be long enough to accommodate all vehicles that may be expected on that bay. The dock leveller is sunk into a pit and operated by a hydraulic ram.
- *Doors.* These often retract above the opening when in use. They are frequently fitted with windows so that warehouse staff can see whether there is a vehicle in the bay.
- *Dock shelters and seals.* Some form of weather protection is common to prevent draughts and dust from entering the warehouse around the vehicle.
- *Bumpers.* These are used to reduce the shock load exerted on the building structure when vehicles reverse up to the bay.
- *Lighting.* Lights on swivel arms are required to provide adequate illumination inside the vehicles, particularly at night.
- *Camera and sensor systems.* These may be used to record the condition of cargo on arrival or dispatch and to sense the presence of staff in the vehicle (e.g. to warn a warehouse truck driver not to enter the vehicle). 3D sensors and image-based systems, combined with data analytics, may also be used to provide real-time information on the progress of loading or unloading. RFID and similar systems

can be used to ensure that the correct goods are being loaded onto the correct vehicle.

- *Warning lights.* Red and green lights may be fitted to the outside and inside of the loading bay. These act as an indication to the driver as to whether the vehicle is ready to be driven away, thus reducing accidents that might result from trucks being driven into the vehicle at the exact moment that the driver decides to pull away.
- *Vehicle restraints.* Some warehouses are fitted with an even more rigorous system in that the wheels of the vehicle are restrained until the warehouse staff decide that it is safe for the vehicle to be driven away. An alternative system is for an interlocking mechanism between the dock door and the vehicle trailer brake lines so that the brakes on the vehicle cannot be released until the dock door is closed.
- *Wheel guides and bollards.* These are used to assist the driver to park centrally in the loading bay.
- *Dock houses.* The loading bays are usually fitted along one or more sides of the warehouse. However, particularly if space within the warehouse is limited, dock houses may be fitted so that the door can be positioned a couple of metres outside the wall and thus provide additional space for loading and unloading activities.

Layouts

The receiving of goods to the warehouse site begins at the gatehouse. The receiving and dispatch layout thus needs to include all the external areas within the perimeter fence, such as:

- *Vehicle roadways.* Roadway markings and signage are essential. The vehicle flow may be one-way around the site or two-way to and from the loading bays. In the latter case, access still needs to be provided for emergency vehicles, such as fire tenders, to all sides of the building. In the case of one-way flows, a clockwise direction may be better for right-hand-drive vehicles to allow drivers to reverse a trailer on to a bay more easily, whereas anticlockwise is more suitable where left-hand-drive vehicles are the norm.
- *Parking areas.* Adequate vehicle, trailer and swap-body parking needs to be provided. Power points may be needed where temperature-controlled units are to be parked. The car park for staff and visitors should be separated from the heavy-goods-vehicle areas for safety reasons, as well as for security reasons (i.e. keeping cars away from direct access to the warehouse).
- *Ancillary areas.* Many such areas may be needed, for example fuel points, vehicle washing facilities, weighbridge, generators, empty unit load area, waste

compactors, sprinkler tanks and fire assembly points. In addition, landscaping to shield the warehouse and vehicles from the local environment may be required, as well as lagoons for rainwater collection and reuse, and space for wind turbines, etc.

The unloading and loading bays may be at opposite ends of the building, to enable a through-flow of goods, or may be adjacent to each other on the same side of the building, to enable a U-flow. Other options include an L-flow, or some mix of these.

A *through-flow* may offer a better flow of goods within the warehouse itself, although in practice, with goods moving from receiving to reserve storage and then to picking, sortation, packing and dispatch, it is not always the case that this flow is any better than a U-flow. Through-flow is often used when the number of unloading and loading bays required is too great to fit on one side of a building, as in a warehouse handling a rapid turnover of goods. A through-flow layout is also particularly suited to a cross-dock warehouse, such as a parcel sortation centre, where a long thin building may be appropriate, with incoming vehicles along one of the long sides and outgoing vehicles on the opposite side. However, in an inventory-holding warehouse, a U-flow may be more suitable for cross-docking, as the distance that the goods need to travel would be far less than with through-flow.

A major benefit of *U-flow* is in situations where the receiving and dispatch activities occur at different times of the day. For example, in many warehouses, receiving occurs during the morning and dispatch in the afternoon and evening. In this situation, the same doors, materials handling equipment, internal marshalling areas and external vehicle turning areas may be used for both receiving and dispatch activities. It is also easier to divert equipment and staff between the two activities as peaks and troughs arise, even when the two activities are occurring concurrently. A further advantage is that when the same vehicles are used for incoming and outgoing goods (as with back-hauling) then the vehicle can remain on the same dock for both activities. Another consideration is whether a through-flow layout may lead to an unwanted flow of air through the building and thus result in excessive heat loss. This latter point will depend on the geographic position of the site and on the design and use of the loading and unloading doors.

An *L-flow* layout is often used where goods are stored in racks that have access just at one end of the aisles, e.g. automated storage and retrieval systems (AS/RS) and, frequently, narrow aisle storage. In this way, both the receiving and dispatch doors can be close to the access end of the storage racks and thus reduce the movement of lift trucks. This type of rack configuration allows the narrow aisle trucks (or the cranes) to put away and retrieve pallets on the same trip into the aisle. The advantage of an L-flow layout in this situation is probably greatest where there are only limited ancillary operations in the warehouse (e.g. picking, packing and added-value services) that need to be fitted into the overall flow.

The actual vehicle bays themselves may be:

- *Level intake.* This is where the warehouse floor is at the same level as the external roadway. It is suitable for the side-unloading of vehicles by lift truck. Vehicles may be unloaded outside (e.g. under a canopy) or brought into the building, although, with the latter option, care must be taken with fume extraction and maintaining the required temperature in the warehouse.
- *Raised dock.* With a raised dock, the warehouse floor is at the same level as the bed of the vehicle, so that a pallet truck or lift truck can drive directly on to the vehicle by means of a dock leveller. This is normal in the case of end-unloading (e.g. box vans or containers). Raised docks are normally at 90 degrees to the building, but may also be set out in a 'saw tooth' or 'finger' configuration. In the latter instance, side-unloading may also be possible.

Normally a mix of level intake and raised docks is needed. For raised docks, it is often necessary to build a depressed driveway leading down to the docks. In this case, a gentle slope is required from the roadway level (i.e. less than 10 per cent), but the vehicle should be on the level at the loading bay, to facilitate truck movement on the vehicle and to avoid the top of the vehicle fouling the building. Frequently, level intake and raised docks are placed on the same side of the building, in which case they should be separated by a crash barrier (or by placing a transport office at this point to serve the same purpose).

For the loading and unloading of double-deck trailers, raised docks may be used where the upper deck is powered and thus can be lowered into position. In the case of fixed double-deck trailers, pods may be fitted to the outside of the warehouse dock. These may have scissor lift platforms so that a vehicle load of roll-cages, for example, can be lifted to, or lowered from, the upper-deck level.

Inside the warehouse, the space needed for all of the activities listed under receiving and dispatch processes should be estimated and laid out. This can be a substantial requirement, as quite frequently a total of 20 to 30 per cent of the floor area needs to be allocated to these activities to facilitate the efficient flow of goods into and out of the warehouse. It should be noted that many of these activities require only a fairly low building height and can therefore take place in low-bay areas of the building. The height above the receiving and dispatch areas may, however, be used by introducing a mezzanine floor for other purposes, such as offices or packing activities, although care must be taken with regard to the restrictions that support columns may impose.

Yard management

Large warehouses receive and dispatch many vehicle loads in a day and therefore the management of the vehicles in the yard can play an important role in the overall

operations of the warehouse. Loading/unloading bays need to be allocated to each vehicle and these should be immediately adjacent to the appropriate receiving and storage area for incoming vehicles and to the appropriate marshalling lane for outgoing vehicles. If the warehouse dock is not yet available, then the vehicle should be allocated a parking bay.

Where shunters (i.e. tractor units used to move articulated trailers around the site) are employed in a yard, these can be assigned tasks via radio frequency so that movements and special instructions (e.g. plugging in refrigerated trailers) can be communicated to in-cab screens. The use of autonomous driverless shunters is a further possibility. The overall control of activities in large warehouse yards is normally managed with the assistance of a yard management system (YMS).

Closed-circuit television (CCTV) cameras are often used so that the yard controllers can see the exact position of each vehicle and, in very large yards, drones are sometimes used to gain an aerial view. The drones may be fitted with light detecting and ranging (LiDAR) technology to create a map of the yard and to identify the position of each vehicle or container. They may also use vision systems combined with artificial intelligence (AI) to look for potential security breaches in the yard. Another technology is geo-fencing, which is the creation of virtual boundaries using GPS or wireless beacons, and this may be used to identify when vehicles move across a boundary so that appropriate action can be taken (e.g. allocation of an unloading bay).

Warehouse design

23

Introduction

An organization's business plan and supply chain strategy represent the starting point for warehouse design, as they define the warehouse's precise role, throughput requirements, inventory levels and customer service levels. From these types of requirement, the warehouse designer must select the appropriate equipment and operating methods, determine the internal and external layouts, calculate the equipment and staffing numbers, identify the supporting information systems, and present the capital and operating costs. This chapter examines the strategic issues that should be considered before starting to design a warehouse, together with the various steps that are necessary to achieve a successful final design.

Strategic issues affecting warehousing

Since warehouses operate as an integral component of the supply chain, the wider business context must be taken into account when making key decisions about these facilities. The areas that should be considered are very wide-ranging and include the following:

- *Market/industry trends.* Almost all industries have seen dramatic changes in their marketplaces, as well as in the technology available to them. For example, major food retailers have witnessed such developments as an increase in online shopping and smaller town centre stores, as well as the availability of such technology as robotics, micro-fulfilment solutions and artificial intelligence (AI). All of these developments have involved substantial changes to warehouse design and operations, and thus any warehouse that is built without the latest trends in mind may be unsuitable by the time it comes into operation.
- *Corporate objectives.* Different companies often have quite different objectives in terms of their market positioning (e.g. service commitment to customers), staff policies (e.g. working conditions), environmental policies and shareholder expectations (e.g. which may affect acceptable payback periods for capital

investments). Again, any warehouse needs to fit with the particular objectives of the company.

- *Business plan.* The business plan will include factors such as new markets and sales projections, as well as the degree of certainty of the projections. These will affect design features such as the expansion potential that needs to be incorporated into the warehouse and the degree of flexibility that should be allowed for. In the case of the latter, it may be necessary to undertake scenario planning for how the warehouse facilities can accommodate possible variations in the business plan.
- *Supply chain strategy.* Each warehouse will be one component in the overall supply chain strategy and therefore needs to be designed accordingly (see Chapter 6). This strategy will determine factors such as the ownership (e.g. owned or outsourced), roles, location and size of each warehouse. The size may be determined in terms of both the throughput capacity and the inventory capacity that will be required.
- *Other related strategies.* The business plan will need to be implemented through various departmental strategies, as well as that of the supply chain. Many of these will affect the warehouse design, as they will determine factors such as incoming batch sizes from production or from suppliers, customer order characteristics, available information technology and financial restrictions.
- *Customer service levels.* A number of the strategies previously described, particularly those of marketing and the supply chain, will determine the service levels that the warehouse needs to provide (see Chapter 3). It is these service levels that are key to how the warehouse should be designed and operated.
- *External factors.* There are likely to be constraints imposed by external factors, particularly in terms of regulation. A wide range of regulations may impact on warehouse design and operations, including laws in such areas as construction, health and safety, manual handling, working hours, the environment, fire precautions, equipment, hazardous substances, food safety and packaging waste, as well as possible local planning constraints (e.g. on building height and operating hours).

There is thus a wide range of factors that needs to be taken into account prior to the detailed design of the warehouse.

Design procedure

The design of a large and modern warehouse is very complex and requires a range of skills and disciplines, including, for example, operations, construction, materials handling, information systems, personnel, finance and project management. The

operations (e.g. supply chain or logistics) function often sponsors the project, as that function will be responsible for its eventual successful running. External warehouse designers may be an important part of the team, as many organizations only design warehouses on an infrequent basis and therefore do not necessarily possess all the necessary skills in-house. Usually, a steering group that comprises senior directors and executives oversees the project and provides guidance on future business strategy, environmental policies and financial resources.

The design process is shown below as a series of steps. In reality, these steps are normally undertaken in an iterative manner, as decisions at a later step may necessitate decisions made at an earlier step being reconsidered. Suggested steps are as follows and are described in detail in the remainder of this chapter:

- 1 Define business requirements and design constraints.
- 2 Define and obtain design data.
- 3 Formulate a planning base.
- 4 Define the operational principles.
- 5 Evaluate equipment types.
- 6 Develop environmental aspects.
- 7 Prepare internal and external layouts.
- 8 Draw up high-level procedures and information system requirements.
- 9 Evaluate design flexibility.
- 10 Calculate equipment quantities.
- 11 Calculate staffing levels.
- 12 Calculate capital and operating costs.
- 13 Evaluate the design against business requirements and design constraints.
- 14 Finalize the preferred design.

Define business requirements and design constraints

The wider business requirements set the context and the design requirements for a warehouse. These are likely to include, for example, the required:

- warehouse roles (e.g. to act as a decoupling point, a cross-dock facility or a returns centre)
- throughput levels and storage capacities
- customer service levels
- specified activities, such as production postponement and added-value services

These requirements should also indicate how quickly the warehouse needs to be operational, any financial constraints (e.g. on capital expenditure) and any wider corporate policies that may affect the design (e.g. information technology, environmental and personnel policies). There will also be design constraints, or considerations, to be taken into account from various other stakeholders, such as:

- government agencies, for example in terms of health and safety regulations (e.g. manual handling and equipment), working time directive, packaging regulations, product recovery and environmental legislation
- fire officer (e.g. requirements in terms of evacuation, fire exits and fire/smoke containment)
- insurance company (e.g. regarding fire detection and fire suppression – overhead or in-rack sprinklers, etc)
- local authority (e.g. maximum building height, working times, noise, etc)

A warehouse is a long-term asset, with the building often having a depreciation period of 20 to 25 years and the equipment about five to ten years. There are ways of reducing the length of this commitment by leasing buildings, renting certain types of equipment, or outsourcing. However, the long-term nature of the asset still has to be considered very carefully, as leases are often for a lengthy period of time and logistics contractors negotiate contract periods so as to minimize their own exposure. From the perspective of the logistics contractor, it is a challenge to provide such long-term assets on the basis of contracts that are often of between only one and three years in duration. In the case of outsourcing, there may therefore need to be compromises between the logistics contractors on the one hand and manufacturers, wholesalers or retailers on the other hand in relation to such issues as the length of the contract, the nature and ownership of equipment, buy-back clauses (of buildings and/or equipment) and other contractual terms.

In view of the long-term commitment that is normally associated with warehouse design, it is quite likely that a number of business scenarios can be envisaged within this period of time. In fact, it is almost certain that the original business plan will change. It is therefore important to undertake scenario planning so that the most likely future possibilities are identified and the warehouse (or the wider supply chain strategy) can be designed to accommodate these scenarios if and when required. This means incorporating flexibility as an integral part of the design.

Define and obtain design data

The next step is to define and obtain the base data on which the design will be conducted. Although data are often obtainable for recent months and years, the

warehouse will almost certainly need to be designed for future requirements. The data will therefore need to be adjusted to reflect likely changes such as business growth, new market channels, changing customer requirements and competitive market pressures. Normally, data is collected for the base year (e.g. the most recent year of the current operation) and then projected forward in line with the business plan to the planning horizon. There may in fact be a number of planning horizons used. For example, a 1-year horizon may be used to calculate the initial staffing level, a 5-year horizon may be used for sizing the building and the design of fixed equipment, and a 10-year horizon may be considered for the purchase of land and for possible modular expansion of the building.

Typical data required for warehouse design include:

- *Products*: for each product line, information is required concerning: quantity throughput (e.g. by item, case, pallet or cubic metre); value throughput (to reconcile with business plan); seasonality; number of order lines; inventory holding (at average and peak); weight/dimensions and unit load characteristics.
- *Order characteristics*: order profile (e.g. lines per order and units per order line); order frequency (by season, week, day and time); number of order lines for each SKU (to identify pick frequency); time profile (e.g. percentage of orders received by week, day and hour); unit load and packing requirements; service levels (e.g. order cut-off times and order lead times).
- *Intake and dispatch patterns*: number of vehicles per day and by hour; types of vehicle (e.g. bed-height and end- or side-loaded); unit load types and profiles (e.g. SKUs per pallet and need for re-palletizing); volumes per dispatch route; own vehicles or third party; cross-docking profiles (e.g. quantities, timing and sortation requirements).
- *Warehouse operations*: basic operations to be undertaken and ancillary functions, e.g. 3D printing, packing, returns, quality control, battery charging, offices, warehouse cleaning, maintenance workshop, services, stand-by generator, restaurant, locker rooms.
- *External area requirements*: security facilities (including gatehouse); truck parking and manoeuvring areas; vehicle wash and fuelling points; car parking and charging.
- *Site and building details (where existing facilities are to be redesigned)*: location, access and ground conditions; drawing to show building dimensions, columns and gradients; drawing to show external area and roadways; services (e.g. electricity supply).
- *Cost data*: rent (or land and building costs) and rates; building maintenance and security; heat, light and power; wage rates and shift premiums; equipment costs, depreciation rules and maintenance costs.

- *Any existing equipment that may be used: size, condition and numbers.*

Most organizations do not keep the exact data required for warehouse design and therefore a wide range of methods normally need to be used to assemble the data. These methods include extracting data from computer records and paper records, sampling or surveying existing operations, projections based on forecasts, interviews with customers, site drawings, information from equipment and information technology suppliers, and input from relevant management and staff. Assumptions often have to be made based on informed opinion and experience, and these should be clearly highlighted and agreed with the steering group.

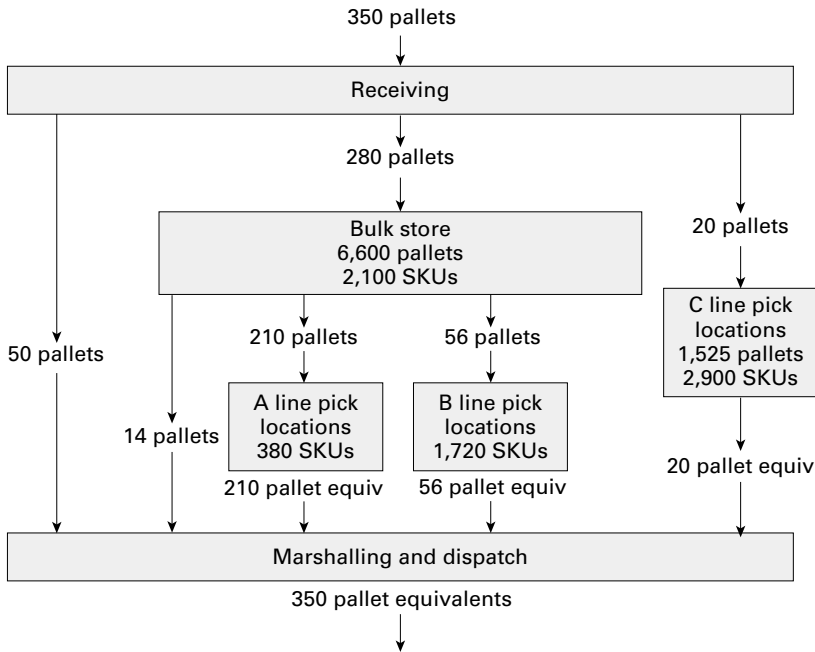
Formulate a planning base

The relevant data needs to be brought together as a structured planning base. This requires detailed data analysis and needs to be presented to the project team, steering group and external stakeholders as clearly as possible; for example, by means of summary tables, graphs, charts and drawings.

A useful way to present the throughput and storage data is as a warehouse flow diagram, as shown in Figure 23.1. In this diagram, a typical day in the life of the warehouse is presented in terms of flows and inventory quantities. It is a schematic diagram with the receiving area at the top and the dispatch area at the bottom. This does not represent the layout in any way, as no decision has been taken at this stage as to whether to have a through-flow, U-flow or other configuration. The flows are represented by the arrows, and are given in the most useful units for the operation under consideration. For example, they may be represented in pallet equivalents throughout, and some of these may be converted to other unit loads, as the design develops. The storage quantities are shown in the boxes, together with the number of SKUs that they represent.

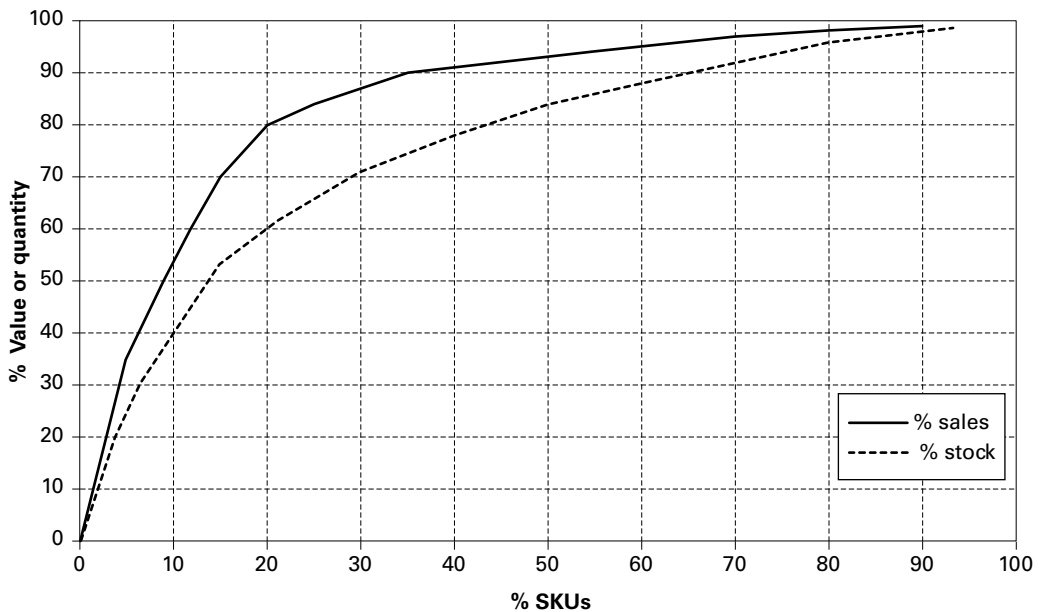
A number of such warehouse flow diagrams may be constructed for the various planning horizons that are relevant to the design (e.g. for initial staffing, provision of fixed equipment, building size or for further expansion). Similarly, consideration needs to be given to whether to draw these at average, peak or some other level of activity in the planning year. The level used will depend on the precise purpose for which the flow diagram will be used. For example, the design of AS/RS equipment is likely to be based on peak flows, while staffing may be based on a figure such as average plus a specified percentage uplift (e.g. 10 per cent). This uplift will depend on the extent of seasonal, weekly and daily variations, and how these may be accommodated.

The flow diagram forces some initial consideration of warehouse zoning, in terms of whether to separate picking stock from reserve storage inventory (which is likely to be the case if the volume of goods is too great to fit into one convenient size

Figure 23.1 Warehouse flow diagram

location). Also, the warehouse may be divided by product groups, by temperature regime, by the degree of hazard, by the need for security, by size of items or by Pareto classification.

The Pareto classification is named after an Italian economist who lived in the late 19th and early 20th centuries. It is often used to classify SKUs by annual sales (or usage) value. 'A' class items normally refer to the top-ranked items (i.e. the fast movers), 'B' class to the medium movers and 'C' class to the long tail of slow movers. For warehousing, throughput analysis is normally conducted in terms of meaningful physical units (e.g. pallets or cases) whereas picking analysis is normally concerned with the number of order lines (or visits to the pick face). Pareto classification or analysis is in fact often referred to as ABC analysis. Another common term for this type of classification is the 80/20 rule as it is often found that about 80 per cent of the throughput of a company is accounted for by only 20 per cent of the SKUs (although figures may in fact vary widely from this because of differing product range profiles, industry types, etc). A simple example of this is shown in Figure 23.2. It should be noted that, where the sales Pareto is found to be approximately 80/20, then the inventory Pareto is likely to be less than this, often at about 60/20 (i.e. 60 per cent of the inventory may be accounted for by the top-selling 20 per cent of SKUs). This is due to the inventory of the top-selling lines turning over more frequently than that of slow movers. Thus, the fast movers may account for 80 per cent

Figure 23.2 Pareto diagram, for throughput (sales) and inventory

of the fork-lift truck movements but only 60 per cent of the pallet rack locations and the warehouse will need to be designed accordingly. Similarly, the picking accessions may represent a different percentage split, as, for example, greater quantities per order line may be ordered of the fast-moving lines. This type of analysis is often the basis for segregating products in a warehouse, so that appropriate equipment types can be used for movement and storage and also in order that the product locations can be determined (e.g. fast movers should normally be located so that they need to be moved the shortest distance).

The planning base should be presented to the steering group, representing (and often consisting of) the organization's executive, and agreed and signed off before detailed design commences. This is an important step, as this planning base is what the warehouse will be designed to achieve, and changes to requirements become more costly to incorporate as the design progresses.

Define the operational principles

The basic operations will have been determined at the outset by the definition of the various roles that the warehouse must perform (e.g. as a decoupling point, consolidation centre, assembly centre or returns centre). However, it is necessary to detail these as far as possible before design commences. For example, the warehouse tasks may include vehicle unloading, quality assurance, storage, picking, production

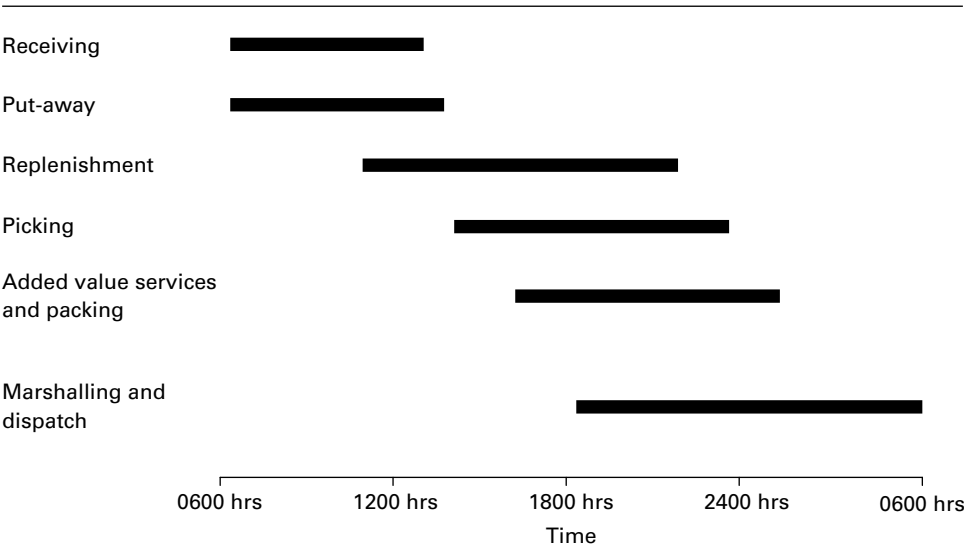
postponement, added-value services, packing, cross-docking, sortation and vehicle loading as well as such ancillary activities as accommodating sales offices or providing vehicle wash facilities.

The time available to undertake each activity is an important factor in determining how they should be performed. For example, if there is a late evening cut-off time for orders and the service level is for next-day delivery, then the time window available for order picking may be limited to only a few hours. On the other hand, it may be possible to instruct suppliers to deliver goods to the warehouse earlier, so this activity could be scheduled for the morning in order to balance the workload over the day. An indicative time profile, for example as in Figure 23.3, could therefore be established.

At this stage, general operational methods may be identified for each activity. For example, if there are many small orders across a wide range of SKUs, then batch picking may be identified as the most likely picking concept. Similarly, for cross-docking, a pick-by-line concept may be adopted. Each activity should be examined to determine whether some general operational methods of this nature can be identified at this early stage.

The choice of unit loads (e.g. pallets, stillages, roll-cages, skid sheets, tote bins and hanging garment rails) to be handled and stored in a warehouse is critical and should therefore be established early in the design process. Suppliers may impose the unit loads in which material arrives at a warehouse, and customers may specify dispatch unit loads, but the warehouse designer should use whatever freedom of choice exists to ensure the most appropriate unit loads for the processes being carried out. As an example, if roll-cage pallets are specified for dispatch to retail stores, then it may be advantageous to pick directly into these.

Figure 23.3 Time profile of warehouse operations

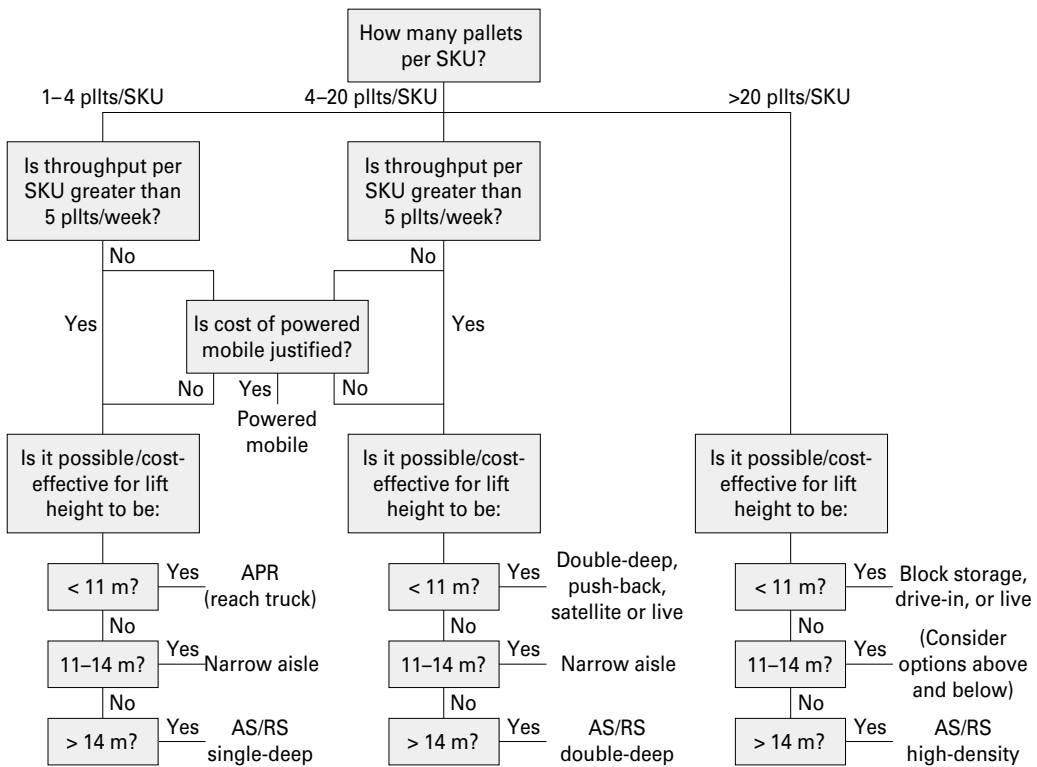


Evaluate equipment types

There is a wide range of equipment available to warehouse designers, as outlined in Chapters 19 to 22. Some of these may be well suited to a particular operation and some very badly suited. It is vital that an appropriate equipment type is identified, as subsequent changes could be extremely expensive and disruptive to implement.

It is therefore important to proceed in a structured manner so that appropriate equipment types are not discarded without proper consideration. A narrowing down of options should therefore be carried out. It should be noted that the reasons for discarding equipment at each stage are just as important as the reasons for selecting equipment. A structured approach to equipment selection may comprise the following stages:

- *Initial automation assessment.* Automated equipment may have distinct advantages in terms of good use of floor area (e.g. high-bay AS/RS), low running costs, security, accuracy and low damage levels. However, it may be possible to take a decision at an early stage as to whether to discard automation in certain situations, for example where land and staff costs are low or where the operation needs to be up and running very quickly. Thus, in situations where a conventional warehouse may take one year to design and build, an automated warehouse may take up to 18 months. In addition, the full commissioning and refinement of the automated systems may take several more months. Some small-scale automated systems (e.g. for micro-fulfilment) are available and these can be operational much more quickly. Also, robotic solutions often tend to be more scalable and flexible than large-scale automated systems.
- *Attribute assessment.* It may be possible to discard certain equipment types based on their attributes. For example, by referring to Table 19.2, it can be noted that only certain storage equipment types are suitable for strict first-in first-out, if this is a requirement of the operation.
- *Decision trees.* Clarity of thinking can be established by developing decision trees, as set out in Figure 23.4 (and as shown by a further example Figure 21.4). The decisions may not be clear-cut at each point for a particular operation, but this process can help to narrow down further the options available.
- *Cost comparison.* At the end of this process, there may be two or three equipment options left for a certain activity, and these can then be subjected to a cost evaluation. It is important to include all the relevant cost factors. For example, when choosing storage equipment, it is likely to be necessary to include costs for land, buildings, services, sprinklers, lift trucks, operators, maintenance and running costs, as well as the cost of the racks themselves. As some of these costs are capital and some are annual, a satisfactory method of comparison is needed, for example by using net present values or annualized costings (i.e. converting all capital costs to annual costs).

Figure 23.4 Decision tree to identify possible pallet storage systems

- *Equipment choice.* When the preferred equipment has been identified for each warehouse activity, then a final choice needs to be made, based on such factors as the overall equipment mix, the flexibility provided and environmental considerations. Each equipment type can be compared in terms of greenhouse gas emissions (e.g. conventional versus automated equipment energy usage, and alternative fuel types for fork-lift trucks, such as lithium-ion batteries and hydrogen cells). Sensitivity analyses can be conducted to identify whether the preferred equipment is still the most appropriate choice under the different business scenarios that were identified.

Develop environmental aspects

Although environmental factors must be considered in all of the steps, this is a good point to develop the overall environmental approach in more detail.

There are various building certification schemes available in different parts of the world and it should be decided whether the company wishes to apply for one of

these and, if so, at what rating. For example, BRE Environmental Assessment Method (BREEAM) is a UK-based scheme and has ratings up to 'outstanding', while Leadership in Energy and Environmental Design (LEED) is a US-based scheme and has ratings up to 'platinum'. The certification scheme and desired rating will influence the development of the environmental aspects of the scheme.

The environmental aspects of the design can then be developed in more detail, including for example:

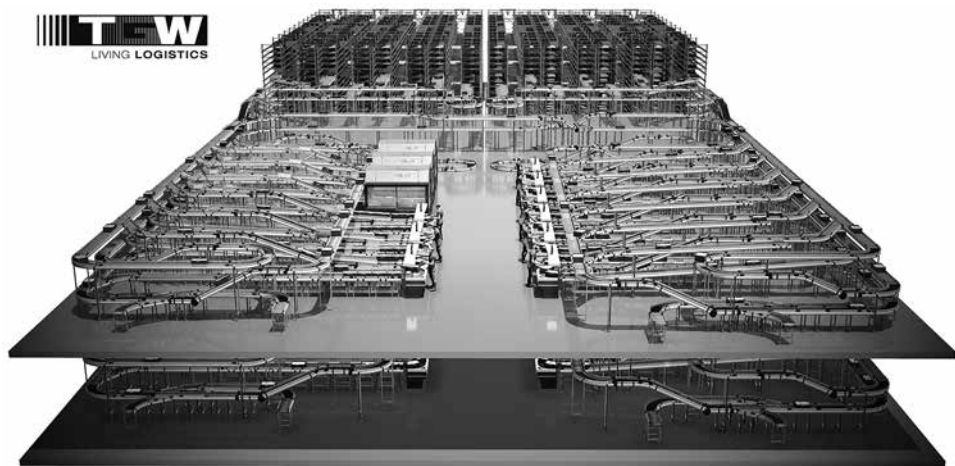
- *Equipment choices.* As mentioned in the previous step, the choice of materials handling and storage equipment may be determined partly by the energy usage and greenhouse gas emissions.
- *Construction materials.* The normal major construction materials for warehouses are concrete and steel, but their manufacture involves the emission of considerable greenhouse gases. This is known as embodied energy, and an important design task nowadays is to reduce the amount of embodied energy involved in warehouse buildings. Alternative sources of materials therefore need to be considered, such as the use of pulverized fuel ash for concrete, and recycled metal for steel, as well as other materials such as timber roof beams and lime/hemp walls.
- *Insulation and airtightness.* Good insulation and airtightness (e.g. through door design) can significantly reduce the amount of carbon emitted during the life of the building, as well as lowering energy costs.
- *Roof lights.* Modern warehouses now tend to be built with a greater percentage of roof lights in the ceiling, so as to allow more natural light into the building. These need to be of a material that does not allow heat loss and is self-cleaning, if possible. Transparent solar photovoltaic panels (see below) can also be used to act as roof lights.
- *Energy efficient lighting.* Energy efficient lighting is available, such as light-emitting diodes (LED) and organic light-emitting diodes (OLED), to replace more traditional lighting such as metal halide and fluorescent bulbs.
- *Energy management systems.* Heating and lighting are the two main emitters of greenhouse gases from warehouses and therefore these need to be controlled tightly by computer-controlled systems (e.g. timers, thermostats and motion sensors).
- *Renewable energy sources.* There is a wide range of alternative technologies available for warehouses, such as solar water heating, solar photovoltaic panels, wind turbines, ground- and air-source heating/cooling, and combined heat and power boilers (i.e. where the heat generated by boilers is also used for tray wash facilities, etc). Any excess power (e.g. from wind turbines) can be fed in to the National Grid or on-site energy storage systems can be used.

- *Rainwater harvesting.* Rainwater can be collected from the roof and used for such purposes as flushing toilets and washing vehicles.
- *Staff transport facilities.* This may include electric charging points for cars, lockable bicycle sheds and the provision of public transport in coordination with suitable providers.
- *Efficient operation.* Finally, the better the layout facilitates an efficient operation then the fewer movements there should be and hence the lower the greenhouse gases emissions.

Prepare internal and external layouts

When most people think of a warehouse design they picture a layout drawing. This is obviously a critical part of the design process. Once the operational principles have been established and the equipment types chosen, then the internal and external layouts can be drawn. Computer packages, such as computer-aided design (CAD) software, can be very useful in this regard, but it is up to the designer to decide how the different components of the warehouse should be brought together (see Figure 23.5 for an example of a 3D computer-aided design).

Figure 23.5 3D computer-aided design, showing miniload storage with goods-to-picker conveyor systems on mezzanine and ground levels



SOURCE TGW

Internal layout

The warehouse flow diagram (see Figure 23.1) is a useful starting point as this shows the relative flows between the different zones. Obviously, the designer will try to

minimize the distances for the greatest flows and will avoid any backtracking or major cross-flows. Typically, a number of draft designs will be drawn and these will be compared by the design team.

This process will have a number of objectives, such as:

- Land utilization: most warehouses are built as single-storey structures albeit with mezzanine floors and high racking inside. However, where land is in short supply and very expensive, other more unusual options may be considered such as underground warehouses or multistorey warehouses with road vehicles accessing different levels (although both can present severe operational challenges).
- Building utilization: e.g. for new buildings, designing to conform to rectilinear building norms for both high-bay and low-bay areas, while for existing buildings, making best use of the available space.
- Throughput efficiency: i.e. achieving the required throughput with least resources.
- Safety: e.g. separating pedestrian from fork-lift truck traffic, avoiding the inclusion of any dangerous junctions between aisles, and ensuring that there is a rapid means of fire escape for all personnel (e.g. no closed aisles).
- Environmental: e.g. reducing energy usage and lowering greenhouse gas emissions.

An important decision is whether to adopt a through-flow, U-flow or L-flow configuration, and this depends on the factors described in Chapter 22. Another significant consideration is the height of the building, which may be determined by such factors as land costs, equipment choices and any local planning constraints. Generally, the cost per cubic metre of space is less for higher buildings, particularly in economies where land costs tend to be high. For low-level activities, the use of mezzanine floors should therefore be considered. Also relevant are the implications for moving the goods onto and off the floors (e.g. by conveyors, lifts or pallet access gates), as well as the possible interference to activities below resulting from the support columns.

Although the warehouse should be designed around the operational requirements, there is a significant interface at this stage with building design. For example, building spans, feasible floor slab dimensions, and fire officer requirements (e.g. fire walls) may all be important.

Other layout considerations include:

- column pitches (i.e. distance between the rows of columns that support the roof), required clear operational heights and floor flatness tolerances, e.g. for narrow-aisle operations
- dock area design for vehicle loading and unloading, e.g. the number, pitch (i.e. distance between doors) and whether raised or level access (e.g. for end- or side-loading)

- the location of, for example, offices, battery-charging area, air-cleaning systems, pump room (for sprinklers), restaurant, toilets, and facilities for delivery and collection drivers

The design also needs to be planned for potential further expansion because it may be better, financially, not to build immediately for likely future requirements and because it is very difficult to estimate likely future requirements with any accuracy. For example, the designer needs to consider how the building can be expanded to accommodate increased throughput (e.g. more marshalling area, more raised docks, etc) and greater storage (e.g. extension to a high-bay AS/RS area), bearing in mind that disruption to the ongoing operation should be minimized during any further construction work.

External layout issues

The external layout will show exactly where the warehouse building is to be located on the site and the relevant roadways and parking area. Critical decisions therefore include whether vehicle traffic should go around the building or whether traffic should just go to one or two sides of the building and then return. This will be partly associated with the decision regarding a flow-through, U-flow or L-flow internal configuration. Even if operational access is only required on one side, then it is still likely that access will need to be considered for emergency services (e.g. for firefighting) on the other sides.

Other external layout considerations include:

- roadway design
- parking areas for trucks, containers, demountable bodies and private cars/bicycles (both of the latter normally being separate from the operational area), together with charging points; multi-level car and van parks may also be considered, where land is expensive or in short supply
- gatehouses, fences, barriers and landscaping
- vehicle wash, maintenance and fuelling facilities (e.g. for diesel, biodiesel, LPG)
- location of sprinkler tanks, wind turbines and hydrogen storage (if hydrogen cells used)
- fire assembly area
- landscaping, control of rainwater run-off (e.g. by the use of ponds and pervious paving) and ecology (e.g. use of native trees and plants)

Draw up high-level procedures and information system requirements

Once the equipment and layout start to become clear, it is important to draw up the high-level procedures of how the operation will work. For example, if zone picking to plastic tote bins on conveyors is adopted, the process of issuing the pick instructions, confirming the pick, and conveyor sortation (e.g. the accumulation of multi-bin orders) needs to be established to ensure that it is in fact a good and workable solution.

In conjunction with this, the information system requirements should be established. For example, in the above instance, it would be possible to use a variety of information systems such as paper pick lists in the totes, reading an RFID tag on the tote and issuing instructions to the picker by radio data terminal, pick-by-light or voice technology. This decision will form the basis of the specification for the warehouse management system and associated information and communications systems.

Evaluate design flexibility

The flexibility of the design to the range of business scenarios envisioned during the first stage should be fully evaluated. Even though this would have been considered at each stage, it is important to evaluate in detail to what extent the proposed design is flexible and can therefore meet the requirements of an agile supply chain, where this is applicable.

The type of flexibility required may include the following facets:

- volume, e.g. to accommodate unexpected growth or sudden surges in demand
- time, e.g. to enable rush orders to be picked and dispatched
- quantity, e.g. to be able to switch to item picking rather than case picking
- presentation, e.g. to present different unit loads to various clients
- information, e.g. to provide specific information on customer labels

This flexibility may be provided by a combination of available warehouse resources, namely:

- land/building, e.g. by designing for modular expansion of the building
- equipment, e.g. by choosing versatile equipment
- staff, e.g. by facilitating the addition of more staff to operations in peak periods
- processes and systems, e.g. by developing processes and systems for a range of eventualities

Table 23.1 Examples of flexible design options

	Extra Capacity	Additional Resources when Needed	Flexible Resources
Land/buildings	Available height for future mezzanine floor	Using extra space when needed in a shared user DC	Free-standing mezzanine, rather than a shelf-supported mezzanine
Equipment	Conveyor capacity	Hire-in additional fork-lift trucks during peak period	'Combi' narrow-aisle trucks that can be used for picking or pallet put-away/retrieval
Staffing	Staffing at above average throughput level	Agency staff	Multi-skilling
Processes/systems	Availability of multiple processes within the WMS	Use of software on demand	Processes in place to support pallet-, case- and item-level picking

With each of these resources, flexibility can be provided for extreme levels of demand by incorporating extra capacity, by bringing in additional resources as required, or by designing flexible resources so that these can be used for different tasks (i.e. moving the resources to perform tasks where the high demand is experienced). Examples of options under each of these headings are shown in Table 23.1.

This flexibility should ideally be provided at minimal cost, in a short period of time, while meeting the required performance and service levels. Obviously, some compromises will have to be made, but these need to be conscious decisions that are taken and agreed during the design process.

Calculate equipment quantities

Based on the warehouse flow diagrams and the equipment choices, it is normally relatively straightforward to calculate the equipment quantities. For storage equipment, the number of unit loads (e.g. pallets) to be stored needs to be increased by using the location utilization figures (see Chapter 19) for that type of equipment and operation, to give the number of unit load positions that should be provided (for example, by dividing by a location utilization figure of about 90 to 95 per cent for single-deep adjustable pallet racking).

Handling equipment requirements are based on material movements in the warehouse, including seasonal variations and short-term peak loads, and on operational performance data, typically from manufacturers' technical data plus operating experience. Shift-working patterns will also need to be taken into account within these calculations, including the requirement for spare batteries where battery-powered trucks are used over a number of shifts. The number of order picking trucks will depend not only on total warehouse throughput but also on order sizes and frequencies.

Data on goods received, including delivery window and times required for vehicle unloading, will dictate receiving dock facilities such as access doors and dock levellers, and the handling equipment for vehicle unloading. Similar considerations apply to dispatch. The provision of raised docks or level docks will depend on the types of vehicle accessing the warehouse – end-loading or side-loading. Space requirements for order collation and assembly should take account of the working patterns of order arrival at dispatch and the way in which vehicle schedules integrate with these internal work patterns.

Using inventory and throughput figures and equipment operating characteristics, the calculations of basic equipment requirements are generally straightforward when taken operation by operation. In some cases, ratios need to be calculated to do this. For example, it may be found that somewhere between one and four cobots may be needed for every order picker depending on the actual operation and distances involved. What is more difficult to calculate, however, is the effect of all the mobile equipment and operating staff, working together, and interacting and interfacing, and sometimes getting in the way of one another, and causing queues and delays. This dynamic situation is nearer the real operational situation than is one based on merely calculating each operation in isolation. For this reason, computer-based dynamic simulation techniques may be used, to validate the 'static' calculations and to take account of potential interference between activities when running simultaneously.

Calculate staffing levels

The requirements for operating staff are closely linked to the mobile equipment requirements, and in many cases will 'fall out' of the equipment calculations. For example, one operator may be required for each shift to drive a fork-lift truck. For staff not associated with materials handling equipment, then staffing levels need to be calculated from performance data. The number of order picking staff for example can be calculated based on the total number of order lines to be picked, their expected performance rate (e.g. number of order lines picked per hour for the designed picking operation) and their available hours actually spent picking. Allowance needs to be made for absenteeism, sickness and holidays, as well as for shift rotas (e.g. for

24/7 working). For managers and supervisors, the appropriate spans of control need to be considered (e.g. in terms of supervisor/staff ratios).

Calculate capital and operating costs

At this stage, the capital and operating costs can be determined. It is often useful to assemble these under the headings of:

- building, including land, construction (or rents), local rates or taxes, power requirements and cost of other services, together with building security and maintenance
- equipment, including static and mobile equipment capital costs (or leasing, rental or 'as-a-service' costs), and maintenance and running costs
- staffing, including management, operatives, clerical staff and maintenance staff
- information systems, including hardware, software and implementation costs

It is also normal to add a contingency to capital costs for unforeseen events and for the detailed design of equipment (e.g. side-shifts and flashing lights on fork-lift trucks).

Under each of the above cost headings, the capital and operating costs should be calculated. These will represent the actual expenditure by the company on the warehouse. In addition, it is often useful to present these costs in a way that represents the timings of the cash outflows (e.g. net present value or annualized costings), both for the comparison of options and for the presentation of the business case.

Evaluate the design against the business requirements and design constraints

Before finalizing the design, all the details determined up to this point should be checked against the defined business requirements and any design constraints that must be met. It is not uncommon for the design to have strayed away from the original criteria during all of the detailed work that has taken place and therefore this is a very useful checkpoint.

It is important not only to ensure that the design works well for 'the business plan', but also to identify how, and at what cost, the various other business scenarios would be accommodated. The use of simulation, therefore, may well be of benefit again at this stage.

Finalize the preferred design

The design process normally involves considerable iteration. For example, the evaluation of equipment types may result in the original warehouse zoning being revisited. At this final stage, all of the aspects of the design need to be finalized, including layout, operating methods, equipment, staffing, information technology and costing. This complete ‘operational specification’ is then normally put forward to the organization’s executive body (e.g. the board of directors) for approval.

Once approval is received, then the actual project implementation can begin. This will involve many different strands of activity, all based on the agreed warehouse design, for example:

- *building*: site search, building design, tendering and selection of the construction company, detailed design and construction, as well as ancillary specialisms such as sprinklers, security and signage
- *materials handling*: detailed design, tendering and supplier selection (or development with preferred supplier), manufacture, installation and commissioning
- *information systems*: specification, selection, development and testing
- *personnel*: job specifications, recruitment and training
- *associated areas*: for example, transport interface

All of these strands will need to be coordinated by a project management activity, which will involve implementation planning, a project network, and change management procedures and continuous control.

Design of specialist warehouses

There are numerous types of warehouses that would require special design features. Two of the most common types are as follows.

Temperature-controlled warehouses

Common types of temperature-controlled warehouses include those for chilled (about +2°C to +5°C) and frozen (about –18°C to –25°C) goods, although other temperature regimes may also be required – for example, for bananas, which may require variable temperatures depending on the extent of ripening required before delivery to stores. These low temperatures require special design features, particularly in terms of insulation and the prevention of condensation. Typical features include:

- Refrigeration plant to maintain the desired temperatures including consideration of the latest cooling plant technologies, for example ammonia cycle refrigeration powered by combined heat and power (CHP) plants, using heat generated in other parts of the site (e.g. for food tray washing).
- Reuse of waste heat from refrigeration process.
- Insulation of walls and ceilings, possibly involving secondary steelwork.
- Specialist floor construction, which could include heating pipes to prevent the subsoil from freezing and damaging the warehouse building, together with insulating panels above the heating pipes to prevent the heat from reaching the cold store.
- Low oxygen environment to reduce the risk of fire in such a low level of air humidity.
- Blast freezing and tempering chambers to ensure that product is received into the warehouse at the correct temperature. This can be particularly important where chilled warehouses are used to store goods that are received in both a chilled and ambient condition (as otherwise the receipt of ambient temperature goods could raise the warehouse temperature above permitted levels).
- Rapid close doors, insulated strip curtains and air curtains.
- Fans and temperature monitoring devices.
- Dense storage systems to maintain the correct temperature and make best use of the expensive refrigerated storage space, such as drive-in racking, powered mobile racking and automated storage and retrieval systems (AS/RS).
- Specialist fork-lift trucks, especially for frozen goods warehouses, including features such as heated windows, cabs, handles and/or floor mats; use of appropriate power source such as heavy-duty or lithium-ion batteries or hydrogen cells; electronic systems designed to prevent moisture ingress; heating of critical switches and components; specialist tyres; and hydraulic oils designed to withstand sub-zero temperatures.
- Personal protective equipment, such as thermal clothing, boots, hats and gloves, for warehouse operators.
- Electric plug-in points in yards for refrigerated trailers and containers.

Dangerous goods warehouses

There are many different types of dangerous goods, such as explosives, flammable gases, liquids and solids, oxidizing substances, toxic substances, corrosive substances and radioactive material. These may be for industrial use but also many everyday items are hazardous by their nature, for example, aerosols, inks, paints and motor

oil. All of these fall within the United Nations classification of dangerous goods and each type may require specialist storage conditions and different emergency procedures in case of an accident. Warehouse design will vary according to the specific nature of the hazard but features may include:

- separated warehouse buildings that can be isolated in case of emergency and/or separate fire zones within a building
- secure and locked area with restricted access for the storage of small quantities of dangerous goods
- access doors fitted with some form of restricted entry device
- low oxygen environment to reduce risk of fire
- specialist extinguisher systems such as in-rack sprinklers with foam additives and inert gas systems in small areas
- safe storage area slotting policies, for example locating highly hazardous materials at low levels where carbon dioxide systems are effective
- emergency lighting
- automatic air ventilation systems and smoke vents in the warehouse roof
- bunded storage area, i.e. where the floor is designed with a low wall (called a bund) to prevent any hazardous substances from leaking away and to retain any liquids that are on fire
- specialist features on fork-lift trucks, such as protection of ignition sources, temperature monitoring of components, gas detection with automatic shutdown, water-cooled exhaust manifolds, and forks made of specialist non-sparking material
- drench showers and eye-wash stations for personnel
- specialist chemical suits, breathing apparatus, escape hoods and other appropriate personal protective equipment placed in prominent positions for rapid deployment
- safe escape areas and routes for personnel, together with suitable signage
- audible and visible (i.e. flashing lights) alarm systems, including gas warning systems
- specialist packaging and hazard labelling of all goods

As can be noted from these two examples, there are many detailed considerations in the design of specialist warehouses that hold goods with particular product characteristics.

Warehouse management and information

24

Introduction

The management of a large warehouse is a very challenging position that requires a range of skill sets. Indeed, a warehouse/distribution centre manager is a senior position in many companies, recognizing the high costs and investment involved in the facility, as well as the key role that warehouses play in the provision of high customer-service levels. This chapter examines some of the key elements involved in warehouse management and then proceeds to explore the supporting information systems that are necessary for the successful operation of a large warehouse, whether it is automated or conventional.

Operational management

The management of a large warehouse/distribution centre is a complex task. There may be thousands of orders received in a day, across a range of thousands of SKUs, and normally requiring consolidation by individual order, packing and dispatch in possibly hundreds of vehicles. The planning of such an operation needs to be undertaken at a number of levels. For example, in the long and medium term, capacity planning must be undertaken to ensure that growth can be accommodated and that seasonal peaks can be met at the required service levels. In the short term, detailed workload planning is required to ensure that the appropriate levels of equipment and staff are available, and that these are correctly balanced between the different warehouse zones.

Capacity planning

Although the warehouse will have been designed for the throughput and storage levels envisioned in the business plan, these parameters are likely to change

significantly over time. It is therefore necessary to plan ahead on a continuing basis so that future requirements can be met by having the required staff, equipment, space and information technology resources available. This is particularly important for seasonal peaks when most warehouses either reach or exceed their capacity limits. Frequently, the storage peak occurs first as goods are brought in to the warehouse prior to the sales peak. Then the throughput peak occurs and finally the levels of returned goods peak. However, this situation may be further exacerbated by other factors. For example, in the UK, marketing campaigns such as ‘Black Friday’ and ‘Cyber Monday’ may shorten the period within which these peaks occur and also cause peaks in returned goods to coincide with very high continuing festive sales levels. Planning for the next season may need to begin over one year ahead – before the current peak season has even started. This is particularly necessary with automated systems where possible future capacity constraints need to be identified and budget approval obtained for extra equipment so that the implementation can start immediately after the current peak season. In this way, there is then time for the installation and the thorough testing of the new complete storage and handling system before throughput levels begin to increase.

Workload planning

For short-term planning the most important resource is that of staffing because any changes in demand will affect labour requirements significantly. Fortunately, staff resources can often be changed fairly rapidly, by such means as overtime, temporary staff and agency workers (although this is becoming increasingly difficult in many areas). The number of people required in the warehouse can be planned based on the operational efficiency performance metrics described later in this chapter. For example, the order picking rate (e.g. in terms of order lines per hour or cases per hour) would be used as a basis for planning the number of order pickers required for the next day or week. This can now be undertaken at a very detailed level, taking into account for example:

- *The work that has to be carried out at each stage of the operation.* Thus, the receiving workload can be estimated by the number of vehicles booked in for the following day, taking into account their type of load (e.g. palletized or loose loaded cartons – as this will affect the work content considerably).
- *The availability of individual workers,* together with their specific skill sets.
- *The anticipated performance levels* of teams or individuals, noting for example that workers new to an operation may not be as productive as more experienced workers.

There are information technology systems available to facilitate workload planning and these are often known as labour management systems (LMS).

In addition to staffing levels, short-term workload planning needs to include such factors as the required number of warehouse trucks and automated mobile robots (AMRs) for each area, and the capacity limitations of autonomous equipment, packing machines, storage space, loading bay space, etc. As well as long-term capacity planning and short-term workload planning, these factors need to be taken into account in real time to manage the optimum release and processing of orders. This planning therefore needs to be undertaken across various timeframes and should also be integrated into the company's overall sales and operations planning (S&OP) or integrated business planning (IBP) processes. As discussed later in this chapter, appropriate information technology needs to be in place to assist management in accordance with the complexity of the warehouse operation.

Performance monitoring

The continuous measurement of performance is obviously essential to monitor process improvement. Warehouses need to operate within tight service and cost standards, and failure to meet these standards can mean the difference between a successful and unsuccessful business, particularly as warehouses are often the last link in the chain before delivery to the customer. The wider aspects of cost and performance monitoring in logistics are discussed in Chapter 38. In this chapter, the more detailed requirements for monitoring in the warehouse are addressed.

Warehouses are trying to achieve a number of objectives simultaneously, such as cost minimization, on-time dispatches and order accuracy. It is therefore common to monitor a range of performance metrics to ensure that the warehouse is operating effectively. These measures typically include:

- *Service levels*: e.g. percentage of orders dispatched on time, percentage of orders fully satisfied (i.e. all order lines supplied), order fill accuracy, returns and customer complaints.
- *Operational efficiency*: e.g. number of cases picked per person hour, number of order lines picked per person hour, percentage level of engineered labour standards achieved, equipment uptime (e.g. percentage hours equipment available, with no breakdowns or routine maintenance).
- *Cost efficiency*: e.g. cost per case throughput, cost per pallet stored, conformance to budget (for staff costs, rent, equipment maintenance, packing materials, etc).
- *Resource utilization*: e.g. number of standard hours worked, percentage pallet storage capacity used, number of hours per day that equipment is used (e.g. sorters, robots or narrow-aisle trucks) although note that high utilizations may prevent peak throughputs being achieved, so these measures need to be interpreted with caution.

- *Stock integrity*: e.g. percentage of locations with correct stock (i.e. in accordance with the computer records, as measured during a physical stocktake), percentage of SKUs with correct stock, stock turn (i.e. annual throughput/average inventory level). The latter figure is also often represented as the number of weeks of inventory held in the warehouse (i.e. a stock turn of 10 equals $52/10$ or 5.2 weeks of inventory in the warehouse).
- *Cycle times*: e.g. average number of hours between arrival of goods on site and put-away to storage location (i.e. available for replenishment or picking), average number of hours between customer order receipt and dispatch of goods.
- *Safety*: e.g. number of days without an accident, number of days safety training, adherence to safety audits and hazard monitoring.
- *Personnel*: e.g. number of days skill training, percentage of staff multi-skilled, absenteeism and sickness rates.
- *Environment*: e.g. electricity and gas usage, percentage of energy produced on site (e.g. by solar panels), water recycling, percentage of returned goods or packaging recycled.

This list is by no means exhaustive. As noted earlier, warehouses may perform many different roles and therefore appropriate performance measures need to be selected to monitor how well the warehouse is undertaking its specific roles.

These measures serve different purposes and therefore may be classified in different ways, for example:

- *Leading and lagging indicators*: some indicators provide an early indication of trends while others tend to lag behind. For example, a low level of equipment maintenance may lead to poor equipment uptime, which may in turn impact on order cycle times, which may impact on on-time dispatches.
- *Single and joint indicators*: a common example of a joint indicator is on-time-in-full (OTIF) which combines measures of timely deliveries and order fill. Joint measures can represent the overall situation much better but do not isolate the precise causes of low performance.
- *External and internal indicators*: external indicators normally represent how a customer views the operation, while internal indicators provide managers with detailed performance within the warehouse.

It is important to understand the relationship between performance measures and to select a range of indicators within an appropriate system or framework (see Chapter 38).

Operational parameters define the context in which a warehouse is operating. It is therefore necessary to recognize that these parameters may have a significant

impact on the performance indicators mentioned above. For example, a change in the typical size of order may result in a much greater workload for a warehouse (at the same throughput) and thus may account for an apparent reduction in performance. For this reason, great care must be taken when benchmarking across different warehouses, as performance measures are only comparable within the same operational context (and this may vary significantly within the same industry and even within the same company). These operational parameters include:

- throughput and number of SKUs
- unit load and product characteristics (e.g. size and ease of handling)
- number of lines per order and number of units per order line
- added-value requirements

Benchmarking across warehouses in a meaningful way is thus extremely difficult and can often be very misleading (see also the section on ‘Influencing factors’ in Chapter 38 for further details). However, the use of key performance indicators, and linking these to changes in operational parameters, is an essential tool for successful warehouse management.

Staff management

The availability of such detailed performance data can be extremely useful for the planning and management of large warehouses. However, the correct balance needs to be struck between using such data to improve planning and performance, and the over-monitoring of individuals which can lead to a dispiriting, uninteresting and stressful working environment. The workforce is arguably the most important resource in a warehouse and therefore warehouse managers need to have a clear strategy of how to attract, motivate and retain individuals, ideally in a stimulating environment.

Features of staff management policies may include:

- financial and non-financial motivation and incentives (see Chapter 11)
- providing employees with autonomy of actions, challenging tasks and a clear purpose
- appropriate training: one-to-one coaching, use of virtual reality training, rapid induction for seasonal workers through the use of systems that guide employees, e.g. voice technology or pick-by-light
- good working conditions (e.g. appropriate lighting, heating and ventilation)

Process improvement

For ongoing operations, continuous process improvement is normally sought. A good understanding of operational parameters and performance metrics is key in this respect, as well as a good understanding of the alternative warehouse operating methods that are available. In many warehouses, methodologies such as 'lean' operations, Six Sigma (see Chapter 13) and staff forums have become the norm.

Meeting legal requirements and local regulations

Organizations have a duty of care towards their employees and there is a wide range of legislation that must be complied with in warehouse operations, including, for example, manual handling, lift equipment, working hours and health and safety (including safe working practices and emergency regulations such as social distancing during the Covid-19 pandemic). In addition, there are often rules relating to the goods themselves, such as food and hazardous goods regulations.

As an example, almost all warehouses involve the operation of fork-lift trucks. Diesel-powered trucks tend to produce gases that include particulates that can cause eye irritation and respiratory problems and can contain carcinogenic substances (and these trucks are therefore normally used outdoors). Liquefied petroleum gas (LPG) trucks produce some carbon monoxide, particularly if badly serviced. In the case of electric trucks, the charging of batteries produces potentially explosive gases. Good servicing, good ventilation and, where necessary the use of extraction equipment, are therefore critical considerations for a safe working environment in warehouses where fork-lift trucks are used.

Formal risk assessments need to be carried out to examine potential hazards, and then methods of avoiding the hazard or minimizing the impact should be identified and implemented. In this regard, there are many guidelines (e.g. on ergonomic design for truck driver positions and picking/packing stations) and there are various codes of practice issued by industry bodies. For example, racking guidelines are issued by such bodies as the Storage Equipment Manufacturers Association (SEMA) in the UK, and the Fédération Européenne de la Manutention (FEM) in Europe.

Further details on warehouse safety may be found in Chapter 41.

Other management responsibilities

There are many additional management responsibilities, for example:

- *Inventory accuracy and stock-counting.* This may be undertaken by a periodic stock-count or more normally by perpetual inventory checking (e.g. counting the number of items in a pick location when at its lowest point – just before replenishment). Drones or mobile robots with cameras on telescopic poles may be used for high-level locations.

- *Cleaning.* Specialist cleaning trucks or autonomous mobile robots may be used for this purpose.
- *Security.* This includes features such as perimeter fencing, gatehouses, CCTV, random staff searches and possibly the use of drones with artificial intelligence (AI) to monitor any suspicious behaviour in the yard. Further details on security are covered in Chapter 41.
- *Environmental management.* All environmental features mentioned in Chapter 23 need to be controlled and the warehouse's carbon footprint actively managed.

Information technology

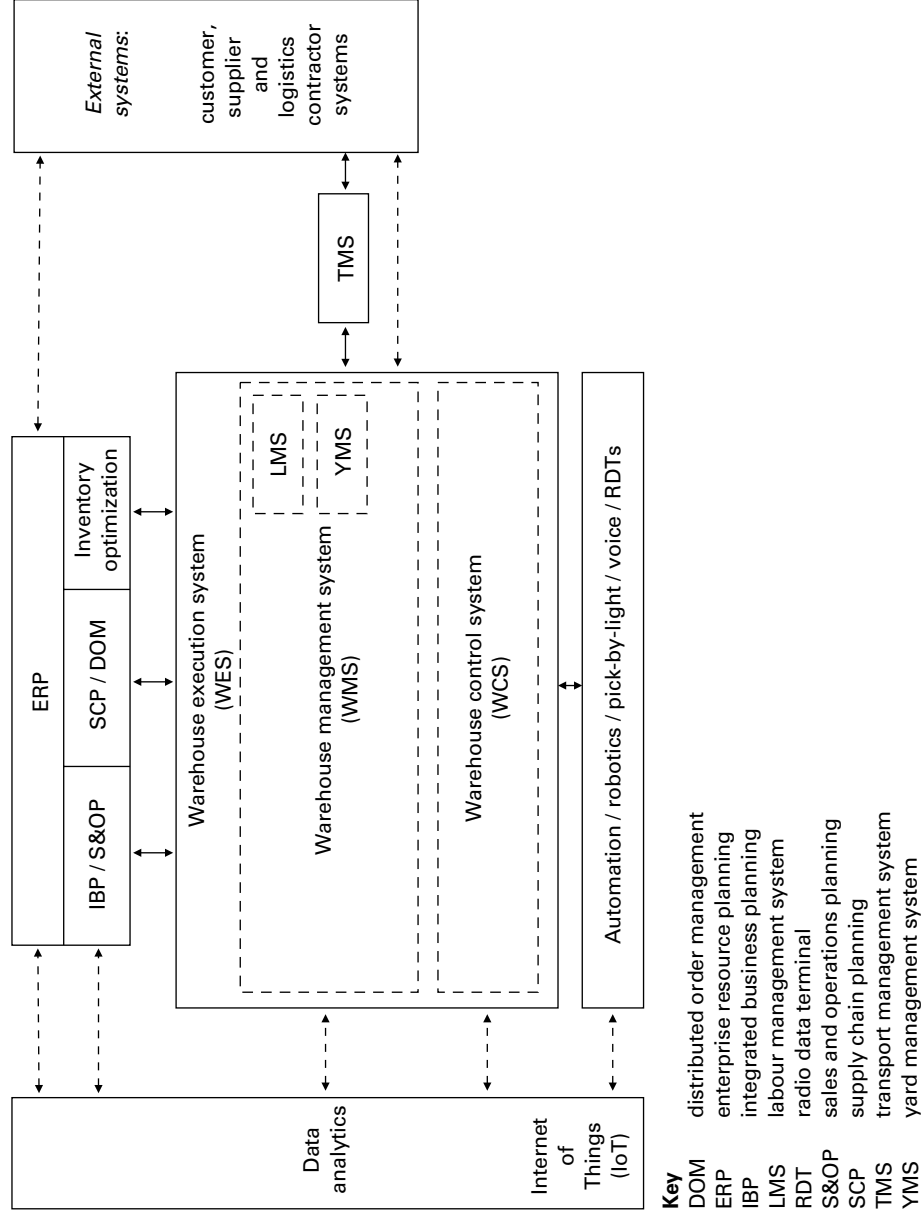
Advanced information technology is essential for the management of large modern warehouses. Even in smaller conventional warehouses, for example with reach trucks and ground-level picking, significant advantages can be achieved in terms of productivity, speed and accuracy with the benefit of a good warehouse management system (WMS).

Systems architecture

Most warehouses are thus managed and operated by means of a WMS. This normally interfaces with the company's main transaction system, typically an enterprise resource planning (ERP) system, to access information such as purchase orders and to download customer orders. In turn, the WMS will feed back information such as goods received and dispatched. It may also interface with various planning systems such as supply chain planning (SCP), integrated business planning (IBP) and sales and operations planning (S&OP), as well as inventory optimization packages.

The WMS is used to control all the operations in the warehouse and issues instructions to subsidiary systems, for example equipment control systems – often known as warehouse control systems (WCS). Thus, a WMS will issue an instruction to an AS/RS control system for a crane to move a specific pallet from a pick-up and deposit station at the end of the aisle to a particular location in the racking. The equipment control system will then direct the crane and provide feedback and diagnostics if the crane cannot fulfil this operation (e.g. owing to mechanical failure). Combined WMS, WCS and other warehouse systems are sometimes referred to as warehouse execution systems (WES). The warehouse systems also normally interface with various other computer systems such as transport management systems (TMS), data analytical tools and external supplier/customer/logistics contractor systems. A typical systems architecture for a warehouse is shown in Figure 24.1.

Figure 24.1 Typical warehouse systems architecture



Data capture and transmission

Data may be captured for the WMS by various means including:

- *Barcodes*. These are the most common form of capturing data in warehouses. A barcode comprises a number of vertical (or sometimes horizontal) bars of varying thicknesses. Each combination of bars represents a letter or number. There are a number of ‘symbolologies’ established by different organizations for varying purposes (e.g. for retail sales, outer packaging or for use in specific industries). The codes are normally structured so that, for example, the first few bars indicate the ‘symbolology’, then the next few bars may indicate the national coding authority, the manufacturer, then the product number and, often, finally, a check digit. The barcodes are read by scanners, or image-based camera systems, for direct input into the WMS. Common applications are to check barcodes on locations within pallet racking, to confirm products when picking, and to read labels automatically on sorters. Barcode labels are inexpensive and normally conform to internationally recognized standards so that they can be read throughout the supply chain. However, normal barcodes can only provide a few digits of data, such as a product code or a pallet identification number. There are two-dimensional barcodes available and, as the name suggests, these are scanned in two directions simultaneously. These can hold hundreds of numbers or characters, but their use is not widespread, as special scanners are required at each stage in the supply chain and common standards are not fully established. They are, however, used in ‘closed-loop’ situations. The main problems with barcodes are that they require line-of-sight, are often labour-intensive to operate and cannot provide real-time data with regard to location.
- *Radio frequency identification (RFID)*. This technology is used for the tracking of unit loads (such as roll-cage pallets and tote bins), for carton identification and for security and other purposes at item level (e.g. for tracking high-value goods), as well as for sensor data (e.g. monitoring a package’s temperature, humidity and shock). As the name suggests, RFID is basically the identification of items by means of radio waves. There are normally four components of such a system:
 - a tag, which is affixed to the goods or container – this normally comprises a microchip and an antenna, and may or may not contain a battery (depending on whether it is an ‘active’ or a ‘passive’ tag)
 - an antenna, which receives the data from the tag (and may also emit to it)
 - a reader, which reads the data received by the antenna
 - a host station, which contains the application software and relays the data to the server or middleware

Active tags tend to be used for high-value units (e.g. for tracking car chassis in assembly plants or for ISO containers). However, the greatest use in commercial

supply chains is in passive tags. These tags rely on incoming signals to provide power and are thus limited in range to between about 1 metre and 4 metres. This is because they need very strong signals to activate the tags and because the power they can emit is very weak. The reader and tag therefore have to be in close proximity. Their low and falling costs mean that it can be cost-effective to place these tags on pallets or cases or even to integrate them into individual products. However, there are issues that need to be considered in such areas as standards, technical feasibility, operational robustness, financial business cases and, with regard to individual products, civil liberties.

- *Other tag/beacon technologies.* There are various alternatives to RFID, including technologies such as near-field communication (NFC), wi-fi, ultra-wide band (UWB) and Bluetooth low-energy (BLE), and these may be used for communicating with sensors, tags or beacons (which are similar to active tags). These have relative advantages and disadvantages in terms of such factors as power requirements, infrastructure, smartphone compatibility, range and provision of real-time location data.

Other methods of data capture and transmission include the use of voice recognition, vision technology (e.g. headsets or ‘smart’ glasses), pick-by-light (normally used for order picking) and put-to-light (normally used for sortation after order picking). All of these systems were described in Chapter 21 under order picking but they can equally be used for other operations within the warehouse such as goods receiving, put-away, replenishment, dispatch and stock-counting.

Error rates in these identification systems tend to be very low. In fact, a more common problem is the non-reading of data, for example, because of defaced barcode labels or the non-receipt of radio waves (e.g. owing to the presence of metals or liquids) in the case of RFID. One comparison of picking systems indicated that 99.3 to 99.5 per cent pick accuracy is typically achieved with handheld barcode scanners, 99.5 to 99.7 per cent with pick-by-light and 99.7 to 99.97 per cent with voice recognition (MWPVL International, 2021). Figures may vary across different operations, for example, depending on whether the location or the item itself is scanned. Thus, when only the location is checked (e.g. in the case of using the location check digit in voice picking, or a location barcode in scanning), such a check would not pick up any errors in the put-away operation (i.e. the wrong goods being placed in the wrong location in the first place). In terms of picking speed for these three technologies, the MWPVL White Paper indicated that pick-by-light has the highest picking rate, followed by voice recognition and then handheld barcode scanners.

Automatic identification systems are often supported by radio data communication. Typically, a number of base stations are located around a warehouse and these provide a means of two-way communication between the warehouse management system and computer terminals. These terminals may be static or mobile – for example, held by a person or fitted to a trolley or fork-lift truck.

In this way, real-time information is provided for management and for the operators. Thus, an order picker can be provided with information for the next pick (e.g. location and quantity) as soon as he/she is ready to do this, and can interrogate the system if there is a problem. Radio data terminals may also be handheld or wrist-mounted, and are often fitted with barcode scanners. In the case of wrist-mounted terminals, the scanners may be located on a glove or a ring on one or two fingers, thus keeping both hands free for picking (see Figure 24.2).

Figure 24.2 Barcode scanning using ring scanner and wrist-mounted radio data terminal



SOURCE ©SSI Schaefer

Functionality

The major WMS packages are very complex and have a wide range of functionality that may be turned on or off for particular applications. For example, in electronics, batch traceability of components in kitting operations may be significant, whereas in food manufacturing the control of sell-by dates may be important. By having common software across industries, it is easier to apply upgrades to the software. However, it is also common for companies to develop bespoke software to meet their particular requirements.

WMS functionality covers all the activities of the warehouse, as shown in the examples below:

- *Receiving*: yard planning, checking against electronic advance shipping notices (ASNs), checking for dimensions and weights, quality sampling.
- *Put-away*: algorithms to determine the best storage location, support for all feasible storage types (e.g. block stacking, double-deep).
- *Replenishment*: fixed trigger point or order-based replenishment to pick locations.
- *Picking*: pick route optimization, slotting (i.e. optimum location of each SKU in pick face), wave or waveless order release, batch and zone picking.
- *Added-value services*: kitting, labelling, final assembly (requiring bills of materials).
- *Packing*: identification of correct carton size (by database of dimensions for all SKUs).
- *Cross-docking*: planning, labelling and sortation.
- *Sortation*: by various categories, such as by order, vehicle or geographical area.
- *Dispatch*: load planning, marshalling lane control, documentation, transmission of ASNs.
- *Dual cycling*: for example, a truck may be tasked with two or more activities during one visit to an aisle, such as put-away, replenishment and full pallet picking.
- *Stock-counting*: full count and perpetual inventory.
- *Yard management*: control of truck parking and dock door allocation.
- *Multiple language capability*: warehouses often employ operators from various ethnic backgrounds who may not be able to speak the home language fluently. Modern systems therefore may communicate in multiple languages and this is particularly common with voice technology where the system can be set up to recognize and understand the sound (and therefore language) of each operator.
- *Management*: performance measurement, productivity schemes, billing, pallet management, customs reporting and other management features, with full graphical interface. Also, workload planning and modelling (e.g. for new product ranges or new racks) may be an integral part of the WMS/WES or be closely linked tools, as described below.

Tracking goods by inward batch numbers and customer order numbers may be carried out across these processes so that the received goods can be identified (e.g. for quality purposes) and so that progress on individual orders can be provided (e.g. through track and trace systems).

Planning tools

The need for capacity planning and workload planning was explained earlier in this chapter. There are various tools available to assist management in this planning and, particularly for large-scale complex operations, these include:

- *Data analytics.* Real-time data can be fed from ‘edge’ computing devices such as voice systems, robotics and other assets or products connected to the Internet of Things (IoT) – for example, a real-time location system (RTLS) using radio tags or beacons can be used to input the actual location and activity of trucks, staff, robots, tote bins or items. This data may be used to analyse how the warehouse has performed, is performing or increasingly how it will perform in the future e.g. as further orders are released.
- *Digital twins.* A digital twin of a warehouse is basically a computer simulation of the operations. The real-time data mentioned above can be used for undertaking ‘what if’ analyses of different operational scenarios, either for future planning or immediate operational planning. For example, they may be used to plan exactly which orders to release to what mix of labour, manual/automated equipment and robotics or to decide for which orders to undertake batch picking. This type of decision-making system for immediate operational planning is often referred to as dynamic work execution.
- *Artificial intelligence (AI).* Over time the work execution system can understand how best to operate by means of machine learning (a particular aspect of artificial intelligence). Thus, many operational decisions can be automated, taking into account the complexities of the specific orders received and the resources available in terms of equipment, labour and robotics. For example, the exact release of orders to maintain waveless picking can be optimized, together with the required combination of labour and associated cobots. Similarly, autonomous mobile robots (AMRs) may operate in ‘swarms’ and these can be controlled by AI. Another use of AI is in slotting, for example, by determining which products are commonly ordered together (and therefore should be located near each other). Similarly, AI may be used to determine when to move products from fast-moving to slow-moving locations as product demand changes, taking into account the cost of physically moving the items as compared to the picking efficiencies that can be gained.
- *Predictive maintenance.* Real-time monitoring can be used to predict maintenance requirements of specific pieces of automated equipment or trucks and hence plan shut-downs at convenient times. This may be undertaken by connecting specific sensors on the equipment to the Internet of Things (IoT). For example, in the case of paying for robotics in the form of robots-as-a-service (RaaS) the supplier may remotely monitor the health of the robots and attend to provide maintenance as required.

PART FIVE

Freight transport

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International logistics

25

Modal choice

Introduction

This chapter provides an introduction to some of the broader issues concerning international logistics and the choice of freight transport mode. Initially, the relative importance of the different modes is briefly considered with respect to freight transport movements, although statistics are only available for internal country movements and those movements within economic unions. It is shown that road freight transport is, generally, the major mode for these freight movements. A simple approach for modal choice selection is then proposed. This approach is split into four stages and the key elements of each of these are reviewed. The four stages cover operational factors, transport mode characteristics, consignment factors, and, finally, cost and service requirements. The chapter concludes with a discussion of some of the main aspects of international trade that are relevant to logistics and to the choice of international transport mode.

The other chapters in Part Five then address each of the major modes on an individual basis. Chapters 26, 27 and 28 provide an overview and description of the major modes of international transport: maritime, air and rail/intermodal. For each of these, the basic infrastructure of the industry is reviewed, together with a variety of other aspects such as equipment, safety, pricing, security and documentation.

Road freight transport is then discussed in a number of chapters. Vehicle selection factors are described in Chapter 29, including the main types of vehicle and vehicle body, different operational aspects, and load types and characteristics. In Chapter 30, vehicle and fleet costing is covered. The main transport costs are indicated, and whole life costing is described. Chapter 31 concentrates on the planning and resourcing of road freight transport operations and in Chapter 32 the key aspects of vehicle routing and scheduling are considered. Finally, Chapter 33 reviews the key elements of international freight forwarding, such as the crucial role of documentation, cargo insurance, specialist services and project logistics, which often integrates several modes of transport to achieve its goals.

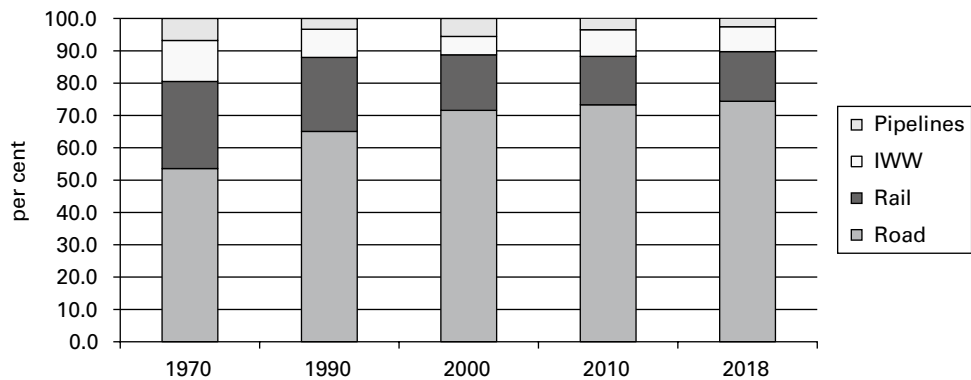
Relative importance of the main modes of freight transport

The changing nature of logistics and the supply chain, particularly the move by many companies towards global operations, has had an obvious impact on the relative importance of the different modes of freight transport. In a global context, more products are moved far greater distances because of the concentration of production facilities in low-cost manufacturing locations and because companies have developed concepts such as focus factories, some with a single global manufacturing point for certain products. Long-distance modes of transport have thus become much more important to the development of efficient logistics operations that have a global perspective. Thus, the need to understand the relative merits of, say, sea freight as against air freight is crucial, although for many localized final delivery operations it is still road freight transport that offers the only real option. All of these developments serve to emphasize the need to appreciate the many different facets of transport modal choice for international logistics.

Road freight transport continues to be the dominant mode of transport for many countries, although some countries that cover large geographical areas, such as the United States and South Africa, do have very significant rail freight movements. A look at recent European statistics confirms the importance of road freight transport in continental Europe. Figure 25.1 is based on statistics for the main European Union (EU) countries. This indicates the relative importance of the different modes of freight transportation within the EU, and allows for a comparison of modal split over time since 1970. Deep-sea and air freight transport, which are of course of major importance for international freight movements, are not represented in these and the following sets of statistics. Figure 25.1 shows that road transport has continued to be the most-used mode for many years, and it seems unlikely that this will change in the near future. Rail freight has remained relatively static since the turn of the century. Inland waterways (IWW) are still relevant in some countries and pipelines remain important for certain specialized movements.

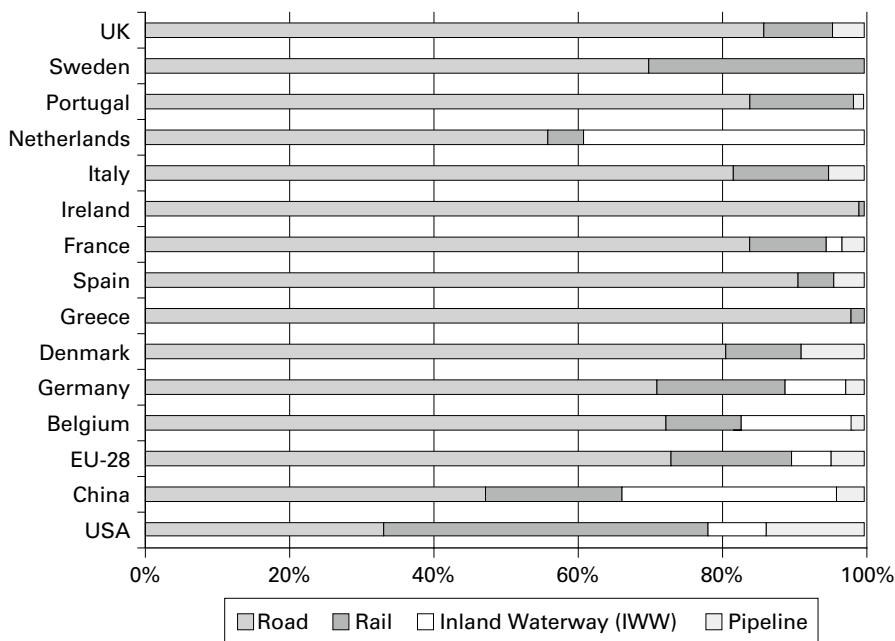
The importance of road freight transport is also emphasized when the modal split is compared for freight transport movements within some individual countries, as Figure 25.2 illustrates. However, it is also clear from Figure 25.2 that for some countries rail freight transport does still play a major role. This is shown for the United States, China and Sweden. Rail freight transport tends to be more prevalent in countries with a large geographical spread or where there are significant environmental issues and restrictions on road freight transport. Note also the importance of inland waterways for freight movement in some countries, such as the Netherlands and China.

Figure 25.1 Freight transport modal share percentage in the key EU countries (% of tonne kilometres)



SOURCE European Commission, 2021a and 2021b

Figure 25.2 Freight transport modal share for selected European countries (2018), China (2015) and the United States (2018) (% of tonne kilometres)



SOURCE European Commission, 2021a, and Statista, 2021

All of the major modes of transport can be considered for the movement of goods internationally, where deep-sea and air freight are often favoured due to the distances travelled. The selection of the most appropriate transport mode is thus a fundamental decision for international distribution and logistics management, the

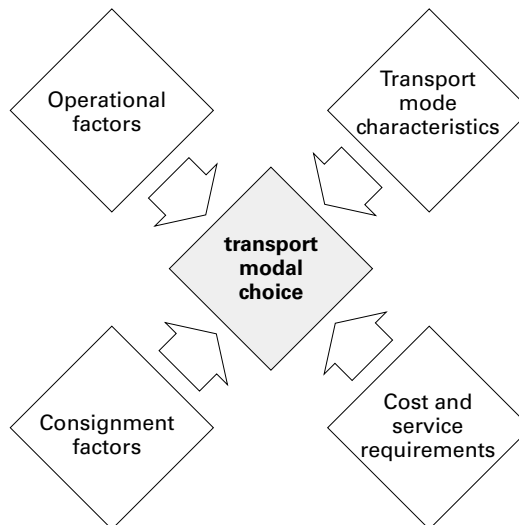
main criterion being the need to balance costs with customer service. There are very significant trade-offs to be made when examining the alternatives available between the different logistics factors and the different transport modes.

For the remainder of this chapter, a broad method of modal selection is outlined. This takes into account operational factors, transport mode characteristics, a series of consignment or route factors, and cost and service requirements. In addition, some particular aspects of international trade are also considered.

Method of selection

In this section the process for selecting a suitable mode of transport is introduced. The broad approach is split into four key stages, as shown in Figure 25.3, covering operational factors, transport mode characteristics, consignment factors and, finally, cost and service requirements. These key elements are described in the bulk of the remainder of this chapter. Many of these considerations may seem relatively obvious, but the problem lies with the large number of different aspects that need to be taken into account and the way that these factors interact. This is why a methodical selection process is required.

Figure 25.3 Modal choice: selection process



There are a large number of associated operational factors that need to be considered as a part of the modal selection process. These have been categorized as those that are external to the direct distribution operation, customer characteristics that need to be taken into account, physical product characteristics and other

logistics components. The different transport mode characteristics also need to be understood and assessed. Clearly, some transport modes are more suitable to certain types of operational requirements than are others. A series of consignment factors also need to be addressed to ensure that the particular choice of mode is appropriate. For example, an urgent order or consignment should be moved via a fast transport mode. Finally, there is the ever-present and important logistics trade-off between cost and service that needs to be included in the selection process.

Operational factors

External factors

Encompassing the many operational factors that may need to be considered are those that are external to direct distribution-related factors. These are often particularly relevant when contemplating the international context of modal choice, because from country to country these factors can vary significantly. They include:

- The basic infrastructure in the country. In particular, the transport infrastructure is likely to be important. For example, opportunities to use rail will be significantly affected by the rail network that exists within a country. Many countries have limited track availability, while others may have mainline track but an insufficient number of railheads, or railheads in inappropriate locations for industrial or commercial use.
- Trade barriers. These might include, for example, customs duty, import tariffs or quota payments. These can have a big impact on the overall cost of a product which may affect the decision concerning the most appropriate mode of transport to use. The likelihood of border delays may also impact on the best choice of transport mode.
- Export controls and licences. With these, there may be implications for the quantity of product that can be shipped in given periods of time.
- Law and taxation. Clearly, legal requirements in both a general and a specific context are likely to differ from one country to another. There is, for example, some very different road transport and environmental legislation that can affect the use of vehicles in terms of size restrictions, load restrictions and time restrictions.
- Financial institutions and services, and economic conditions. Elements such as exchange rate stability and inflation, for example, can influence modal choice. Where financial changes occur at a dramatic rate in a country then speed of delivery may be important.

- Communications systems. These can have an impact, for example, on the supporting processes and paperwork of freight movements. Delays can be more likely with some modes of transport. For example, sea freight can have particularly lengthy and onerous procedures.
- Culture. Differing cultural aspects may influence how trade and commerce are undertaken. For example, the choice of transport mode may rest on ownership rather than cost-effectiveness.
- Climate. Extremes of weather, temperature and humidity can have a major impact on some products. Thus, modes of transport must be selected carefully to ensure that prevailing climatic conditions do not badly affect freight while it is in transit. Suitable protection must be guaranteed.
- Environmental issues. As with most logistics operations, companies involved with international transport are aware of the impact that this has on the environment and look to set standards and monitor the effects of their performance accordingly. Areas of importance include carbon emissions, green transport corridors, vehicle utilization and alternative fuels. These and other factors are described in Chapter 42.

This list can be a long one, and the relevant inclusions will vary according to the country under consideration (see Chapter 33 for some related aspects).

Customer characteristics

Particular customer characteristics may also have a significant effect on the choice of transport mode. Most of the characteristics will need to be considered for both national and international modal choice; that is, they are not specific to overseas distribution. The main characteristics to take into account are:

- Service level requirements/service level agreements. Some service level requirements and agreements can have a significant impact on choice of transport mode. Delivery time constraints can mean that certain relatively unreliable modes should not be considered. This may occur when there is a need for delivery to be at a certain time or on a certain date, or when a specific time delivery window is stipulated. This is very common in retail delivery operations and supply industries such as oil and gas where failure to deliver on time can lead to very expensive shut-downs.
- Delivery point constraints. This factor is a very important one. It refers particularly to the physical aspects of delivery, including the location of the delivery point, any access constraints concerning the size of vehicle that can make the delivery and any equipment requirements for unloading. Once again, these are common problems in retail delivery.

- Credit rating. The credit rating of a customer may impose a limit on route selection and modal choice. New customers and existing customers with a poor credit rating mean that a company will want to be sure that payment is confirmed before delivery is made. Thus, commercial arrangements may override any logistical preference for a particular transport method. It should be noted, however, that for shipments by sea the bill of lading can be held through a letter of credit until payment is made at a bank, although the situation is different for air freight owing to the speed of transit and the fact that an air waybill (AWB) is not a document of title to the goods.
- Terms of sale preference. There are a number of different terms of sale that can be used, ranging from ex works (at the supplier factory) to delivered duty paid (at the customer's delivery point). The terms of sale preferred by a customer therefore have a very large implication for the choice of transport mode – and, of course, who makes that choice, the supplier or the customer. The different terms of sale (Incoterms®) are outlined later in this chapter.
- Order size preference. The physical size of an order clearly has an impact on modal choice, as some modes are more suitable for small orders and others for large ones. There may be significant cost implications here.
- Customer importance. Most suppliers have 'A'-rated customers who are deemed to be their most important and who really must be given a delivery service that does not fail. For these customers, service reliability is essential and so certain routes and transport modes will be preferred.
- Product knowledge. Some products or orders may necessitate some knowledge transfer to the customer at the time of delivery. This may relate to the need to assemble the product in some way, or information on how to use the product. It is not likely to be an element that affects many orders, but would be important to both route and modal choice where it does.

Other logistics components

The final series of important characteristics that need to be considered when determining modal choice concerns the other logistics components. These are the elements concerned with the classic logistics trade-offs described in Chapter 2. In any company's distribution structure, there will be a number of factors that are interrelated. These may be fixed and unchangeable, and seen as sacrosanct by certain sections of the company or they may be subject to change – providing overall benefits can be identified from any change. These factors need to be known. There is no point in designing a system or choosing a mode that fails to allow for fixed and unchangeable factors. It is important to be aware of the constraints that these factors impose on any proposed new system. The main elements that might affect route and modal choice may include:

- **Supply points.** The location of raw material or component suppliers will clearly impact on route and modal choice. This applies particularly where supply is sourced from abroad. Modal choice issues will be key where a raw material or component is vital to a manufacturing process or where inventory levels are relatively low at the point of production.
- **Production plants.** The location of manufacturing and production plants will impact on route and modal choice. This applies particularly where supply is sourced from abroad, as shipment delays may be unacceptable.
- **Warehouses and storage facilities.** Finished goods warehouses are often located adjacent to production points and factories, but they may, on the other hand, be some distance away and thus involve regular movement of finished product from factory to warehouse.
- **Depots.** Inventory and stockholding policy will usually determine where depots are located. The location of depots with respect to their supply points (usually production or warehouse facilities) in terms of distance and geography will have an impact on the choice of transport mode.
- **Marketing plans and policies.** These may affect transport choice because some plans and policies call for a very fast response time to customer orders, so, depending on depot location, a fast method of transport is essential. A good example is where new products are marketed or where there is a promotion of a particular product. Fast transport may often be required to support any marketing-induced surges in demand.
- **Supply philosophy.** The use of just-in-time and other supply policies that are based on minimum stockholding levels will have an impact on transport modal choice as delivery reliability is key for these approaches in order to avoid costly stockouts.
- **Existing delivery system.** There may be elements of the existing delivery operation that need to be retained. This often applies where there are sunk costs in a transport fleet, which means that it is a cost imperative to keep all or some of the vehicles in the short to medium term.

Transport mode characteristics

The modal choice selection process described so far has been concerned with the various operational factors that might need to be taken into account. The next main set of considerations involves the various attributes of the different modes themselves. These major attributes are considered specifically in relation to the factors outlined in the previous section. More detailed structural and practical aspects of the different modes are discussed in the chapters that follow.

Conventional sea freight

Of the main alternative types of sea freight, both the conventional load and the unit load are relevant. The unit load (container) is considered later. For conventional sea freight, the main points to note are:

- **Cost economies.** For some products, the most economic means of carriage remains that of conventional sea freight. This particularly applies to bulk goods, products that are larger than shipping container size and commodity products like bales of rubber that are going long distances. Where speed of service is completely unimportant, then the cheapness of sea freight makes it very competitive.
- **Availability.** Most types of cargo can be accommodated.
- **Speed.** Sea freight tends to be very slow for several reasons. These include the fact that the turnaround time in port is still quite slow, as is the actual voyage time.
- **Need for double-handling.** Conventional sea freight is disadvantaged by the slow handling methods still used. This is especially true when compared with the more competitive ‘through transport’ systems (such as container systems and roll-on roll-off ferry systems) with which sea freight must compete. The problem is particularly apparent on some of the short sea routes.
- **Delay problems.** There are three major delay factors that can lead to bad and irregular services, as well as helping to slow up the transport time itself. These are over and above the journey time. They are pre-shipment delays, delays at the discharge port and unexpected delays due to bad weather, missed tides, etc.
- **Damage.** The need to double-handle cargo on conventional ships tends to make this mode more prone to damage for both products and packaging.

International road freight

As already indicated, road freight transport is the most important mode for national movements within most individual countries. In the context of international distribution, road freight transport is also important, even where there are fairly significant geographic constraints such as sea crossings. In the UK for example, road freight is viable via the use of roll-on roll-off (RORO) ferry services and the Channel Tunnel route. These allow for the through transport of goods from factory or warehouse direct to customers’ premises abroad.

Compared with the other forms of international freight transport, the major advantages and disadvantages of road freight transport services are as follows:

- They can provide a very quick service (ferry and tunnel schedules can be carefully timed into route plans, e.g. drivers’ breaks, if they are a necessary part of the journey).

- For complete unit loads with single origin and destination points, they can be very competitive from the cost viewpoint.
- There is a greatly reduced need to double-handle and trans-ship goods and packages, and for direct, full-load deliveries this is completely eliminated. This saves time and minimizes the likelihood of damage.
- Packaging costs can be kept to a minimum because loads are less susceptible to the extreme transit 'shocks' that other modes can cause.
- The system can provide regular, scheduled services due to the flexibility of road-vehicle scheduling.
- Road freight transport can lose its speed advantage when used for less than lorry-sized loads (LTL). These entail groupage and so involve double-handling (at both ends of the journey), additional packaging and time delay.

Rail freight (conventional)

There are several different rail freight systems that are used. Common categories are bulk, covered rail wagons and intermodal (container and swap-body), although there are specialized automotive wagons as well. These are described in Chapter 28. More conventional rail freight systems have the major benefit of being relatively cheap forms of transport, particularly suitable for bulky and heavy consignments that require movement over medium to long distances and where speed is not vital. There are also environmental advantages to using rail freight transport compared to some of the other modes. The principal disadvantages of conventional rail freight are as follows:

- Rail wagons are prone to some very severe shocks as they are shunted around goods yards. Shunting shocks can cause damage to products. To overcome this, costly packaging needs to be used where products may be susceptible to damage.
- There is a need to double-handle many loads because the first and last leg of a 'through' journey often needs to be by road transport.
- There are a limited number of railheads available at factories and depots, making direct origin-to-destination journeys very rare. Few companies now have railway sidings on their premises due to their high cost of upkeep and operation.
- In general, rail transport is a very slow means of carriage – particularly when the whole journey is taken into account. Many freight trains have to fit their schedules around passenger trains, which take priority. This can cause significant time delays to the rail freight.
- Rail freight transport can be very unreliable. Batches of wagons may arrive at irregular intervals. This can cause further delays for international traffic if a complete shipment is on a single customs document.

- For international movements, there are significant compatibility issues (especially across Europe). These include variations in track gauge sizes, bridge heights and (lack of) electrification.

Air freight

The use of air freight as an alternative transport mode has grown rapidly in recent years. Major developments in the areas of integrated unit loads, improved handling systems and additional cargo space, together with the proliferation of scheduled cargo flights, have increased the competitiveness and service capability of air freight (see Chapter 27).

The major attributes of air freight are as follows:

- Air freight compares very well with other transport modes in terms of speed over longer international movements. This is because it has very rapid airport-to-airport transit times over these longer distances.
- Although air freight is very quick from airport to airport, there can be occasions when this speed factor is diminished because time can be lost due to airport congestion and handling, paperwork and customs delays.
- One particular advantage of air freight is known as 'lead-time economy'. The ability to move goods very quickly over long distances means that it is unnecessary to hold stocks of these items in the countries in question (spare parts, etc). The short lead time required between the ordering and receiving of goods, and the resultant saving in inventory-holding costs give this benefit its name of 'lead-time economy'.
- The air freighting of products allows for a great deal of market flexibility, because any number of countries and markets can be reached very quickly and easily. This is particularly advantageous for a company that wishes either to test a product in a given area or to launch a new product. The flexibility of air freight means that a company need not necessarily set up extensive stockholding networks in these areas.
- The movement of goods by air freight can result in a marked reduction in packaging requirements. As a general rule, the air freight mode is not one that experiences severe physical conditions, and so its consignments are not overly prone to damage and breakages.
- Air freight transport is very advantageous for certain ranges of goods, compared to many of the alternative modes. This includes those commodities with high value-to-weight ratios (the high product value means that an expensive freight on-cost is not significant), perishables (where speed is vital), fashion goods (which tend both to be expensive and to have a short 'shelf life'), emergency supplies (speed again is vital) and finally spare parts (the lack of which may be holding up the operation of a multimillion-pound project).

- For the vast majority of products, air freight is a very expensive form of transport. This is by far its greatest disadvantage. In some instances, and for some products, cost is of very little consequence, and it is for these types of goods that air freight tends to be used.
- Air freight has suffered to a certain extent due to security concerns at airports. This is one reason for the gradual growth in all-freighter aircraft, although a high proportion of air freight is still carried in the belly-hold of passenger aircraft.

Container and intermodal systems

Container systems can be viewed as a specialized mode of freight transport, although the container is now a fundamental feature of all the major national and international transport modes – road, rail, sea and air. Containerization makes possible the development of what is known as the ‘intermodal’ system of freight transport, enabling the uncomplicated movement of goods in bulk from one transport mode to another (see Chapter 28 for more details).

The main attributes of containers and container systems are as follows:

- They enable a number of small packages to be consolidated into large single unit loads.
- There is a reduction in the physical handling of goods, as they move from their point of origin to their point of destination.
- There is a reduction in individual packaging requirements, depending on the load within the container.
- There is a reduction in damage to products caused by other cargo.
- Insurance charges are lower due to the reduced damage potential.
- Handling costs at the docks and at other modal interfaces are reduced.
- There is a quicker turnaround for all the types of transport used. Port utilization also improves.
- The all-round delivery time is speedier, and so raises service levels.
- Documentation is simpler, although this may not be true for consolidated containers carrying multiple LCL consignments.
- The concept of ‘through transit’ becomes feasible, and allows for a truly integrated transport system to be developed.
- There is a need for special facilities and handling equipment, and these are very costly. Thus, there are a limited number of transfer points available.
- The initial cost of the containers themselves is very high, but as most containers are owned by shipping lines this should not affect users directly.

- The return of empty containers can often be an expensive problem. Trade is seldom evenly balanced, so return loads may not be available.
- Containers may leak, thereby causing damage due to rain or seawater.
- Loads may be affected by their position of stow, e.g. above or below deck.

Consignment factors

Certain consignment factors may have an impact on the final decision concerning the best mode of transport for each individual shipment. These factors normally relate to specific characteristics of the order or load that may influence the choice of transport mode. Often only a few of these factors will apply, but sometimes several need to be taken into account for any given order or load. The physical nature of the product is as important in determining modal choice as it is with all the other logistics functions. The main factors that need to be considered include:

- Volume-to-weight ratio: this concerns the relative amount of cubic capacity taken up by a given weight of product. For example, one tonne of paper tissues takes up far more space than one tonne of bricks. This is relevant when considering the different charging structures of the different transport modes – whether charged by weight or by cubic volume. For example, one tonne is normally charged the same as one cubic metre for sea freight, but the same as six cubic metres for air freight. Heavy goods are thus relatively more expensive by air freight.
- Value-to-weight ratio: this takes into account the value of the product to be transported. The relative transport cost of a high-value, low-weight product is likely to be so insignificant to the overall value of the product that the choice of mode from a cost perspective is virtually irrelevant (e.g. jewellery or computer chips).
- Substitutability (product alternatives): if a product can be substituted by an alternative from another source (and the sale lost), it may be worthwhile using a fast but expensive mode of transport to ensure that the order is accepted by the customer. Where no substitute is possible, a slower and less expensive mode can be used.
- Special characteristics (hazard, fragility, perishability, time constraints, security): a hazardous product may be restricted in how it is allowed to be transported (e.g. some chemicals), and a time-constrained product may have to be moved on a fast and expensive mode of transport to ensure it does not miss its time deadline (e.g. newspapers and promotional products).

These characteristics are considered in more detail in Chapter 6.

In addition to these physical factors, there are other elements specifically related to international movements that may need to be considered:

- **Routeing and through transit:** there may be some distinct routeing factors that must be adhered to and these may limit the options available to the shipper. Questions that might need to be considered include:
 - Is a direct route stipulated by the customer?
 - Are there countries through which the shipment may not travel?
 - Who is responsible for the through transit, the supplier or the customer?
 - Who is paying for the freight costs, the supplier or the customer?
- **Distance:** the distance that the load has to travel for delivery will have an influence on the mode of transport that might be considered:
 - What is the distance to be moved?
 - Does distance restrict the modal options that are available?
- **Type of cargo:** cargo characteristics will certainly need to be carefully considered when the route and type of mode are determined:
 - If it is bulk or general cargo, will limited alternatives mean that a certain specific route is preferable?
 - If it is bulk or general cargo, are certain routes cheaper?
 - Does the cargo have specific characteristics (i.e. it may be perishable or high value) that make certain routes more attractive?
 - Is the cargo hazardous? If so, are some routes unavailable?
- **Quantity:** the load quantity may influence the type of mode that can be used:
 - Full load: container and trailer options should be attractive.
 - Part load: consolidation is a possibility – but there may be time delays because the load is general cargo and there will be implications for packaging.
 - Small size: consider parcel, air freight, groupage/consolidation.
- **Unit load:** Is the load unitized? If not, is this an option and would it be cost-effective?
 - Will unitization help?
 - Is it a small or large unit load?
- **Priority:** it is vital to be able to understand and balance the need for the urgency of an order against the cost of delivery:
 - How soon must the goods reach their destination? This will influence the choice of mode.

- Does ‘Urgent!’ really mean ‘Urgent!’?
- Who pays the additional freight costs for an urgent order?
- Regular shipments: where regular shipments are to be made on certain routes it should be possible to negotiate competitive freight costs:
 - How often will these shipments be made?
 - Should a contract be negotiated or is ‘spot hire’ adequate?

Cost and service requirements

The ultimate decision for modal choice is the familiar logistics trade-off between cost and service. This must be considered in relation to the relevant operational factors, transport mode characteristics and consignment factors that have been outlined previously. In theory, the volume of freight (or size of load) to be moved and the distance to be travelled dictate the choice of mode based on relative costs. This is summarized in Figure 25.4.

Figure 25.4 Modal choice: selection matrix

Size of order/load	100T	Road	Road/rail	Rail/sea	Sea
	20T	Road	Road	Road/rail	Rail/sea
	Pallet	Road	Road	Road/rail	Air/sea
	Parcel	Post/road	Post/road/air	Post/road/air	Post/air
		Short	Medium	Long	Very long
Delivery distance					

SOURCE Alan Rushton, Cranfield University (unpublished)

On one extreme there is the small parcel that has to go a short distance. This is likely to be routed via road transport in a small van or perhaps post if a very small parcel. At the other extreme there is the 100-tonne-plus load going thousands of kilometres. This is most likely to go via sea freight.

In practice, other elements such as the speed of delivery required or the reliability of service may override these purely economic factors:

- Speed of delivery. Orders may be required quickly for a number of reasons that override the cost factor – such as urgent orders for spare parts. Air freight is often used instead of sea freight because the additional transport costs can be offset against inventory savings/stock availability.
- Service reliability. Some customer service policies are based on orders reaching customers to meet tight delivery windows, so control and reliability are important.

Rail is often cheaper than road for long-haul, but timing issues can mean that delivery time reliability is problematic. Many customers use road in preference to rail after suffering service interruptions.

Aspects of international trade

There are several key elements of international trade that are very relevant to logistics, particularly to the choice of international transport mode. Freight forwarding and documentation are discussed in Chapter 33, but other elements are considered in this final section of the chapter and include:

- trade agreements and economic unions
- financial issues
- terms of trade

Trade agreements and economic unions

This is a particularly exciting period for the development of logistics in a global context. The establishment, and realignment, of a number of international trade agreements and economic unions, such as the European Union (EU), the United States–Mexico–Canada Agreement (USMCA) and the Association of Southeast Asian Nations (ASEAN) among others, has had a major impact on the globalization of trade. Many products are produced and distributed across regions and continents, and there has been a significant impact on transport opportunities. As these changes have taken place, they have been a major influence on the structure of distribution and logistics systems throughout the world as trade barriers have been dismantled and new transport networks have been initiated. It will be interesting to see whether there will be any significant consequences from the changing composition of these unions, but it would seem that they will continue to be of major importance. For example, although the EU has lost the UK from its ranks after Brexit, there are many countries that have joined in recent years to swell the number of members.

Within the EU, for example, major barriers to trade have been overcome. These include:

- Physical barriers: this has involved the removal of customs control, the use of the single administrative document and the removal of immigration and passport control for EU members.
- Technical barriers: included here are the removal of all barriers to trade between member states of the EU; the free movement of goods, capital, services and workers; the harmonization of technical standards; common protection for intellectual and industrial property; and the opening-up of public procurement.

- Fiscal barriers: developments include the approximation of indirect taxation (VAT and excise duties), and the consequent removal of fiscal frontier checks.
- The broadening of geographic horizons such as the inclusion of many Central and Eastern European countries into the trade agreements.
- The broad acceptance and use of the euro currency, which allows greater transparency of pricing and the simplification of financial transactions.

Those provisions and changes that are particularly relevant to logistics can be summarized as:

- goods and services can be bought anywhere in the community
- internal customs barriers have been virtually abolished
- documentation has been simplified and standardized
- operating (transport) permit restrictions have been removed
- testing standards are acceptable in all community states
- there is free movement of capital

There remain certain policy areas where there are still some important differences between member states that have an impact on transport and logistics. These include:

- environmental issues (some countries ban road freight movements at certain periods during the week)
- duty on fuel (this varies between the different EU countries, making it more attractive to locate fleets in some countries)
- rail subsidy (this can provide some advantage to the movement of products by rail in certain countries)
- labour laws (these are important in a number of ways, making it more attractive and cheaper to employ labour in some countries)

Some significant opportunities have arisen for transport and distribution companies resulting from the development of economic unions. These have encouraged companies to increase the scope of their services across the wider geographic areas. They include the following:

- There is more competition between third-party companies because of the increased market.
- Transport and third-party distribution companies can offer and provide a more comprehensive Europe-wide service.
- There is easier and faster movement of goods across internal borders.

- Distribution and transport can be bought in any country – there is more cross-trading and cabotage (transport companies collecting and delivering goods in other member states).
- Increased opportunities for joint ventures with other European and international operators have enabled Europe-wide and global integrated logistics and transport organizations to develop.
- New depot locations and consequent transport flows can be determined to suit both sources and markets.

See Chapter 33 for further discussion regarding trade agreements and economic unions and their effect on international trade.

Financial issues

Identifying the most cost-effective opportunities in international transport and logistics requires a very sophisticated understanding of some of the key financial issues involved. There are many different elements that need to be taken into account when trying to identify the most cost-effective solution from a myriad of alternatives. The main factors include:

- Types of payment. These can include, in order of risk to the supplier:
 - an open account (where terms of payment are prearranged with the buyer)
 - a draft (where title of the goods is retained until payment is received)
 - a letter of credit (where the bank will authorize payment for an order once the precise conditions of the letter of credit have been met)
 - cash in advance (money paid up front – which few customers are happy to accept)
- Taxes and duties. These can have a big impact on the overall cost of a product. They may include import tariffs, value added tax or quota payments.
- Transport costs. These will include costs related to any of the different modes. Unless direct delivery is being undertaken using a single mode of transport, an allowance should be made for inland carriage from point of origin, plus international carriage, plus final delivery from the destination port.
- Associated transport charges. These can include port fees, bunker adjustment fees and fuel charges (see also Chapter 26).
- Other charges. These can include insurance, break bulk, storage and handling.

Terms of trade

It is important to be aware of the basic methods of undertaking business when concerned with international transport. There are a number of different ways in which goods can be purchased on an international basis, and it is essential that both the buyer and the seller are aware of which terms have been agreed. Different terms mean very different responsibilities for both the organization and the payment of the transport element of the order, and also determine the point at which the risk passes from seller to buyer. These terms are reviewed periodically and need to be checked accordingly. The latest published terms are known as Incoterms® 2020 rules and there are 11 of these predefined terms. They are divided into two categories based on method of delivery. The first group of seven rules applies regardless of the method of transport, while the second group of four are only applicable to sales that solely involve transportation over water. They are outlined in the box.

Incoterms® 2020

Any mode of transport

- **EXW: ex works** (named place of delivery). The seller makes the goods available at its premises or some other named place. The buyer bears all risk and costs, and is responsible for uploading. This term places the maximum obligation on the buyer and minimum obligation on the seller. The ex works term is often used when making an initial quotation for the sale of goods without any costs included. EXW means that a seller has the goods ready for collection at their premises (works, factory, warehouse, plant) on the date agreed upon. The buyer pays all transportation costs and also bears the risks for bringing the goods to their final destination. The seller does not load the goods on collecting vehicles and does not clear them for export. If the seller does load the goods, he does so at the buyer's risk and cost.
- **FCA: free carrier** (named place of delivery). The seller is responsible for making the goods available at its own premises or at a named place, e.g. a carrier's export depot. The seller is responsible for loading the goods on the buyer's transport and is responsible for delivery to the named place and export clearance including security requirements. Risk transfers once the goods are loaded on the buyer's transport at the named place.
- **CPT: carriage paid to** (named place of destination). The seller clears the goods for export, delivers them to the carrier and pays for carriage to the named place of destination e.g. a carrier's import depot. Risk transfers to the buyer upon handing

over the goods to the first carrier at the place of shipment. The seller is not responsible for insurance.

- *CIP: carriage and insurance paid to* (named place of destination). This is the containerized transport/multimodal equivalent of CIF but can be used for all modes of transport. The seller clears the goods for export, delivers them to the carrier and pays for carriage and insurance. Risk passes when the goods are handed over to the first carrier.
- *DAP: delivered at place* (named place of destination). The seller clears the goods for export and bears all risks and costs for delivering the goods not unloaded. The buyer is responsible for all costs and risks concerning the unloading and customs clearance.
- *DPU: delivered at place unloaded* (named place of destination). The seller clears the goods for export and bears all risks and costs for delivering the goods and unloading them. The buyer is responsible for all costs and risks from this point, including customs clearance. This term is often used for consolidated containers with multiple consignees. It is the only term that tasks the seller with unloading the goods. It was previously named delivered at terminal (DAT), but has been renamed because the buyer and/or seller may want the delivery of goods to occur somewhere other than a terminal.
- *DDP: delivered duty paid* (named place of destination). The seller is responsible for delivering the goods to the named place in the country of the buyer, and pays all costs in bringing the goods to the destination, including import duties and taxes. The buyer is responsible for unloading. This term places the maximum obligations on the seller and minimum obligations on the buyer.

Sea and inland waterway transport

- *FAS: free alongside ship* (named port of shipment). The seller must place the goods alongside the ship at the named port. The seller must clear the goods for export. Suitable only for maritime transport but *not* for multimodal sea transport in containers. This term is typically used for heavy-lift or bulk cargo.
- *FOB: free on board* (named port of shipment). The seller must load the goods on board the vessel nominated by the buyer. Cost and risk are divided when the goods are actually on board the vessel. The seller must clear the goods for export.
- *CFR: cost and freight* (named port of destination). The seller must pay the costs and freight to bring the goods to the port of destination. However, risk is transferred to the buyer once the goods are loaded on the vessel. Insurance for the goods is *not* included. Maritime transport only.

- *CIF: cost, insurance and freight* (named port of destination). Exactly the same as CFR except that the seller must in addition procure and pay for the insurance. Maritime transport only.

NOTE Incoterms® is a trademark of the International Chamber of Commerce.

Introduction

Of the world's international trade 90 per cent is transported by sea. The customs and practices associated with this form of transport have been refined over centuries of worldwide trade. Sending cargo by sea is ideal for high-volume cargoes that are not necessarily time-sensitive or have long lead times for delivery. However, this mode of transport is slow and fraught with possibilities for delay. The Covid-19 pandemic of 2020–21 and the blocking of the Suez Canal by a ship in 2021 emphasized these possibilities. As globalization has increased and sources of manufacturing moved to India and China more companies have outsourced their manufacturing to this part of the globe. As a consequence, due to the elongated supply lines and slowness of this form of transport, higher levels of in-transit inventory need to be accounted for.

The use of shipping containers has revolutionized the way that cargo is handled and transported (see Chapter 28). This chapter aims to give a general overview of maritime transport or, as it is often called, sea freight. The reference to maritime transport as 'shipping' has been avoided in order to prevent confusion, as many people often use the term 'shipping', especially in the United States, in the context of dispatching cargo from its origin, whatever the mode of transport used.

Structure of the industry

Liner conferences

Liner conferences are formal groups of shipping lines that operate on certain shipping routes that bring together all lines operating in a specific geographic zone. They were first set up to control the trade between colonial powers and their colonies in the 1870s. Today they are seen by many as being a controversial anachronism as they work together to agree tariffs for certain routes. They work fundamentally

for the interests of the member shipping lines to help to avoid destructive price competition (as they see it). For their part the shipping lines would argue that there would be much more price and capacity volatility without the stability that the liner conferences provide. The shipping lines have invested huge amounts of capital in the ships themselves and the conference system provides a way of managing forward revenue streams.

The European Union (EU) (as well as many of the conference's customers) has criticized liner conferences for anti-competitive actions. In 2006, the EU Council voted unanimously to stop liner shipping lines from meeting in conferences to fix prices and regulate capacities on trades to and from the EU. This came into effect in 2008.

As a matter of record, the liner conferences are the only industry that is currently exempted from anti-competition laws in the United States (where it is called anti-trust legislation). There is a huge body of opposition to these price-fixing organizations and it is very likely that further legislative action will be taken against them. The Ocean Shipping Reform Act of 1998 (OSRA) that took effect on 1 May 1999 does allow carrier rate discussion agreements to operate on US trades. At the time of writing this exemption continues to be challenged by certain bodies in the United States as it denies the market the full benefits of competition. Further tightening of these laws was introduced in 2018.

Since April 2010 the EU has allowed consortia to cooperate operationally by sharing space on each other's vessels. Consortia are groups of liner shipping companies who work together to provide joint sea freight services but sell the space individually. On a regular basis, consortia work certain fixed routes against published timetables. The consortia must have a combined market share of >30 per cent. In June 2014 the European Commission announced a further five-year extension to this consortia block exemption regulation (BER). The reason given was that research had shown that these agreements bring benefits to customers and do not unduly distort competition. This regulation is in force and renewed until April 2024.

Shipping lines

They own and operate the various types of ships in their fleets. Their role is to provide the physical means by which cargo may be safely and efficiently transported by sea.

Ships' agents

They provide services to the shipping lines in the ports where the ships call. A ship's agent will deal with many important and diverse matters on behalf of the shipping line. These services may include: provisioning with food and spare parts; arranging

any necessary repairs for the ship; dealing with local port and customs authorities; organizing berths, pilots, tugboats (if required), crew change and refuelling.

Freight forwarders

Often referred to as freight management companies, these days their role is to oversee and manage the movement of freight from the point of origin to the point of destination. Freight management companies provide integrated door-to-door solutions for their customers that may include arranging different modes of transport, customs clearance and documentation, arranging port handling and generally supervising all aspects of the movement. In order to do this effectively they usually have worldwide networks of offices, and agents in many countries (see Chapter 33).

Common shipping terms

As with many specific areas of industry, sea freight has developed a whole plethora of terms and abbreviations over a period of time that spans centuries. In fact, there are so many that it is not possible to outline them all in this chapter. The terms that are listed below are the ones that most commonly cause problems for the newcomer to the trade. The list is a very long way from being exhaustive and many useful websites exist with very detailed lists for those who may need more information.

Full container load (FCL)

As the term implies, this refers to a load that will fill a given container.

Less than container load (LCL)

Again, as the term implies, this is a shipment that will not fill a container and therefore will require to be consolidated with other LCLs in order to economically fill a shipping container.

Hook to hook

This term is used by many shipping lines when quoting prices for break bulk sea freight. It means that the shipping line's price includes loading the goods onto the vessel and unloading the goods at the destination port. It also includes the cost of transporting the goods between the origin and destination ports. It is important to note that this price does not typically include insurance nor does it include the

stevedoring cost at both ports to attach or detach the cargo from the ship's lifting gear. In addition, it does not include other port handling costs.

Full liner terms

This means the same as hook to hook.

Liner in

The shipping line is responsible for the cost of loading the cargo on board the vessel.

Liner out

The shipping line is responsible for the cost of unloading the cargo at the destination port.

Free in and/or free out

In effect, this is the opposite of hook to hook. Many purchasers of sea freight who are new to the industry make the mistake of interpreting 'free' as meaning free to them. Whenever the term 'free' is used in this context it means free to the shipping line. Therefore the party purchasing the sea freight will be responsible for the cost of loading and unloading the goods on and off the ship.

Break bulk cargo

This is a general term for non-containerized loose freight. Out-of-gauge cargo and heavyweight items that are unsuitable for containerization fall into this category. Bulk cargoes such as crude oil, loose grain or bulk powders, and iron ore would not be classified as break bulk.

Weight or measure (W/M)

This is a common method used by shipping lines to price sea freight for break bulk shipments. It is important to understand that this method considers that one metric tonne is equal to one cubic metre and that the price quoted applies to the higher of the two numbers. Rather confusingly this system can also be referred to as 'freight tonnes' or 'revenue tonnes'.

For example:

The cargo to be transported by the carrier weighs 1,500 metric tonnes and has a volume of 7,500 cubic metres. The price quoted is \$75 per weight or measure. Therefore, the price will be calculated by taking the higher number of the weight or measure and multiplying it by \$75:

$$7,500 \times \$75 = \$562,500$$

Stackable cargo

Another very important note to remember is that not all cargo is stackable. In other words, it does not lend itself to having cargo loaded on top of it. Therefore, if we continue with the example above and consider how much ship's volume capacity is required to carry 7,500 cubic metres, we can reasonably assume that we will require a ship with a volumetric capacity somewhat in excess of 7,500 cubic metres. If a cargo is non-stackable it will mean by definition that any space above it will be lost as loading capacity. In addition to this problem the shape of the cargo or the contours of the ship may also result in lost loading capacity. These issues will be dealt with by the shipping company who will prepare a stowage plan. Some cargo may be suitable for securing on deck, thus exposed to the weather and seawater.

Stowage plan

This is a plan prepared by a representative of the shipping line, which will clearly show where each item to be loaded will be placed in the ship's holds or on the open deck. The plan will be based on a detailed packing list (see below) provided by the consignor.

In November 2014 the International Maritime Organization (IMO) adopted amendments to the Safety of Life at Sea (SOLAS) regulations regarding container weights. The regulations came into force in 2016. The verified gross mass (VGM) of a container is in effect the total gross weight of the container, which includes the weight of the empty container, the goods loaded and the weight of any packing or dunnage used inside the container. The shipper is responsible for providing the VGM of containers, and without a VGM containers will not be loaded on to vessels or included in the stowage plan. This important change came about due to a number of incidents where the mis-declared weights of containers played a part.

Lost slots

A slot is a term used to describe the space taken up by an ISO shipping container on a cellular container vessel. If certain types of specialist container are used to transport the goods, such as flat-racks or open-top containers, then there is the possibility that the cargo will protrude outside the normal cubic dimensions of a standard

shipping container. For example, a piece of machinery may fit inside the confines of an open-top container but protrude through the top of the container. In this case the carrier will be forced to either load the container on the top of the stack or lose the potential for loading on top of this particular container. This will lead to a request from the shipping line for the consignor to pay for the ‘lost slots’. In other words, pay for the slots that cannot be used by the shipping line because the cargo is protruding into another slot’s space. In some cases where flat-racks are used the number of lost slots could be quite high if the cargo protrudes in several directions. In Figure 26.1 two large pieces of out-of-gauge cargo have been loaded on top of standard containers. Together the two pieces of cargo are using several slots, which is illustrated by the standard containers in the background of the picture and the numbered rows. A close examination of the image reveals that the large pipe reel is at least two slots high and is spanning three rows of slots. It is also clear that no containers could be loaded on top of this cargo.

Figure 26.1 Out-of-gauge cargo loaded on to a cellular container vessel



SOURCE Maersk

Port rotation

This refers to the order and names of the ports at which the ship is planning to call.

TEU

This stands for 20-foot equivalent unit and is equal to one 20-foot ISO shipping container. Cellular container ships are usually described by the amount of TEUs they can carry.

FEU

This stands for a 40-foot equivalent unit and is equal to one 40-foot ISO shipping container.

Plimsoll line

The Plimsoll line or international load line is found painted on the hull of a ship around the water line. The Plimsoll line is a mandatory requirement and indicates the maximum safe load level for the ship in question. A series of lines are indicated that show the safe load level in different seasons and different densities of water, e.g. seawater or fresh water. The system is named after Samuel Plimsoll, a 19th-century British member of parliament who campaigned to improve the safety of maritime transport after a series of marine disasters and was known as the 'sailors' friend'.

Surcharges

When international sea freight prices are being quoted anywhere in the world as a matter of custom and practice, as well as convenience, all prices are generally quoted in US dollars or in euros. In addition to the basic cost of sea freight there are a number of other surcharges that may be applied.

Bunker adjustment factor (BAF)

BAF is a common surcharge applied to sea freight rates by shipping lines. It is designed to take account of the variations in the price of marine fuel sold in local currency in different parts of the world. The BAF is changed from time to time.

Currency adjustment factor (CAF)

CAF is another common surcharge that is applied to take account of any differences in cost incurred by the shipping line due to currency exchange fluctuations for

services bought by them in foreign currencies in the execution of their services on the customer's behalf. All sea freight rates are generally priced in US dollars or in euros but local services purchased by the shipping company will be in the local currency of the country in which the goods or services are bought. The surcharge is designed to compensate the shipping line for this and is usually charged as a percentage of the basic freight charge.

Peak season surcharge (PSS)

PSS is a surcharge that is applied to both air freight and sea freight originating in the Far East. Due to the rapid growth in exports from countries such as China, and the lag in the provision of commensurate infrastructure to handle this unprecedented growth, backlogs occur at certain times of the year. A shortage of transport carrier capacity and an imbalance in trade flows means that carriers can apply this surcharge, which customers are forced to pay. The surcharge may be a considerable uplift on the normal freight rates.

Repositioning charge

This is a surcharge that is sometimes applied by the shipping line to cover the cost of returning an empty container to a location where it may be loaded with revenue-earning cargo. The cost of handling, shipping and trucking the empty container is a loss to the shipping line. In addition, because an empty container is repositioned by being transported on one of its ships, there is the lost opportunity cost associated with utilizing this space. This type of charge is most likely to be applied where there is an imbalance in trade volumes on a given route. For example, between the United States and China there is an imbalance. In other words, more cargo is shipped in full containers from China to the United States than the other way round. Therefore, of all the containers that leave China fully loaded, a significant number will be returned to China empty. The China–United States imbalance is by no means the only trade route where this phenomenon occurs. This is a big headache for shipping lines and the surcharge is applied to help mitigate the costs they incur.

War risk surcharge

This may be applied to any mode of transport in a war zone as well as an area around the actual war zone. It is applied to take account of the increased possibility of incidents that could result in the partial or total loss of the transport company's assets.

Carrier security fee

This surcharge is applied by shipping lines to cover the cost of complying with the International Ship and Port Facility Security Code (ISPS). The code requires shipping lines and ports to have key personnel and plans in place to deal with any security issues that arise. The code was devised by the IMO in response to the 9/11 attacks in 2001.

Documentation

One very important aspect of moving goods internationally by sea is the associated documents required by various government agencies, financial institutions and trading partners at both origin and destination. The following contains a brief overview of some of the major documents used.

Bills of lading

A bill of lading is issued by the shipping line as a receipt for the cargo being transported on its ship. It is also a contract of carriage to deliver the cargo to a named destination. In addition it lays out what has been loaded and in what condition. A bill of lading is a negotiable document unless it states otherwise. This means that the goods may be bought and sold during the sea voyage using the bill of lading as title to the goods. Therefore, the legal bearer of the bill of lading is the owner. There are several different types of bills of lading to suit differing circumstances.

Letters of credit

Although these documents are not necessarily required to facilitate the actual international transport of goods by sea or to fulfil the customs authorities' requirements, they are nevertheless crucial to facilitating the exchange of goods for money across international borders. They act as a protection for both the buyer and seller. A letter of credit (LC) issued by a bank in one country (the issuing bank) on behalf of a buyer names the seller as beneficiary to the funds outlined in the LC, provided that certain terms are clearly met by the seller. The LC is then sent to the seller's bank in a different country, which is known as the advising bank. This method is used to guarantee that the seller gets their payment in time and in full, and that the buyer does not release funds until the goods are received in full and in good condition. This is an extremely complicated financial area and the above description is intended as a general guide only.

Certificate of origin

This is a document issued by a certifying body that establishes the origin of the goods being transported. This is often required by customs authorities at the final destination due to trade tariffs, international trade treaties or embargoes on trade with certain countries.

Commercial invoices

The commercial invoice produced by the seller establishes, among other things, the weight of the goods, the number of items, a description of the goods, and the price of the goods being sold. Where LCs are also being used there should not be any discrepancy between the details contained in the two documents. The cost of the goods being imported assists the customs authorities to arrive at a customs duty tariff. However, it should be noted that they are under no obligation to accept the value on a commercial invoice if they disagree with the value stated.

Packing lists

A packing list is a detailed list of all the items to be transported. A packing list typically contains as a minimum a brief description of the items: their weight; the length, width, height of each item; and how many items are contained in each package. This allows a cubic capacity to be calculated for each item. In addition the shipping line will ask the consignor to identify which items on the packing list may be stackable and which items could be loaded on deck and exposed to the elements. It is very important to understand that items loaded on the open deck will be exposed to extremes of temperature, salt and water from sea spray or rain, and the possibility of being lost overboard in the sea. Packing lists are required for customs formalities as well.

Other documents

Depending on the nature of the goods, the originating country and the final country of delivery, various other documents may also be required. These may include:

- insurance certificates
- certificates stating that the goods meet a certain safety or engineering standard
- data sheets relating to the management of certain hazardous chemicals
- certificates verifying that pallets or packing materials have been fumigated to avoid the importation of biological pests

This list is by no means exhaustive and requirements often change very quickly and with little warning.

Vessel classification and certification

Ships are classified to a class that defines their permitted use, the additional certification required and specifies the survey and inspection scheme required to meet the needs of the classification. The ships are classified by the type of cargo they carry, the gross tonnage and the type of voyages undertaken.

Ships are classified by recognized classification societies that survey and classify vessels. They are licensed by governments who issue ship certificates for ships registered in their country. This is commonly known as being registered under a certain 'flag'. Classification societies are licensed by these governments to issue these certificates on their behalf. Lloyds Register and Bureau Veritas are among the oldest and most well-known classification societies.

Ships' certificates are often required by insurance companies and shippers when engaging the services of a shipping line. This helps them establish the class, age and minimum standard of maintenance related to the ship being used to carry the cargo. As a general rule insurance companies would increase their insurance premium for older vessels.

In addition to a classification certificate ships may be required to be certified in certain other specific areas. By way of example, some of the certificates are listed below (this list is by no means exhaustive):

- cargo ship safety radio certificate
- cargo ship safety equipment certificate
- cargo ship safety construction certificate
- load line certificate
- minimum safe manning document safety certificate
- sewage pollution certificate

Therefore a ship is assigned to a certain class and issued with a certificate, which in turn triggers a requirement for a number of other specific certificates related to safety and other international regulations.

Deadweight tonnage (DWT)

Deadweight tonnage is a measure of how much weight a ship may safely and legally carry. It includes the weight of the cargo, crew, passengers and provisions. In short, it is the weight of absolutely everything that the ship is carrying, but not the weight

of the empty ship. In simple terms it is the difference between the laden and unladen weight of the ship. It is the common term used to classify ships when fully loaded to the legally accepted maximum. Traditionally, deadweight tonnage was stated in long tons, which are the imperial measure. However, it is normal today to express deadweight in metric tonnes. One long ton equals 2,240 pounds (1,016 kilogrammes) and a metric tonne equals 2,204 pounds (1,000 kilogrammes).

Common ship types and their cargoes

Cellular container vessel

This ship is specifically designed to carry ISO shipping containers (see Chapter 28). These vessels have continuously grown in size and speed over the last few years and tend to work to very strict schedules. This is possible because of the relative ease of handling containers on and off these vessels. In fact they often load and unload at the same time in order to speed up operations. At the time of writing the largest container vessel in terms of carrying capacity is the HMM *Algeciras*, with an official capacity of 24,000 TEUs. At the time of writing the previous edition of this book the *Emma Maersk* was the largest container vessel in the world and is now some way behind the largest (see Figure 26.2). It is worth noting that container shipping lines calculate their ship capacities differently; some calculate based on an average weight per container and others on the actual number of TEUs that may be loaded regardless of the weight of each container. Therefore, the physical carrying capacity may be significantly higher or lower in terms of actual TEUs loaded on each voyage.

Break bulk freighter

These vessels carry any kind of loose cargo that is not liquid or loose bulk commodities. They used to be very common ships, but these days with the increased use of shipping containers and specialized ships they have become much rarer. They are still used in parts of the world where cargo handling is less well developed. The term LOTO (lift-on lift-off) applies to this type of vessel. They are usually equipped with their own cranes to facilitate loading and offloading (sometimes referred to as a self-sustaining or self-geared ship). These vessels tend to be less efficient when it comes to time schedules, due to the many problems that may occur while loading and unloading.

Roll-on roll-off (RORO) vessel

These ships are designed specifically to carry wheeled vehicles, and are equipped with a ramp that can be raised and lowered to allow vehicles to be driven on and off.

Figure 26.2 The *Emma Maersk*: one of the largest cellular container vessels in the world, capable of transporting 15,200 TEU



SOURCE Maersk

They are similar to vehicle ferries but are usually much larger and have more decks to carry thousands of vehicles. These ships are mainly utilized by vehicle manufacturers to transport their products to their chosen markets around the globe. They are also commonly used to carry vehicle traffic on short sea journeys such as crossing the Irish Sea between the UK mainland and Ireland.

ConRo vessels

These ships are designed to carry containers on deck and wheel vehicles below deck. Their tweendecks may be raised or lowered to accommodate different heights.

LNG vessel

Liquefied natural gas (LNG) is cooled to a temperature of -162°C , which causes it to reduce in size to 1/600th of its volume at ambient temperatures. LNG tankers are constructed in such a way that they have a number of large spherical tanks that are positioned longitudinally along the entire length of the cargo-carrying area of the hull. The LNG is loaded and unloaded in liquid form just like any other bulk

liquid. It is important to note that due to the potential for a terrorist attack or straightforward explosion the US government has adopted very specific safety measures regarding these vessels when they visit US LNG terminals.

A recent development has been the redesign and building of much higher capacity LNG vessels known as ‘Q-Max’ ships. A normal vessel (as described above) might carry a load of 140,000 cubic metres of LNG whereas these new ships are capable of carrying 266,000 cubic metres.

Oil tanker

These ships carry large volumes of crude oil in liquid form. Some of these vessels are extremely large and carry oil over very long distances from where it is produced to where it is required. Due to the environmental impact of crude oil, modern tankers have a twin hull to help avoid the possibility of spillages in the event of a collision. Various sizes of oil tanker are explained below. Figure 26.3 shows the deck of a typical oil tanker.

Figure 26.3 The deck of a typical oil tanker



Specialized heavy-lift vessel

These ships are designed to carry very heavy or large cargoes that other ships cannot accommodate. They are designed with most of the hull being covered in a flat open

deck that can aid loading and offloading. They usually have their own cranes with heavy lifting capabilities. Some of these ships are capable of semi-submersion to facilitate the loading of cargo by floating it across the submerged deck. Once the cargo is precisely located, the seawater is pumped out of the ship. This causes the vessel to rise with the cargo located on board. In Figure 26.4 a heavy-lift vessel has just arrived at the Panama Canal from Trieste in Italy, laden with four new lock gates. In the photograph the ship is being positioned by tug boats so that it will dock at the white jetty protruding from the right-hand shore. Once docked the gates will be unloaded using self-steering hydraulic trailers and positioned on stands that can be seen in the four white bays positioned at an angle to the right of the jetty. Each lock gate has a different weight depending on where it is to be located. The lightest is 2,100 tonnes and the heaviest is 4,200 tonnes. There are 16 rolling lock gates in total. The physical dimensions also vary but they are all 57.6 metres long. This is a classic project logistics exercise (see Chapter 33).

Figure 26.4 A heavy-lift ship delivering four new lock gates to the Panama Canal



SOURCE Courtesy of the Panama Canal Authority

Dry bulk carrier

These ships are designed to carry any type of loose dry bulk commodity such as grain, stone, ores, coal or phosphates.

Handysize

This is a smaller-sized ship used to carry bulk commodities or crude oil. It will have a size of between 10,000 dwt (deadweight tonnes) and 30,000 dwt.

Handymax

This is a vessel used to carry bulk commodities or crude oil of a size between 30,001 dwt and 50,000 dwt.

Aframax

A crude oil tanker of between 80,001 dwt and 119,000 dwt. This is the largest crude oil tanker in the average freight rate assessment (AFRA) Large Range 1 category compiled by the London Tanker Broker's Panel. This term was derived by the US oil companies who used the AFRA system to establish tax liabilities on sea transport with the US Internal Revenue Service. This term is in common usage but is not used by the London Tanker Brokers' Panel as their AFRA monthly results cover vessels up to ultra large crude carrier (ULCC) (see page 431) 549,999 long tons deadweight.

Suezmax

The maximum size of ship that can pass through the locks of the Suez Canal is 200,000 dwt. Ships up to this size may be referred to as Suezmax. The limiting vessel dimensions are: 20.1 metres draught with a beam less than 50 metres; 12.2 metres draught with a beam of less than 77.5 metres; length 275 metres. Some large oil tankers offload part of their cargo to a pipeline before transiting the canal in order that they can meet the draught requirements.

Panamax

The Panama Canal (see below) original locks are 1,000 feet long, 110 feet wide and 85 feet deep (see Figure 26.5). This can accommodate vessels that are no larger than 965 feet long, 106 feet wide and 39.5 feet deep.

Post-Panamax or New-Panamax

In 2016 after a major redevelopment two new additional larger locks became operational, one at each end of the canal. These allow vessels that are 1,400.92 feet long, 180.45 feet wide, and 60.4 feet in draught to pass through them.

Figure 26.5 Gatun lock on the Panama Canal



SOURCE Courtesy of the Panama Canal Authority

Very large crude carrier (VLCC)

A crude oil tanker used to carry bulk oil of between 200,001 dwt and 350,000 dwt.

Ultra large crude carrier (ULCC)

A crude oil tanker used to carry crude oil on long-distance routes that are too big to use the Suez or Panama canals. They are the largest vessels in the world and exceed 350,000 dwt. They are so large that they require specially constructed terminals to facilitate loading and offloading.

Capesize

These ships are too large to pass through either the Suez or the Panama canals. They are therefore forced to take the long route around either the Cape of Good Hope at the southernmost tip of Africa or Cape Horn, which is at the southernmost point of South America. Their size also requires them to service only deep-water terminals. They are used for the transport of bulk commodities such as mineral ores.

Tug boats

Although tug boats are not designed to carry cargo they nevertheless play a very important role in maritime transport. Tug boats are relatively small but powerful vessels that are used to assist much larger ships manoeuvre in ports with limited space. Tug boats are capable of both pushing and towing vessels. They may be used to tow disabled vessels to port among other things. In Figure 26.4 tug boats can be seen assisting a heavy-lift ship into position. In Figure 26.6 a tug boat can be clearly seen.

Ports and cargo handling

Terminal handling

Whenever cargo is sent to a port, due consideration needs to be given to the nature of terminal handling facilities available. Not all ports are capable of handling all types of cargo and some ports are solely established to handle one type of cargo only, for example crude oil terminals. Others may have separate facilities for handling different types of cargo, for example ISO containers and break bulk cargo.

Figure 26.6 A tug boat**SOURCE** Maersk

Charges for terminal handling vary from port to port and by the type of cargo handled. Many ports will offer free periods of storage prior to loading of the ship or after unloading of the vessel. If these periods of free time are exceeded for any reason then charges known as demurrage or detention (see Chapter 33) will usually be charged in addition. If goods are unloaded from a ship directly on to a truck, and vice versa, then this is usually referred to as direct delivery and ports will offer a reduced charge for allowing this activity to take place. This can speed up vessel turnaround times in the port but needs careful planning to ensure that sufficient trucks are continuously available to maintain the direct delivery process until the ship is fully discharged or loaded.

If stevedores are required to lash cargo, operate cranes and carry out other associated duties then ports usually have a separate tariff for these services.

Other factors

Cargo surveyors

In the event that any party to the movement by sea of a given cargo is unable or unqualified to attend the loading, unloading or handling of the cargo being shipped

then a cargo surveyor may be appointed for a fee. This independent third party can document through photographs and a written report the way in which the cargo was handled during loading, stowing or unloading. The surveyor may be able to prevent some events happening but if they cannot then at least they will be able to provide a reliable independent professional view of any incidents that occurred. This may help with insurance claims and in some cases is insisted upon by certain parties involved in the movement.

Cargo superintendents

A shipping line may employ a cargo superintendent whose job is to ensure that a vessel is loaded and secured in accordance with stowage plans and the requirements of the ship's captain.

Security, piracy, politics and war

At the time of writing, the issue of piracy has once again become headline news as pirates operating from the Horn of Africa have been seizing vessels in the waters approaching the entrance to the Red Sea and the coasts of East and West Africa. Another hot spot is the Malacca Strait between Indonesia and Malaysia. The objective of the pirates is to demand ransoms from the owners, which invariably get paid in order to avoid loss of life, the vessel or the cargo. Unstable political or security situations, and in extreme cases outright war, are capable of causing huge disruption to international sea transport.

This phenomenon is nothing new in the history of sea transport but the consequences are that this increases insurance premiums and encourages ship owners to take longer diversions. In turn, this has the effect of increasing costs, which are passed on to the client.

Suez and Panama canals size restrictions

Since the building of the Suez Canal in the late 19th century and the final opening of the Panama Canal in 1914, many vessels have been able to save very long journeys around either the Capes of Good Hope or Horn. However, it needs to be remembered that these canals have size restrictions and that many large vessels still are forced to make these long voyages.

Panama Canal expansion

The Panama Canal Authority completed the process of significantly developing the existing Panama Canal in 2016.

The development includes the construction of new lock complexes at both the Pacific and the Atlantic ends of the canal (see Figure 26.7). The new third lock lane will be capable of handling vessels of much larger dimensions. In addition, Gatun Lake and Culebra Cut will be widened and made deeper. The Atlantic and Pacific entrance channels are also being made wider and deeper.

The dimensions of the new locks will be 427 metres long, 55 metres wide and 18.3 metres deep. The maximum dimensions for New-Panamax vessels will be 366 metres long, 49 metres beam and 15.2 metres draft.

Land bridges

Another way of avoiding long sea journeys around South America and Africa is to use a technique referred to as land bridging. Using this method, one ship delivers cargo to a port on, say, the East Coast of the United States and then the goods are transported by road or rail to the West Coast where they are reloaded on to another ship for the onward journey. The problem in Africa is that transcontinental routes are inefficient and the infrastructure is not currently in a good condition. This situation will improve in the coming years due to massive investment by China in its Belt and Road Initiative (BRI). The scope and scale of this project is extraordinary. At its heart is the concept of reviving the ancient silk roads that spanned Asia connecting China with Europe. BRI involves building highways, railways, airports and expanded seaports across Asia, Africa and Europe and will bring 60 per cent of the world population within its reach. The obvious advantage for shippers will be the ability to avoid the long and slow sea route from the Far East to Europe.

Sea–air options

Another way of achieving a balance of cost and speed is to use both the sea and air transport option. For example, a less than container load (LCL) shipment can be sent by sea from the Far East consolidated with other shipments in one shipping container to, say, Dubai where the container is deconsolidated and the LCL shipment is then loaded on to an air freighter for final delivery to Europe.

Speed, weather, port congestion

Whenever sending cargo by sea transport it needs to be remembered clearly that although it can be a very cost-effective option it is the slowest form of transport generally available. Vessels may be delayed due to adverse weather conditions, vessel breakdowns and port congestion. In addition, the ship owner may decide to divert his ship in order that he can take advantage of revenue-generating opportunities in ports that are off the original route planned.

Figure 26.7 New Panama Canal locks under construction, 2015



SOURCE Courtesy of the Panama Canal Authority

Inland waterways

Although the main subject of this chapter is deep-sea shipping it must always be remembered that many ocean-going vessels and barges are able to penetrate deep into some land masses through the use of navigable rivers and canal systems. Examples of well-known navigable rivers include the Amazon in Brazil, the Nile in Egypt, the Yangtze in China, the Rhine–Danube in Europe and the Mississippi–Missouri in the United States. In addition, many developed countries have networks of canals that are capable of transporting cargo between industrial centres.

Environmental initiatives

Most ships use heavy fuel oil for propulsion, producing greenhouse gases (2 to 3 per cent of the world's total) as well as other pollutants, such as sulphur. Since 2020 there has been a cap on the percentage of sulphur that can be emitted, resulting in ships either being fitted with scrubbers to remove sulphur from the exhaust or using very low sulphur fuel oil (VLSFO).

As regards greenhouse gases, various alternative fuels are being developed or deployed that may be suitable for deep-sea shipping, including methanol, biofuel,

alcohol-lignin blends, liquefied natural gas (LNG), ammonia and nuclear power. Electric power using lithium-ion batteries can be used for short sea shipping, for approaching ports and for port manoeuvring. Hydrogen cells can also be used for similar purposes. Power assistance to the main engines may be provided using wind, such as rotor sails that consist of vertically rotating drums, or solar panels.

In addition to these alternative propulsion systems, carbon emissions can be reduced by improved hull, propeller and rudder design, as well as the use of silicon paint and air lubrication (i.e. air bubbles pumped through vents on the underside of the ship) to reduce frictional resistance of the hull. Slow steaming is another common approach as travelling slower through the water requires less power for the distance covered. In port, shore power provision by electric plug-in points can enable ships' engines to be turned off while providing for lighting, heating, refrigeration, etc.

Introduction

Unlike sea transport, the air transport industry is just over 100 years old. Due to the very particular requirements associated with the air cargo business it has developed methods of operation that are unique in the world of logistics. These tend to be most noticeable in the field of cargo handling due to the restrictions imposed by the aircraft themselves. The whole area of safety of operation and security from terrorist attacks significantly impacts the business. Due to the specialized nature of air transport this chapter aims to give only a very brief overview. The advantages of transporting goods by air are obvious in that cargo may be carried securely for very long distances in a short space of time. This delivers the possibility of reducing inventory carrying for global businesses; allows certain perishable goods to be available all year round instead of seasonally, thus expanding markets; can provide rapid emergency support to industries where critical equipment is required in a short time-scale to avoid plant downtime; and is able to deliver essential humanitarian aid swiftly and effectively. The disadvantages are the high unit costs as well as size and weight restrictions. Security and safety considerations also limit what type of cargo may be transported by air.

According to the International Air Transport Association (IATA), ‘each day more than \$16 billion of goods travel by air – one-third of all world trade by value’ (IATA, 2016). Covid-19 travel restrictions imposed by authorities around the world severely impacted the industry during 2020. IATA reports that demand was down by a massive 65.9 per cent when compared with 2019 (IATA, 2019).

Structure of the industry

National governments have always taken a large and keen interest in the way that the airline business is organized. This has led to international treaties regarding how the business should be operated. For example, the Convention for the Unification of Certain Rules Relating to International Carriage by Air (often referred to as the Warsaw Convention) was signed in 1929. This international agreement lays out the rules relating to the conditions for international transport by air, establishes the liabilities of international air carriers and sets limits for their financial liability for

damage, delay or loss. There are many other such international agreements and national restrictions that limit among other things access to certain trade routes, overflying rights and the carriage of certain types of cargo. National governments take a great interest in the air transport industry due to strategic military concerns and the potential effectiveness of air attack by foreign military powers as well as its economic importance.

International Air Transport Association (IATA)

Along with its US equivalent, Airlines for America (A4A) (formerly the Air Transport Association of America), these two trade associations set many of the standards of operation for the industry; examples include standards related to safety, security, training, unit load devices (ULDs) and many others. They also provide services to their members such as the cargo accounts settlement system (CASS), which is a web-based system that allows airlines and freight forwarders to make only one payment a month to, or receive one payment from, airlines or cargo agents. This has significantly reduced the burden of paperwork.

Airlines

These are the companies that own (or lease) and operate the aircraft used to carry both passengers and cargo. The national airlines of some countries are still owned by the respective governments of the countries the airline represents and are known as 'flag carriers'. Some airlines specialize in providing certain services only. For example, the so-called budget airlines specialize in no-frills cheap air transport for passengers. Others concentrate solely on air cargo and a few offer only heavy-lift air cargo options. It should always be remembered that passenger aircraft often carry cargo in their holds along with passenger baggage.

Lessors

These companies own aircraft and exist to provide the industry with aircraft in the situation where owning the assets is unfavourable to the airlines that lease them. Airlines make the decision to lease for a number of different reasons. At the time of writing three of the largest lessors are AerCap Holdings, Dubai Aerospace Enterprise, and Chapman Freeborn.

Cargo agents

Cargo agents are freight forwarders that are licensed by IATA to handle freight on behalf of customers who wish to send cargo by air. IATA sets standards of operation,

ensures that the agents are insured, and allows the agent to issue their own air waybills known as house air waybills (HAWB).

Airport authorities

Airport authorities own (or lease) and operate the airport infrastructure.

Air cargo handling

Unit load devices (ULDs)

ULDs are the shipping containers of the skies. They come in many forms but perform exactly the same purpose as any transport container. They allow cargo to be stowed efficiently and safely while maximizing the use of the available space. Many ULDs are designed to reflect the shape of the aircraft hold and are therefore often specific for use in certain aircraft. Air freighters may have a main deck and a lower deck in the fuselage. The main deck is often loaded with flat metal pallets of specific dimensions that carry the cargo secured by netting (see Figure 27.1). Lower deck ULDs may be shaped to reflect the fuselage shape and be made of light metal with a door or netting on one side to allow for cargo stacking. IATA has developed a system of identifying ULDs that uses three capital letters, for example AMA or AMU. The first letter is a description of the container, the second describes the base dimensions, and the third describes certain physical details such as the shape, load restraint and handling required. If this is not complicated enough, Airlines for America has another system of classifying ULDs. The IATA ULD Regulations (ULDR) provides information on the ULD cargo handling system.

Air cargo handling equipment

Due to the physical restrictions imposed by aircraft design, sophisticated handling systems have been developed to transfer cargo quickly and safely from the airport cargo handling centre to the aircraft itself. ULDs are moved around using fixed conveying systems that consist of tracks fitted with rollers that are often powered. These conveying systems are also capable of turning the pallet to travel in a different direction. For example, when a ULD is being rolled into a cargo hold on the plane it may need to be turned through 90 degrees to correctly position it for safe stowing inside the aircraft. Aircraft holds are accessed through side, front or rear doors, which themselves have restrictions in terms of dimensions (see Figure 27.2). The ULDs, having been transported to a position next to the plane, are lifted by a

Figure 27.1 Air cargo pallets being loaded through the side door



SOURCE Cargolux

powered lifting device (often referred to as a hi-loader) that presents the ULDs to the door of the aircraft. From this point they are conveyed into the hold, which is also usually fitted with roller floors.

Figure 27.2 Cargolux air freighter being loaded using the powered rolling floor



SOURCE Cargolux

In addition to cargo and passengers being loaded on to aircraft there is a requirement to provision the plane with meals and drinks for the passengers and crew. There may also be other items such as toiletries for the lavatories, duty-free products for sale to passengers, blankets, pillows and so on. These are packed into small mobile cases that are rolled on to the passenger deck and secured into slots designed for the purpose. These goods are transferred on to the aircraft via a side door from a vehicle fitted with a scissor lift (see Figure 27.4).

Larger heavy-lift aircraft may be accessed by front or rear doors that lower to ground level allowing certain cargo to be loaded by fork-lift truck. These planes also often have overhead gantry cranes fitted in the cargo area to assist the loading process. In Figure 27.3 a Cargolux air freighter is being loaded through the nose with out-of-gauge cargo. The famous Antonov An-225 heavy-lift cargo freighter may be loaded through the nose section, which tilts upwards allowing access to a hold that has a potential load volume of 1,100 cubic metres and a carrying capacity of 250 tonnes. The smaller, more common Antonov An-124 has a drive-through capability using both the front and rear ramps.

Figure 27.3 Air freighter being loaded through the nose with out-of-gauge cargo



SOURCE Cargolux

Figure 27.4 Aeroplane being loaded through the side door by a specialist vehicle equipped with a scissor lift



SOURCE Mercedes Benz Classic

Types of air freighter

There is a great variety of aircraft that carry air cargo: from the Piper PA-31 Seneca with a payload of just 600 kilogrammes to the Antonov An-225 with a carrying capacity of 250 tonnes.

Helicopters are often used to gain access to areas where there are no facilities for fixed-wing aircraft. Widely used by the military, they are also used in a civil context to carry cargoes of between 4 tonnes and 20 tonnes. Helicopters also have the ability to carry loads slung underneath the aircraft rather than carried inside the cargo hold. This can be most useful when positioning equipment such as mobile phone masts on top of tall buildings. Helicopters are also widely used by the oil industry to gain access to offshore oil installations. Humanitarian aid agencies use them to shuttle medical supplies, specialist personnel and emergency supplies to disaster locations. It is important to note that helicopters can only operate to a certain height before the air becomes too thin for them to hover safely. This limit varies from helicopter to helicopter.

In some cases, fixed-wing cargo aircraft are capable of dropping cargo from the air using their rear cargo doors and parachutes attached to the cargo. Both the

military and humanitarian aid agencies use this method to get supplies to difficult locations with no facilities for aircraft to land safely.

It should also be understood that many passenger aircraft carry cargo in their belly-holds in addition to passenger baggage and are responsible for transporting a high volume of air cargo worldwide.

In Table 27.1 there are listed some common large capacity air freighters. This is not an exhaustive list and is designed to give only a sense of what may be carried by air cargo, and therefore its limitations as well. For example, at the time of writing there is only one Antonov An-225 operational. Figure 27.5 shows an A300-600ST Super Transporter, which is a very specialized aircraft built by Airbus to transport fuselages and wings between its factories in different countries. It is unofficially called the ‘beluga’ due to its unusual shape.

Table 27.1 Common cargo-carrying aircraft types and their carrying capacities

Aircraft Type	Maximum Payload (Tonnes)	Maximum Load Volume (Cubic Metres)
Boeing B767-300F	54	438
Lockheed L1011 Tristar	55	420
Douglas DC10	65	451
Boeing MD11	85	600
Ilyushin IL-96	92	580
Boeing B747-100	96	585
Boeing B777-300F	103	633
Boeing B747-200	111.5	605
Boeing B747-400	120	605
Antonov An-124	120	800
Antonov An-225	250	1100

Sustainable alternative fuels

As with all transport modes a great deal of effort is being used to find a viable alternative to normal aviation fuel. However, unlike other transport modes, the constraints imposed by the physical size and the operating environment of aircraft present very difficult challenges. Some sustainable aviation fuel (SAF) is being used at the time of writing, produced from renewable feedstocks such as household, industrial and agricultural waste. This can be used with current aircraft jet engines and airport fuelling infrastructure. Electric battery power is another alternative and has been used for small aircraft. However, the power-to-weight ratio of current

Figure 27.5 A300-600ST Super Transporter: a special aircraft built and operated by Airbus Industries



SOURCE Mercedes Benz Classic

battery technology is not scalable. Much attention is now focused on hydrogen as an alternative fuel in the form of:

- synthetic hydrogen fuel using hydrogen produced from renewable sources, together with carbon dioxide – this could be used in conventional jet engines as a hybrid fuel combined with normal aviation fuel or as a stand-alone fuel
- hydrogen combustion in modified gas turbine engines
- hydrogen fuel cells producing electric power

Many trials and a great deal of research are currently underway.

A particular feature of aviation as a mode of transport is that current aircraft emit water vapour (and soot particles) at altitude. These result in ice crystals forming artificial cirrus clouds, seen as ‘contrails’ from the ground. These clouds trap heat radiating from the ground and therefore act as an additional greenhouse gas. In examining alternative aero-engine design and propulsion technologies it is important that this further greenhouse gas contributor is also addressed.

Documentation

Air waybills (AWB)

An air waybill is a contract to transport goods by air and is issued by the carrier airline. It limits the liability of the airline and details the goods being carried. It also includes the charges for this service. Unlike a sea freight bill of lading, an air waybill is a non-negotiable document. They are sometimes used as through-delivery documents by road transport companies where the majority of the journey distance has been completed by air. They may be used for both domestic and international carriage of goods.

House air waybills (HAWB)

A house air waybill is issued by a freight forwarding company that is entitled to do so. For example, an IATA cargo agent would be entitled to issue a HAWB as they will have the relevant insurances in place and as issuer will assume the liability as the carrier in the same way as the airline carrier would for an AWB. These are most often used in the situation where small cargo shipments are consolidated by the freight forwarder for onward shipment to the final destination. These individual HAWBs for all the shipments consolidated will be detailed in a master air waybill (MAWB), which details the contract between the freight forwarding company and the carrier airline.

Other documentation

Packing lists, commercial invoices, certificates of origin and a variety of other cargo or country-specific documents may be required by the airlines, security services and customs services at both origin and destination airports. These are outlined in Chapter 26 and further discussed in Chapter 33.

Air hubs and spokes

Due to the high unit costs associated with air transport, created by relatively low volumes of cargo compared to other transport modes, long distances and the high operating costs of aircraft, air carriers utilize a system of air hubs. These hubs are located around the world and are strategically located relative to their geographical position and proximity to markets for air cargo.

These hubs are utilized by airlines, freight forwarding companies and air cargo customers in order to gain the best efficiencies from the use of carrying capacity over very long distances. Cargo is consolidated by freight forwarding companies or the airlines and then carried between air hubs where the cargo is deconsolidated and either loaded on to a feeder aircraft or mode of transport for the final destination. This does not necessarily mean that the cargo will be carried by the shortest route, but it generally means that the lowest cost of transport is achieved.

Airports such as Chicago O'Hare, United States; London Heathrow, UK; Paris Charles de Gaulle, France; Amsterdam Schiphol, Netherlands; Frankfurt, Germany; Dubai, UAE; Singapore; and Hong Kong, China all act as air hubs, or gateways as they are sometimes known. As an example the Al Maktoum International Airport being built in Dubai is planned to be the largest air hub in the world with a capacity equivalent to London Heathrow and Chicago O'Hare combined. It is operational for both cargo (in 2010) and passengers (in 2013) and when it is completed it will have a capacity of 160 million passengers and 12 million tonnes of cargo annually (Dubai Airports, 2021).

It is important to understand that this system is employed on the major trade routes around the world and that many areas of the world are not served by this system. In these cases, smaller cargo aircraft may be required to make direct deliveries between the origin and destination. This is only possible where there are suitable airport facilities. Otherwise cargo will have to be transferred to another mode of transport for the final delivery.

Air freight pricing

All space on aircraft is limited by not only the total volume of space available inside the cargo hold but also by the size of the access doors and payload restrictions. In addition, the shape of the fuselage also presents challenges for the load masters. Another factor relates to the reality that a large volume of air cargo is carried by passenger aircraft and therefore air cargo may be left off the aircraft due to other priorities such as passenger baggage or balancing the loading of the aircraft for safety reasons. Therefore, air freight is generally the most expensive mode of transport that may be used, when costs per tonne are compared for the same journey using different transport modes between origin and destination. This becomes obvious when it is noted that air freight is generally quoted in costs per kilogramme as compared to road, rail and sea freight costs, which generally refer to tonnage. The principles by which air freight prices are calculated can be a little confusing to those who are not directly related to the process. The following section lays out the basic principles.

Basic principles of price calculation

- 1 The dimensions of the cargo need to be accurately measured in centimetres to the most extreme points of the piece to be carried. This calculation establishes the volume of the cargo and is based on:

$$\text{length} \times \text{width} \times \text{height} = \text{cargo volume}$$

It is important to note that any cylindrical (or any unusually shaped item) will be calculated in volume terms based not on the actual volume of the cylinder but on the basis of the volume of a box that the cylinder would fit inside exactly. Therefore, all calculations are cubic and based on rectilinear shapes not actual shapes. Another point to note is that if there is a part of the cargo that extends outwards from the piece, such as a pipe or aerial, then the entire additional cubic area that this extension consumes will be charged, however small the pipe or aerial may be in terms of volume itself.

Once the dimensions and volume have been accurately calculated for each individual piece of cargo it is then possible to move to the next stage of the calculation.

- 2 As with sea freight, the pricing of air freight is based on a weight or measure system. This means that the airline will charge air cargo at the higher of the two calculations of the weight or the volume. If the weight is higher than the volume then this will be the basis of the price; if the volume figure is higher this will be used. The airline industry calculates the relationship between weight and volume in the following way:

$$6 \text{ cubic metres} = 1 \text{ metric tonne}$$

or

$$6,000 \text{ centimetres cubed (cm}^3\text{)*} = 1 \text{ kilogramme}$$

therefore

$$1 \text{ cubic metre} = 166.67 \text{ kilogrammes of chargeable rate}$$

* This is the industry standard but some air freight carriers may use different cubic measures such as 5,000 cm³ to calculate their rates. However, this does not change the basic method of calculation.

- 3 The air freight rate is calculated by multiplying the agreed kilogramme tariff rate for the piece of cargo in question by the chargeable weight, which is always rounded up to the next half a kilogramme.

For example, a piece of cargo that weighs 150 kilogrammes and has dimensions of 120 cm × 80 cm × 50 cm would be calculated as follows:

volume = 1.2 m × 0.80 m × 0.50 m = 0.48 cubic metres (expressed as m³)

Therefore, the volumetric weight is:

$$0.48 \text{ m}^3 \times 167 \text{ kg} = 80 \text{ kg}$$

Using the same example, the volumetric weight may also be calculated in the following manner:

$$120 \text{ cm} \times 80 \text{ cm} \times 50 \text{ cm} / 6,000 = 80 \text{ kg equivalent volume}$$

The chargeable weight is 150 kg as the weight exceeds the volume equivalent of 80 kg.

- 4 Once the chargeable weight has been calculated it is a relatively simple process of looking up the agreed tariff for this weight from the origin airport to the destination airport on the schedule of rates provided by the freight forwarder or the airline.
- 5 Rate tariffs can be agreed in advance with freight forwarders or airlines. There is always a minimum chargeable weight and generally the cost per kilogramme diminishes as the chargeable weight increases.
- 6 The airlines may also impose certain surcharges such as a fuel surcharge or a war risk premium, if appropriate, depending on the destination and the surcharges applicable at the time of shipment.
- 7 It is important to note that this air freight rate only covers the cost of carrying the cargo from one airport to another. There will be other additional charges that must be considered. Some of these are likely to include:
 - a at origin:
 - i the cost of transporting the cargo from the consignor's premises to the freight forwarder's warehouse and the subsequent transfer to the airport by the freight forwarder
 - ii origin airport handling charges
 - iii freight forwarder's costs for processing the necessary documentation
 - iv cost of customs clearance if applicable
 - v costs for security screening if required
 - b at destination:
 - i destination airport handling charges
 - ii freight forwarder's costs for processing the necessary documentation
 - iii cost of customs clearance if applicable, which may include duties and taxes
 - iv costs for security screening if required

- ▼ the cost of transporting the cargo from the destination airport to the consignee

The basic carrier's liability accepted by air carriers is very limited. In fact, air freight liability is limited by the Montreal Convention in 1999 (revised 2019) to 22 special drawing rights (SDR) per kilogramme – current values in local currency can be found on the IMF website (IMF, 2021). At the time of writing 1 SDR = US \$1.43493 (calculated daily) therefore 22 SDRs = US \$31.56846 per kilogramme. As this may not cover the value of many cargoes, it is necessary to consider insuring the cargo while in transit. The price is usually based on a small percentage of the declared value (to the insurance company) of the goods. Of course, full door-to-door insurance should be acquired as the above only covers the flight and nothing else.

These additional charges are usual but there may be other charges related specifically to the destination country or the nature of the cargo. It is always advisable to use an IATA-registered cargo agent to handle these issues and especially one experienced in dealing with the destination country or type of cargo.

There are restrictions on what type of goods may be transported by air, details of which may be obtained from your freight forwarder or IATA.

It will be necessary to use specialist air cargo charter agents and carriers for large consignments or the chartering of an air freighter for any large cargo movement. The pricing of these jobs will involve a certain amount of negotiation but the basic principles will remain the same. However, it must be remembered that single charters are often charged on a round-trip basis and may be very expensive compared to standard per kilo rates.

Air cargo security

The major risks associated with air cargo security and air industry security in general may be summarized as:

- the placing of explosive or incendiary devices inside air cargo prior to being loaded on the aeroplane
- the undeclared or undetected transport of hazardous material on board an aircraft
- the possibility of smuggling contraband goods inside air cargo
- theft from air cargo
- hijackings of aircraft or sabotage by people with access to the aircraft

These risks may be limited by:

- implementing or improving cargo screening and inspection
- improving the physical security of air cargo facilities
- ‘known shipper’ programmes
- improving staff security training
- restricting access to aircraft and air cargo facilities
- use of the latest air cargo security technology such as tamper-proof seals, blast-resistant hard-sided air cargo containers, biometric data for personnel working with air cargo, and improved air cargo screening systems

In January 2007 the EU enacted Regulation 831/06, which required member states to ensure that regulated agents and airlines acquired some specific factual information (including financial information such as bank account details) regarding the clients who consigned air cargo through their systems. These same clients were also required to allow compliance inspectors to audit them. This change to the previous system of self-regulation by regulated agents and airlines was deemed necessary by the EU because the system was considered to be not working to a satisfactory standard.

In the UK, the Department for Transport (DfT) makes the following statement on its website:

All cargo which is to be carried on either a domestic or international flight originating in the UK must be screened to a standard sufficient reasonably to ensure that it does not carry a prohibited article such as an incendiary or explosive device. The screening process will involve a number of different techniques, which can be carried out either by the airline or a regulated agent. Once screened, cargo must be stored and transported in secure conditions until it is placed on an aircraft. Unscreened cargo is termed ‘unknown’ cargo, while screened, protected cargo is considered ‘known’.

DEPARTMENT FOR TRANSPORT, 2009A

In 2010 a consignment from Yemen bound for the United States was found to contain a bomb. As a result, from 2012 the US Transport Security Administration (TSA) requires that all cargo shipments loaded on passenger aircraft are screened for explosives. Since 2012 the EU has required all cargo bound for the EU to be screened at origin. In addition, since 2014 the EU requires all carriers serving the EU to be Air Cargo Carrier Third Country (ACC3) compliant. This requires an EU national airline to inspect and approve the cargo security screening system of non-EU airlines at origin. Further to this, since 2014 all carriers serving the EU have had their cargo security arrangements both inspected and approved at the departure airport by independent validators.

In 2012 the United States and the EU mutually recognized each other’s air transport security arrangements.

All of the above measures help to ensure that as far as possible air cargo is screened and secure before it is presented to the airport cargo handling terminal for air transport. Similar systems are used in other countries around the world, such as C-TPAT in the United States (see Chapter 41). However, there is still some way to go before all the various air cargo security screening initiatives are working in harmony. This was sadly demonstrated by the bombing of a Russian airliner in 2015. It is believed that the aeroplane was destroyed by a bomb that was placed in the hold of the airliner in the Egyptian holiday resort of Sharm el-Sheikh.

Space freight transport

This is a rapidly developing and expanding area of freight transport. Estimates vary but most predict a massive growth in this sector over the next 10 years. Satellites that are used for communications and observations of the Earth for a myriad of reasons require transport to their orbits. Both personnel and materials are required to be moved to the International Space Station and space junk orbiting the Earth needs to be monitored and removed to avoid collisions. Also, freight will need to be transported to the Moon, to Mars and possibly beyond, as well as any samples or extracted minerals returned to Earth. Space transport used to be the province of national governments but the emergence of privately owned companies such as SpaceX operating in this field has increased the scope and scale of space freight transport.

SpaceX has successfully demonstrated that it is possible to produce a rocket that may be reused. Previously space craft jettisoned used parts of the rocket as it was propelled into orbit. According to SpaceX they have relanded their Falcon 9 orbital class reusable rocket on 72 occasions and subsequently relaunched it 55 times. This will dramatically reduce the cost per kilogramme of transporting cargo into space in the future.

Rail and intermodal transport

28

Introduction

Around the world both the developed and rapidly developing nations are investing very large sums of money in their transport infrastructures. Roads, airports, seaports and railways are all being developed, especially in countries such as China and India. Massive investments in both high-speed passenger and freight rail systems are being made. China alone is investing hundreds of billions of US dollars in passenger and freight rail lines as part of their Belt and Road Initiative (BRI). A 2,397-kilometre (1,489-mile) high-speed passenger rail line from Beijing to Hong Kong was completed in 2018. China is also investing billions of dollars in a road and rail route through Pakistan from China's western border to both Karachi and Gwadar on the Arabian Sea, which will open up a short cut to markets in the Middle East, Africa and beyond. These massive investments in infrastructure have been compared with the development of the rail and road network in the United States during the 19th and 20th centuries. China is by no means alone in recognizing the environmental and economic benefits of rail links especially over long distances.

This chapter is primarily concerned with intermodal transport. However, as railways play a key role in transporting intermodal containers as well as carrying large volumes of bulk freight such as coal, grain, fuel and other bulk commodities, some wider information on rail transport has been included.

What is meant by intermodal transport? The following is a useful definition from the European Conference of Transport Ministers: 'the movement of goods in one and the same loading unit or vehicle, which uses successively several modes of transport without handling of the goods themselves in changing modes'.

Undoubtedly the introduction of unitized loads in the form of International Organization for Standardization (ISO) containers and pallets revolutionized the movement of freight from the 1960s onwards. Pallets first appeared on the global transport stage courtesy of the United States military forces in the 1940s. The assembly of goods on to pallets allowed swift transfer of loads from warehouse to truck

or any other mode of transport such as trains, ships or aircraft. The reduction in personnel required and transit times were remarkable. In 1958, the shipping line Fred Olsen reported loading 975 tons of unitized cargo in 10 hours with an 18-to 22-man longshore gang (stevedores) instead of the usual 200 tons (Van Den Burg, 1975).

Rudimentary freight containers were certainly in use as early as 1911 when they were known as lift vans in the United States, but it was the 1960s that saw the birth of the ISO container for freight movement. Pioneering companies in container transport were Sea-Land Service Inc on the US Atlantic coast, Matsons on the US Pacific coast and Associated Steamships Ltd in Australia. A number of ISO recommendations helped the standardization of containers and therefore allowed for interchangeability between different modes of transport around the world.

These standards allow the same container to be safely carried by truck, train, deep-sea cellular container ship and aircraft, although it should be noted that aircraft have their own special form of shipping container known as unit load devices (ULDs) (see Chapter 27, 'Air Transport'). This removes the requirement for multiple handling of the products, improves security, reduces loss and damage and above all speeds up the whole process of freight transportation. Containers of freight move around the globe with an ease that could only have been dreamt of at the start of the 20th century. It is said that as much as 90 per cent of all non-bulk international cargo is carried inside containers. This ability to move freight swiftly and safely aids the logistics process, as the elimination of wasted time is a key objective of logistics management. Containers also have another benefit in that they can be traced through the transport system and their progress monitored.

Intermodal equipment

The following section is designed to provide an overview of the various types of equipment specifically used in intermodal transport. The list is not exhaustive but the most common equipment is identified and described briefly.

Intermodal containers

ISO containers

ISO containers are so called because the ISO has standardized the design of containers to allow for the widest possible use of this equipment around the world. Containers are usually rectilinear boxes constructed of steel. Open-topped versions, which are covered by a fabric curtain, are available for loads that may not fit into a standard container or need to be lifted in from the top. Another common variation

is the tanktainer, which is a steel frame that conforms to the ISO dimensions but has a tank container fixed inside the frame. This allows bulk loads of liquids or powders to be carried by intermodal carriers (see Figure 28.1). Refrigerated and flat-rack options are also available.

Figure 28.1 Articulated vehicle loaded with a tanktainer



SOURCE Mercedes Benz Classic

The most common sizes of container available are 20, 40 and 45 feet in length. The height and width dimensions are the same for all lengths at 8 feet wide $\times$ 8 feet 6 inches high, although high-cube containers at 9 feet 6 inches high are becoming increasingly common. As with most rules, exceptions do exist, but these are the most commonly used dimensions.

Two acronyms used widely in intermodal circles are TEU and FEU. The initials stand for '20-foot equivalent unit' and '40-foot equivalent unit'. They are often used as definitions of cellular container ship capacities. A ship may be described as being able to carry 6,000 TEU. The 20-foot equivalent unit refers to the 20-foot container. Therefore, two 40-foot containers would equal four TEU or two FEU.

Refrigerated containers (often referred to as 'reefers') are used for products that need to be transported in a temperature-controlled environment. Frozen products may be safely transported over very long distances due to the construction of

modern refrigerated containers. However, it is not only frozen products that may be transported but other products that require higher controlled temperatures such as chilled produce that may only need a constant temperature of +4°C.

The container walls are insulated by means of a sandwich containing polyurethane foam. The temperature is controlled by the addition of an electrically powered refrigeration unit with typically a temperature range of +30°C to −35°C (see Figure 28.2). Refrigerated containers comply with the external dimensions of other types of ISO container but differ significantly internally. This is due to the fact that the insulation of the container walls as well as the space used by the refrigeration unit reduces the available internal capacity for cargo. In addition, cargo may not be loaded above a certain level inside the container because the temperature control system requires the free flow of air over, around and in some cases under the goods. The cold air passes from the refrigeration unit under or around the goods and the warm air returns over the top of the load. This maximum load level is often clearly marked by a line on the internal walls of the container.

Figure 28.2 Refrigerated containers showing the refrigeration units fitted to the front



SOURCE Maersk

When these containers are loaded on board a container vessel they are plugged into the ship's electrical system. This process has become so sophisticated that some shipping lines offer the facility to monitor and if necessary adjust the temperature, the humidity level, the rate of air exchange or the carbon dioxide (CO₂) level of the

container while in transit. When ripening fruit and vegetables are being transported the ripening process generates heat, consuming oxygen and producing CO₂, which needs to be removed by a process of air exchange inside the container. The consignors plan their journeys in such a way that the produce completes its ripening process en route so that it arrives at its destination ready to be sold.

The precise details regarding the necessary temperature, humidity, CO₂ and O₂ levels naturally vary from product to product. In a similar fashion, shipping lines vary in their ability to provide the most sophisticated temperature-controlled containers and monitoring services. Therefore it is incumbent on the consignor to carefully research the transporter's capabilities in this regard.

The swap-body

This is a type of container used primarily on bimodal intermodal operations, which use the road and rail modes of transport. The swap-body is a self-supporting body that has supporting legs that may be folded away when not required. Swap-bodies conform to a different set of standards. There are three European standard lengths of 7.15, 7.45 and 7.82 metres. These lengths are used because the swap-body will be carried by road transport for part of its journey and must conform to the strict requirements pertaining to vehicle dimensions inside the EU.

The swap-body is transferred from road vehicle to rail wagon by means of an overhead straddle crane, which has four arms that locate into slots permanently fixed to the bottom of the swap-body.

A further version of the swap-body is the *caisse mobile*. This is 12 or 13.6 metres long, which conforms to EU dimensions for articulated semi-trailer lengths. Caisse mobiles do not usually have self-supporting legs but very often are able to be top-lifted in the same way as ISO containers. Unlike ISO containers, most swap-bodies cannot be stacked.

RoadRailer® trailers

RoadRailer is the brand name for a method of effectively converting a road-going articulated semi-trailer into a rail-going rail wagon. This is achieved by placing a railway bogie under the rear of a specially designed road semi-trailer. This same bogie attaches itself to the kingpin of the following road trailer (see Figure 28.3). This process is repeated until the train is complete. The road wheels of the semi-trailer are mechanically retracted to prevent them from interfering with the movement of the train. This system does not require specially adapted rail wagons and allows for a more rapid transfer of vehicles from road to rail. It does require that the road vehicles are specially designed for the purpose.

Figure 28.3 RoadRailer® semi-trailers coupled to form railway rolling stock



SOURCE Wabash National

Unaccompanied trailers

Unaccompanied road semi-trailers may be used to send goods by roll-on roll-off sea ferry (RORO). This method does not require any adaptation of the road trailer and avoids the added cost of sending the tractor unit and driver with the trailer. This is important, as tariffs on shipping services usually relate to the length of the vehicle. Unaccompanied trailers are shorter and therefore cheaper to transport than trailers accompanied by tractor units. The unaccompanied trailers are moved on and off the ferry by means of a motive unit (often called a tug) fitted with a hydraulic mechanism for attaching to the front of the trailer and lifting the semi-trailer without the need to raise the landing legs. This speeds up the operation at both ports.

Another effective use of unaccompanied trailers is called piggyback. This uses the same principle as the road–sea version but applies the principle in a road–rail context. In this situation, unaccompanied semi-trailers are carried on specially constructed rail wagons. Because articulated road semi-trailers tend to be higher at the front than at the rear, a specially constructed well in the rail wagon allows the landing legs to sit at a lower level than the rear wheels. This has the effect of making the trailer sit on the rail wagon with the roof at an overall even height to the ground.

The French have dubbed this method ‘le kangourou’ because of the well being likened to a kangaroo’s pouch.

The problems caused by the landing legs and the road wheels are effectively overcome by a development known as the spine rail wagon (see Figure 28.4). In this system road trailers are loaded on the rail wagon with the road wheels and landing legs either side of a central spine on the rail wagon. This allows the semi-trailer to sit squarely on the rail wagon and reduces the overall height. The spine wagon is also able to carry ISO containers. In Figure 28.4, the twist locks for securing ISO containers are visible, which demonstrates the versatility of the system.

These methods of unaccompanied transport have been in use for some time and are not always thought about when intermodal transport is discussed. However, they do fit the strict definition of intermodal transport given above and use effectively the road, rail and sea modes.

Figure 28.4 Spine wagons being loaded by a reach stacker equipped with a grapple



SOURCE John G Russell (Transport) Ltd

Intermodal handling equipment

Ship-to-shore gantry crane (SSGC)

These are large devices mounted on rails, which are able to speedily transfer containers from the sea-going vessel to trucks or rail wagons (see Figure 28.5). A large boom spans the distance between the ship's cargo holds and the quayside. The ship-to-shore gantry crane is capable of moving along the quayside parallel to the ship's side to aid positioning.

Figure 28.5 Ship-to-shore gantry crane loading a cellular container ship



SOURCE Maersk

Gantry (or portal) crane

This is a crane designed to lift containers and swap-bodies (see Figure 28.6). It has four legs, one at each corner, with wheels at the bottom of each leg. It has the ability to straddle stacks of containers, rail wagons and road vehicles. Unlike the smaller straddle carrier it can straddle something like eight containers wide plus a lane for the truck. It is also higher in that it can hoist one container over six stacked containers. It is able to transfer containers and swap-bodies quickly from road vehicles to rail wagons and vice versa. It is also able to transfer containers from road vehicles or rail cars to a storage stack of containers. It is equipped with a spreader beam that has a twist-locking device at each corner, which locates in the corner casting of the con-

Figure 28.6 Two gantry cranes loading ISO containers on to railway freight wagons. Note the double-stacked containers as this is in Canada



SOURCE Liebherr

tainer. The spreader beam is able to move in several directions to aid accurate location either prior to picking up the container or when positioning the container on a road vehicle, rail wagon or in a stack.

Straddle carrier

Straddle carriers are smaller versions of gantry cranes. They are capable of performing the same basic functions as a gantry crane but on a smaller scale. As they are smaller they only straddle the width of one container, but they can be quite high and some are capable of straddling three containers high and placing a fourth container on top. Smaller versions are capable of placing a third container on top of a stack of two. The driver sits in a cabin at the very top of the machine.

Grappler lift

This is a similar handling vehicle to the gantry crane except that it is fitted with four arms and is designed specifically to handle swap-bodies. The arms locate in the spe-

cial slots built into the bottom of every swap-body. The grappler lift straddles the vehicle, positions the four arms and then lifts the swap-body.

Reach stacker

This is a heavy-duty materials handling truck that is fitted with a lifting arm and a spreader beam. It is capable of lifting containers and swap-bodies (only if the swap-body is equipped with twist locks on top). It can be used to load and unload road and rail wagons. It can also be used to stack containers one on top of the other and to reach over a row of stacked containers (see Figure 28.7). Empty containers can be stacked up to eight high using specially equipped lift trucks.

Figure 28.7 A reach stacker stacking ISO containers



SOURCE Liebherr

Intermodal vehicles

Sea

The cellular container ship

This is a custom-built sea-going vessel for the carriage of containers. The containers are loaded one on top of the other and guided into position by the means of vertical guides at each corner of the container. This aids the process of loading, as the guides position the container accurately enough to preclude the need for any further manoeuvring once the container is released by the overhead crane (see Figure 28.8). It also eliminates the potential problems caused by the vessel listing or the crane not being accurately positioned. Once in position, the containers are secured together by means of a twist-locking device. The stacks of containers are also secured by means of deck lashings for added stability during the sea journey.

Containers may be stacked high above deck level. This ability is limited by the structure and stability of the vessel. Owing to the cubic nature of the container load, which is at odds with ship design, some vessels carry other cargo in the spaces in the holds created by the squaring-off effect.

The service provided by these vessels is sometimes referred to as LOLO (lift-on lift-off).

Figure 28.8 Containers being loaded into slots on a cellular container vessel



SOURCE Maersk

The roll-on roll-off (RORO) ferry

This type of sea vessel is designed to carry road vehicles. The vehicles are either driven on to the vessel by the driver or, as in the case of unaccompanied trailers, by port-based vehicles. This allows unaccompanied vehicles or trailers to be delivered to the port of departure and then collected from the port of arrival.

Other versions of the RORO ferry are specifically designed to carry rail wagons. The decks of these vessels are equipped with railway lines to allow ease of loading rail wagons.

River barges

On large inland waterways such as the Rhine/Danube in Europe and the Mississippi River in the United States, there is considerable use made of water as an artery of transportation (see Figure 28.9). RORO facilities and container transport as well as break bulk cargo facilities are available and cannot be forgotten when considering long journeys using different modes of transport. This type of transport is useful for non-urgent freight, as it is by definition slower than other modes.

Figure 28.9 River barges being pushed by a powerful tug on the Mississippi River in the United States



SOURCE Phil Croucher

Rail

It should be noted that a movement of freight that uses both road and rail to complete the journey is sometimes referred to as combined transport.

Rolling motorway

This is the rail version of the RORO sea ferry. Vehicles are driven on to specially designed rail wagons by their drivers. In some cases the drivers stay with their vehicles and in others they are accommodated in a passenger car for the duration of the journey. This type of system is used in Switzerland to carry trucks between Germany and Italy. Another use of this system is in the Channel Tunnel between the UK and France, where it is known as Le Shuttle.

Piggyback and RoadRailer®

These methods of carrying road trailers by rail were discussed in the sections in this chapter on 'Unaccompanied trailers' and 'Intermodal containers' (see Figures 28.10 and 28.11).

Figure 28.10 Gantry crane with grapple attachment loading road semi-trailers on to rail cars in the United States



SOURCE Phil Croucher

Figure 28.11 Road semi-trailers ‘piggybacked’ on rail cars in the United States



SOURCE Phil Croucher

Double-stacking

In some parts of the world, such as the United States and Australia, containers may be carried by rail double-stacked, i.e. one container loaded on top of another (see Figure 28.6). This method greatly improves utilization of equipment, especially over the very long distances found in these countries. This method is not practical in the EU due to the restrictive loading gauges.

Multifret wagon

This is a specially designed low-platform rail wagon for use by intermodal trains using the Channel Tunnel and servicing the UK and European intermodal rail network. This French design overcomes the problem of different loading gauges in the UK and the rest of Europe. However, it must be understood that it doesn't overcome the loading gauge problem on the entire UK and European rail network. The multifret wagon has a platform height of 945 millimetres and a loading platform length of 15.7 metres. These dimensions allow the transport of 13.6 metre swap-bodies, and 40-foot ISO containers. However, it is unable to accommodate piggyback semi-trailers.

Ferrywagon

This is a conventional rail wagon that is capable of being loaded on to a train ferry.

European rail containers

These containers are slightly wider than ISO containers, which are 2.4 metres wide. These containers are 2.5 metres wide and are used in the European rail system.

Road

Skeletal trailer

This is an articulated semi-trailer that is designed to carry ISO containers. It is fitted with twist locks at various points on the trailer to allow the carriage of different sizes of container. It is called a skeletal trailer, as it does not have any loading platform as such. It is a framework designed to support containers alone. In effect, the container becomes the body of the vehicle when loaded on to the trailer.

Some skeletal trailers are equipped with hydraulic rams to facilitate the tipping of the container. Some granular and powder products may be carried in ISO containers. The product is loaded through the top of the container via a special hatch, and the product is retained by means of a liner inside the container. At the point of delivery the container is tipped up by the hydraulic ram and the product is allowed to flow out of another hatch set in the rear of the container or simply through the open doors (see Figure 28.12). In some cases this process is assisted through the use of pneumatic conveyance.

Figure 28.12 Container loaded with grain being unloaded by using a hydraulic ram to lift the trailer. The liner used to secure the grain inside the container can be clearly seen



SOURCE Phil Croucher

A relatively recent development has been the introduction of 40-foot skeletal trailers that are capable of splitting into two separate 20-foot trailers. This facility helps speed the unloading process of two 20-foot containers. The driver locates the rearmost container on the loading dock, splits the trailer in two and then locates the

forward container on another loading door. This way, both containers may be unloaded or loaded at the same time. Some splitter trailers have only one additional axle which provides the wheels for the front 20-foot container and others have two additional axles. The additional axles are lifted and stowed while the vehicle is being driven on the road. The axles are lowered and used only to facilitate the splitting and (un)loading process. However it is possible to drive the front section of the splitter on the road if it is being used as a 20-foot trailer alone. Some types of splitter are designed in such a way that both the front and rear sections may be operated as 20-foot trailers in their own right. Splitter trailers are capable of carrying the full range of container sizes.

Extendable trailers

These trailers are sometimes called ‘slider’ trailers because of their ability to be extended or shortened depending on the size of the container to be carried. In all other respects they resemble skeletal trailers.

Intermodal infrastructure

It is not possible to cover all the intermodal infrastructure developments around the world. Therefore the following sections use the UK and to a lesser extent Europe as an exemplar. The EU and the UK Government are committed to the promotion of intermodal transport. They see the removal of certain types of cargo from the EU’s roads as an environmentally sound policy. The reduction of road congestion, improvements to urban environments and reduction of harmful gaseous emissions from road vehicles are the objectives. Consequently, considerable investment is being made in intermodal infrastructure.

The Channel Tunnel

The fixed link between the UK and France has opened up new possibilities for the movement of freight by rail. Various distances are cited by railway economists for the point at which movements by rail become profitable. One thing is clear: that rail freight has a greater chance of being profitable if longer distances and full train loads are involved. The Channel Tunnel has opened up the possibilities for much longer journeys into continental Europe. In 2017 a train arrived at London Gateway port, UK that had travelled from China. Soon after 30 containers were despatched from there to Yiwu in China, a journey of 7,500 miles and 17 days.

Significant amounts of intermodal traffic pass through the fixed link every day, chiefly accompanied vehicles by Le Shuttle mentioned above but also swap-bodies

and containers by through-trains from and to inland destinations (e.g. from the Midlands of England directly through to Italy).

Strategic rail freight interchanges (SRFI)

The UK Government has defined a SRFI as:

a large multipurpose rail freight interchange containing rail-connected warehousing and container handling facilities. The site may also contain manufacturing and processing activities. In addition, SRFIs represent major gateways to the national rail network that allow businesses to move freight by rail for distances and in quantities appropriate to their operational and commercial priorities. While SRFIs operate to serve regional and cross-regional catchment areas, they are also key components in national and international networks.

DEPARTMENT FOR TRANSPORT, 2009B

The UK Government is developing a strategic rail freight network. The intention is to introduce longer and heavier trains capable of carrying 118 TEU with a train length of 775 metres plus the length of the locomotive. The loading gauge restrictions on certain routes are also being addressed by introducing a W12 loading gauge on all strategic container routes. Key intermodal rail freight routes will be targeted for increased capacity in line with industrial growth forecasts.

The continuing development of SRFIs goes hand-in-hand with the development of further rail–road intermodal interchanges. There are a number of these which are the larger and longer established international intermodal terminals. These are road–rail interchange points that have been strategically placed on the UK mainland and are directly connected to the European rail network via the Channel Tunnel. These termini and freight villages usually have warehouse and distribution companies based alongside the rail facilities. Break bulk and freight consolidation services are usually also available. Some of these facilities are classified as inland ports and so customs services are provided on site. They also meet the UK Government's definition of a SRFI.

The main international intermodal terminals in the UK are:

- Mossend, Glasgow
- Trafford Park, Manchester
- Seaforth Docks, Gartree (Liverpool)
- Hams Hall, West Midlands
- Daventry International Rail Freight Terminal, Daventry
- Doncaster International Railport, Doncaster

- Wakefield
- Willesden, London

The above is not an exhaustive list and Network Rail provides a comprehensive list of intermodal terminals.

Mode shift grant schemes

Mode Shift Revenue Support Scheme (MSRS)

The MSRS scheme provides the financial support to assist companies with the operating costs associated with rail and inland waterway freight transport in place of road. However, this only applies in a situation where using the rail or inland waterways is more expensive to operate than the road alternative. At the time of writing the scheme operates in two ways: MSRS (intermodal) and MSRS (bulk and waterways). The scheme is operated by the Department for Transport (DfT) in England, the Scottish government in Scotland and the Welsh government in Wales. These schemes will be reviewed in 2025 and are valid until then.

Waterborne Freight Grant Scheme (WFGS)

This scheme helps companies for a period of up to three years with the costs of operating coastal and short sea-shipping freight transport instead of using road freight, but only where coastal and short sea-shipping freight is more expensive than road freight.

The Scottish and Welsh governments continue to offer Freight Facility Grants (FFG).

Detailed information on all these grants is available by contacting the various governments outlined above.

Rail transport

The rail transport industry began when the *Rocket* was built by George Stephenson in 1829 in the UK. Rail transport is a relative newcomer to the scene of freight transport, not as young as air transport but very young compared to waterborne and road transport.

Railways generally rely on a system of fixed infrastructure based on two parallel metal rails laid on supports known as ‘sleepers’ although monorail systems do exist. Railways require a solid base and must be constructed with relatively shallow

gradients as well as wide radius curves. Rack and pinion systems may be installed to improve the operational restriction created by steep gradients but nevertheless the problem is a real one for railway engineers. In addition, the rail track needs to be free from barriers to the uninterrupted forward progress of the train. Therefore bridges, tunnels and crossing points for roads need to be constructed to allow an unimpeded passage for the train. Railways also require stations to allow the transfer of passengers or cargo from and to the train. A method of management for the trains' operation is required to avoid collisions between trains operating at different speeds on the same section of track. This is achieved through a system of signalling and train scheduling.

The following sections describe in some detail how the UK's privatized rail industry is structured. Unfortunately there is insufficient space to look at alternative models for operating rail networks. Therefore the following sections are presented as one approach while fully accepting that there are other ways of achieving the same end.

The rail industry structure in the UK

The Railways Act of 1993 changed the ownership of the UK's railways from public ownership in the form of the British Railways Board into various forms of private ownership. The various functions of the national railways were divided and are now operated by various private bodies. There is one very significant exception to this organization, which is the body that owns and maintains the railway infrastructure. In 1993 this responsibility was placed in the hands of a company called Railtrack. However, after the financial collapse of this company in 2001 the ownership of the infrastructure was effectively taken back into public hands in 2002. The new organization is called Network Rail, which in 2003 brought the management of the network's maintenance back in-house.

One notable success story since privatization is the growth in rail freight. Between 1995 and 2020 non-coal rail freight lifted increased from 55.5 million tonnes to 66 million tonnes. Overall rail freight volumes reduced in the same period from 100.7 million tonnes to 72.2 million tonnes due to the steep reduction in both the transport and use of coal (Office of Rail and Road, 2021a). Clearly rail freight has attracted new users.

The structure of the UK's railway industry is by no means simple but some of the more significant elements are outlined below.

Government

The role of the UK Government, in the form of the Department for Transport, in its own words is to provide 'strategic direction and funding to the railways in England and Wales and buys rail franchises and projects. Their work is directed and overseen by the Secretary of State for Transport and his team' (Office of Rail and Road,

2021b). However, it needs to be understood that ‘government’ includes: Transport Scotland, which has responsibilities for transport in Scotland; the Welsh government, which has responsibilities for transport in Wales; passenger transport executives, which have responsibilities for transport services in the city regions; and the Department for Transport. All of these provide funds to the railway network.

The Office of Rail and Road (ORR)

The ORR regulates the railway industry and works with all the bodies that are regulated, which includes safety bodies. The ORR describes its role thus:

We regulate the rail industry’s health and safety performance, we hold Network Rail and High Speed 1 to account, and we make sure that the rail industry is competitive and fair. We are also the monitor of Highways England and we have economic regulatory functions in relation to railways in Northern Ireland and the UK section of the Channel Tunnel.

OFFICE OF RAIL AND ROAD, 2021B

The ‘regulated entities’

The ORR effectively regulates the whole UK rail industry. The regulated entities include the following.

Train operating companies (TOCS)

This sector may be further subdivided into:

- 1 franchised train operators who have a fixed term contract to operate trains and the majority of stations on certain routes or areas
- 2 open access train operators who are under no commitment to government but are allowed to operate trains subject to agreement with the ORR
- 3 Eurostar, which operates high-speed services to France and Belgium through the Channel Tunnel and is owned by Eurotunnel

Freight operating companies (FOCs)

These are the companies that operate freight transport services on the UK railway network.

Rail Freight Group

This group brings together owners of passenger train operating companies, freight operating companies and Network Rail to provide leadership to the rail industry.

Network Rail

As mentioned above, this is the body that owns, operates and maintains the railway infrastructure in the UK.

High Speed 1 (HS1)

HS1 has a 30-year concession to operate and manage the high-speed railway between St Pancras Station in central London and the Channel Tunnel.

High Speed 2 (HS2)

HS2 is an executive non-departmental public body sponsored by the UK's Department for Transport and is responsible for developing this new high-speed rail network. The first stage of the project will build the section between London and the West Midlands. Future stages will further expand the line from the West Midlands to Crewe and then to Manchester and Leeds.

The Channel Tunnel

The ORR regulates the British half of the Channel Tunnel with regard to economic management. A separate body regulates safety, namely the Intergovernmental Commission.

Other regulated entities

- Transport for London
- London Underground
- heritage railways
- metros
- tramways

The industry structure picture is completed by a number of safety bodies, such as the Rail Accident Investigation Branch and the British Transport Police as well as customer groups representing the interests of railway users. Rolling stock leasing companies (ROSCO) own coaches, locomotives and freight wagons which they lease to train operating companies and freight operating companies.

Belt and Road Initiative

Launched in 2013, the Belt and Road Initiative (BRI) is the largest infrastructure development project of its kind in world history. At the time of writing 138 countries had signed agreements with China with respect to this project. Once complete, 60 per cent of the global population will come within its reach. In essence, it is a modern regeneration of the old trans-Asia Silk Roads that carried merchandise from China to Europe and everywhere between. The Silk Road Economic Belt encompasses the road and rail routes across Central Asia. The 21st Century Maritime Silk Road encompasses the sea routes from Asia westwards from China.

At the time of writing, the Eurasian rail network that has developed since the start of BRI connects 48 Chinese cities with 42 European cities. There are still railway gauge issues to surmount as both standard and broad gauge railways are used en route. This means that trains have to stop and trans-ship their loads.

Locomotives

Trains are powered by using motive units known as locomotives. Locomotives may either pull the train from the front or push from the rear. In some cases two or three locomotives are used in a combined effort of pushing and pulling the train (see Figure 28.13).

Figure 28.13 Two locomotives, United States



SOURCE Phil Croucher

In most countries, diesel is the primary fuel used for freight locomotives, as it is relatively low cost and has a high energy density (i.e. provides much energy for the space taken up by the fuel). However, diesel engines produce greenhouse gases (notably carbon dioxide), as well as other harmful gases and particulates that are damaging to health and the wider environment.

The other main power source is electricity from a national power grid generally picked up by the locomotives by means of overhead catenary wires. This system avoids any harmful gases being produced by the locomotive itself but its environmental credentials depend on the sources of the electricity produced in that country (which may range from renewable sources, such as wind, through to coal-fired power stations). Many countries are in the process of making their electricity supplies more environmentally friendly and expanding rail electrification to cover more of the rail network.

However, the latter constitute very expensive capital infrastructure projects and generally only main rail routes are electrified. Other alternative fuels to diesel are therefore also being developed or deployed, including:

- compressed natural gas
- hydrotreated vegetable oil (HVO)
- lithium-ion batteries
- hydrogen fuel cells

Details of these alternative fuels are described in Chapter 42.

Rolling stock

Rolling stock (in the United States these are referred to as ‘rail cars’) is the collective name for the different types of vehicle drawn by the locomotive. The locomotive is coupled to the various pieces of rolling stock to form the train. The variety of rolling stock is diverse and reflects the different types of cargo being transported. Cargo may be transported in enclosed boxcars, refrigerated wagons, flat wagons, tankers, wagons adapted to carry containers (in some countries these may be double-stacked, as in Figure 28.6), hoppers and car transporters. As mentioned earlier in the chapter, some trains are adapted to carry road vehicles that are driven on board and in some cases specially adapted road vehicles are coupled together to form the train (see RoadRailers® above and Figure 28.3). In Figure 28.14 double-decked rail cars loaded with new cars are being towed by a specially adapted UNIMOG road vehicle. The relatively low height of the loaded rail cars is due to the limitations of the loading gauge in Europe (see section on ‘Loading gauge’). Passengers are carried in carriages designed for the purpose.

Railway gauge

This is the distance between the two rails that comprise the railway. The standard gauge that is used in approximately 60 per cent of the world’s railways is 4 feet 8½ inches (1,435 millimetres) wide. Broad gauge refers to rail widths greater than 4 feet 8½ inches. Some railways use a rail width of 5 feet 6 inches (1,676 millimetres). Narrow gauge refers to rail widths less than 4 feet 8½ inches. Some railways use a rail width of 3 feet 6 inches (1,067 millimetres). The truth is that there are several variations of rail gauges used around the world, e.g. in India, Spain and Russia.

Dual gauge railways have three or four rails positioned in such a way that different gauges may be utilized. A break of gauge is the point at which two different gauges meet: this often presents problems at national frontiers where different gauges are used in the countries either side of the frontier. Broader rail gauges are capable of

Figure 28.14 Double-decked rail cars loaded with new cars being towed by a converted road vehicle



SOURCE Daimler AG

carrying heavier loads but utilize more land space and require broader curves in the rail track.

Loading gauge

This refers to the maximum permitted height and width of the rolling stock that may be used on a given section of railway. The loading gauge is a function of the height of overhead restrictions such as bridges and tunnels, which in turn restricts the effective operating height of the train. In addition, the distance between train pathways and trackside structures dictates the width of the rolling stock permitted.

The strengths and weaknesses of rail transport

Strengths

- The potential for high average speeds for journeys in the range of 50 to 300 miles.

- Rail in the majority of cases runs from city centre to city centre, which can cut journey times. This is generally of more benefit to passengers than freight transport, but not exclusively so.
- The railway effectively utilizes land space. Over any strip of land of a given width, the railway can carry more passengers and freight than any other land-based system.
- The general public often perceive railways as being less environmentally adverse than other forms of transport, both visually and as regards physical pollution.
- The bulk-handling capacity of the railway means they are very cost-effective when handling bulk materials in coupled train loads thus relieving the road system of large numbers of heavy trucks (see Figure 28.15).
- The railways are energy flexible and energy efficient. The use of electric traction relieves the railway of reliance on oil for energy.
- The safety record of railways is good, especially for the carriage of hazardous cargo.
- There is great scope for the full automation of the rail network, including the possibility of driverless trains.
- Of all the land-based modes of transport the rail system is the least affected by bad weather.

Figure 28.15 Trees being unloaded from rail wagons at a paper mill in Finland



SOURCE Phil Croucher

Weaknesses

- The financial viability of any rail network is vulnerable to downturns in economic activity. In recessionary times, the volume of traffic using the system may reduce sharply whereas the fixed costs of operating the infrastructure would remain.
- As the railway has a fixed and therefore inflexible infrastructure it is economically vulnerable to major changes in the industrial and social activity of a given geographical area.
- The railways suffer from the need to trans-ship from rail to other modes of transport for some part of the journey. The result is that rail is efficient over longer journeys when the costs of trans-shipment can more easily be absorbed and where the time element may be less significant.
- As a labour-intensive and often unionized industry any rail network is susceptible to industrial action. Where industrial disputes occur regularly and with little warning this has the effect of discouraging clients from using these services.

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Road freight transport

29

Vehicle selection

Introduction

As with most of the decisions that have to be taken in physical distribution, there are a number of aspects that need to be considered when trying to make the most appropriate choice of vehicle for a vehicle fleet. Vehicle selection decisions should not be made in isolation. It is essential that all the various aspects should be considered together before any final conclusions are drawn. There are three primary areas that need to be carefully assessed: efficiency, economy and legality.

Efficiency, in this context, means the most effective way to do the job, based on a number of important factors. The truck should be fit for purpose. These factors might include:

- the nature of the operation, i.e. annual distance travelled, the terrain, climate, etc
- the characteristics of the load, i.e. physical features, weight, etc
- the specification of the vehicle, i.e. engine, gearbox, axle configuration, body, etc

The area of economy is concerned with the purchase price and operating costs of different choices of vehicle. There are a number of points that should be taken into account. These should be analysed and compared with the costs and performance of the various alternative vehicles. The main points concerning economy are:

- the fixed cost of a vehicle, i.e. depreciation, licences, insurance, etc
- the variable cost of a vehicle, i.e. fuel, tyres, maintenance, etc
- the residual value of a vehicle (some types of uncommon vehicle do not have good resale values)
- the whole life costs of the vehicle, i.e. a calculation of the above cost over a given life of the vehicle
- utilization factors, i.e. fuel efficiency, other costs per mile/kilometre, etc
- vehicle acquisition, i.e. outright purchase, contract hire, lease, etc

The third and final area for consideration in vehicle selection is that of legality. This emphasizes the need to ensure that vehicles are selected and operated within the framework of relevant transport legislation. Transport law is complicated and ever-changing, so constant awareness is imperative. The major factors concern:

- operators' licences
- construction and use regulations
- weights and dimensions of vehicles
- health and safety features, i.e. seatbelts, handrails, walkways, etc
- mandatory environmental features, i.e. airbrake silencers, emission controls, etc

In this and the following three chapters, these various aspects are considered, although transport legislation is not covered in any depth due to limitations of space, the fact that the regulations are frequently changed, and the sheer volume and complexity of the relevant laws. This chapter is concerned with those aspects of vehicle selection that relate to the physical effectiveness of the vehicle for the particular job in hand.

Main vehicle types

There is a variety of vehicle types. It is important to be clear as to the precise definition of each type, because these definitions are typically used throughout the transport legislation laid down by different governments. The main types described in this section reflect UK Government definitions.

A *motor vehicle* is a mechanically propelled vehicle intended for use on roads. Mechanical propulsion covers vehicles powered by petrol, diesel, gas turbine, electric battery or steam generation.

A *goods vehicle* is a vehicle or trailer adapted or constructed to carry a load. The term covers all such vehicles.

A *trailer* is a goods vehicle that is drawn by a motor vehicle. There are two main types of trailer: 1) a draw-bar trailer that has at least four wheels and actually supports its load of its own accord; and 2) a semi-trailer, which is a trailer that forms part of an articulated vehicle. This trailer does not support the load on its wheels alone as it only has wheels at the rear: the front wheels are provided by the tractor unit when coupled. When it is uncoupled from the tractor unit it supports itself through the use of legs or jacks at the front end.

An *articulated vehicle* is a combination of motive unit (tractor) and semi-trailer (see Figure 29.1). Thus, the trailer carries the load and the motive unit pulls the trailer.

A *rigid vehicle* is a goods vehicle where the motor unit and the carrying unit are constructed as a single vehicle (see Figure 29.2).

Figure 29.1 Articulated vehicle comprising a tractor and box semi-trailer. Note the skirts on the bottom of the truck to improve fuel consumption



SOURCE Mercedes-Benz Classic

Heavy goods vehicle (HGV) is still in common parlance. However, since 1 April 1991 in the UK the term has been replaced by *large goods vehicle* (LGV) for legal purposes when referring to driver licensing categories.

Types of operation

Goods vehicles are required to undertake a wide variety of jobs. For each of these different jobs, it is important that the most appropriate type of vehicle is chosen. Different jobs or operations require vehicles with different specifications. When selecting a vehicle, consideration must therefore be given to the work that the vehicle will be doing for the majority of its working life, and also to the conditions within which it must operate. The main types of operation are described below.

Primary transport (also known as trunking or line-haul) operations involve vehicles delivering full loads from one supply point (e.g. a factory) to one delivery

Figure 29.2 Four-wheeled rigid vehicle fitted with a refrigerated body



SOURCE Mercedes-Benz Classic

point (e.g. a warehouse or distribution centre). Such long-distance journeys tend to include a large amount of motorway travel; thus, the vehicle is often involved in carrying heavy loads at maximum permissible speeds. The vehicles may be used throughout a 24-hour, 7-day duty cycle. Clearly, for this duty cycle a very high specification is required if service failures are to be avoided. Professional operators usually deploy their newest vehicles on this duty cycle early in the vehicles' life before 'retiring' them to less critical work. These vehicles are often large articulated or draw-bar combinations, given that the loads are often full loads moving from point to point and maximum loads bring the best vehicle economy.

In countries such as the United States, Canada, Australia and the United Arab Emirates (UAE) it is not unusual to see articulated vehicles with more than one trailer. Where there are two semi-trailers and one motive unit this is called a double-bottomed articulated vehicle or road train (see Figure 29.3). Especially in Australia, road trains may consist of more than two trailers. In the UK, serious consideration is being given to their use on motorways. Despite considerable attempts on the part of the European Union, not all maximum truck weights in Europe are fully harmonized. For instance, in Finland for various reasons, road trains may operate at a maximum gross weight of 76 tonnes (see Figure 29.4).

Figure 29.3 Double-bottomed articulated vehicle in Jebel Ali port, UAE



SOURCE Phil Croucher

Figure 29.4 A 6×2 rigid vehicle towing a triaxle semi-trailer by means of a tandem axled bogie fitted with a fifth wheel coupling. Both vehicle and trailer are fitted with refrigerated bodies. Oulu, northern Finland



SOURCE Phil Croucher

Increasingly for loads with a low weight but a high volume, draw-bar combinations are favoured, as they provide a higher cubic capacity for loading within the legal limits (see Figure 29.5). Articulated semi-trailers with two decks may also be used for loads that fall somewhere between the two extremes in terms of weight and volume

Secondary transport involves delivery vehicles making multiple deliveries each day from a depot to large customers. Typical journeys might involve a mixture of motorway and major and minor roads. The specification of vehicles on this duty cycle must also be reasonably high to avoid in-service breakdowns.

Figure 29.5 Close-coupled draw-bar combination



SOURCE Mercedes-Benz Classic

There are a number of similar duty cycles that require trucks to travel relatively short distances in a day. The main example is local delivery work. A vehicle involved in this duty cycle will probably be making a large number of deliveries in a day with lower distances involved. This type of operation tends to be concentrated in urban or city centres, although some of the delivery areas may involve rural settings.

This type of operation often encounters many constraints on vehicle size due to narrow streets, congestion, bans on large trucks, and limitations on access at some delivery points, which requires the use of smaller vehicles. The size constraints, the relatively short distances and the 'stop and start' nature of urban driving will influence vehicle choice for this duty cycle.

As a consequence, the main vehicle type used is a rigid. Increasingly, more operators are using urban articulated combinations for this duty cycle because they offer a higher payload potential with the bonus of being more manoeuvrable than certain rigid vehicles. They also reduce the likelihood of overloading the front axles in a diminishing load situation, i.e. where goods are progressively unloaded from the rear without the load being redistributed, which has the potential for overloading the front axle of a rigid vehicle.

Combination running concerns operations that constitute a mixture of features. A typical example is that of the urban delivery vehicle working out of a regional distribution centre. Such an operation might involve a vehicle making a medium-distance run to a given town or urban area and then making multiple deliveries in that area.

There is a need to balance the requirements of distance travelled and local delivery. A small articulated vehicle, or 'urban artic', may be the most appropriate in this instance.

Multiple deliveries are made by vehicles where the distribution operations are concerned with the handling and delivery of many different types and sizes of commodities and packaging. They are sometimes known as composite delivery operations. Typical examples are haulage contractors that handle and move other companies' produce. Thus, they may have to deliver a wide variety of loads and may have to run short and long distances as well as making single or multiple deliveries. In this case, it is necessary to take account of all the different jobs undertaken and then select multipurpose vehicles that can best cover them all, or provide for a mixed fleet of vehicles.

Quarry, mining and construction work is included as one of the main types of operation because there is a very high movement of sand, gravel, mineral ores, rubbish and other materials to and from construction sites or other facilities. Vehicles that undertake this duty cycle are usually only travelling short distances, but the conditions in which they work are among the worst of all the different types of operation. Many operators choose an eight-wheeled rigid vehicle for this type of work (see Figure 29.6).

International operations also present some particular problems that need to be taken into account. It is likely that all types of terrain may be encountered – flat, hilly and mountainous. Clearly, distances will be very long. In addition, it is important to minimize the likelihood of breakdowns occurring in remote areas where it may be very expensive to complete repairs.

Vehicles undertaking international operations need to be very reliable. Such vehicles tend to represent the expensive end of the goods vehicle market. With the relaxation of trade and political barriers in Europe, North America and other continents, this category of operation has become significantly more important.

As we have seen when vehicles are being selected, many factors need to be taken into consideration before any choices are made. Prior to selecting a specific type of

Figure 29.6 Eight-wheeled rigid tipper vehicle

SOURCE Mercedes-Benz Classic

vehicle, it is worth making a checklist of the requirements that the operation demands. The following list is not exhaustive but does serve to illustrate the potential complexity involved:

- *Product characteristics:*
 - size
 - weight
 - unitization
 - susceptibility to damage
 - hazardous
 - frozen
 - liquid
 - powder
 - hygiene requirements (food)
 - live animals

- *Method of loading or delivery:*
 - by fork-lift truck
 - by manual handling
 - by overhead gantry (height limitations)
 - by straddle carrier (containers)
 - from the side, rear, front, top or bottom (oil tankers)
- *Restrictions at the point of delivery or loading:*
 - narrow roads
 - low bridges
 - weight restrictions
 - night-time restrictions because of noise
 - lack of materials handling equipment
 - low or limited building access
- *Terrain to be covered:*
 - motorways
 - urban roads
 - low-quality rural roads, lanes or graded roads
 - mountainous
 - flat geography
 - extremes of temperature: extreme heat or cold
- *Fuel type:*
 - diesel
 - petrol
 - LPG
 - natural gas (CNG or LNG)
- *Vehicle configuration:*
 - articulated tractor and trailer
 - two-, three- or four-axle rigid vehicle
 - draw-bar combination
 - small goods vehicle
- *Body types:*
 - curtain-sided
 - platform

- skeletal suitable for carrying containers, demountable bodies or swap-bodies
- van bodies
- tankers
- tipping body
- RoadRailers® suitable for use as rail wagons
- bulk carriers
- *Legal requirements:*
 - gross vehicle weight limits
 - vehicle dimensions
 - mandatory equipment
 - vehicle licences
 - insurances
- *Vehicle economy:*
 - fuel consumption
 - tyre wear
 - whole life costs
 - residual values
 - ease of maintenance
 - availability of manufacturer's support and spare parts
- *Drivers' cab types:*
 - sleeper
 - day cab
 - crew carrier
- *Ancillary equipment required:*
 - self-loading cranes
 - blower units
 - hydraulic equipment
 - refrigeration systems
 - fork-lifts carried with the vehicle
 - tail-lifts
 - fire extinguishers
 - load winching systems

- *Vehicle security:*
 - locks
 - alarms
 - sealing devices
 - tracking devices using satellites, GSM or GPS
- *Equipment to reduce environmental impact:*
 - aerodynamic mouldings added to reduce drag on the vehicle (see Figure 29.7)
 - specify speed limiters on all vehicles, not just those with a legal requirement
 - alternative fuels such as dimethyl ether (DME), compressed natural gas (CNG), liquid natural gas (LNG), biodiesel (also known as FAME – fatty acid methyl ester), and so on (see Chapter 42)
 - some truck manufacturers build in a high level of recyclability into their products
 - noise attenuation equipment such as air brake silencers
 - in-cab information systems to avoid wasted vehicle miles/kms
 - to help meet Euro 6 regulations for diesels some manufacturers have fitted selective catalytic reduction (SCR) systems to their vehicles. These systems use diesel exhaust liquid (DEL), which is a mixture of urea (32.5 per cent) and deionized water (67.5 per cent). A common name for this mixture is AdBlue. The liquid is sprayed into the exhaust gases to reduce the production of harmful NOx emissions. The system may be retrofitted to some older vehicles.
 - diesel particulate filters often referred to as ‘particulate traps’ may also be retrofitted to some diesel engine vehicles, although care has to be taken as engine performance could be negatively impacted. These help to reduce the emission of particulate matter (PM), which is a combination of many different substances such as soot and unburnt fuel. In the UK, depending on the specific circumstances, a commercial vehicle retrofitted with a diesel particulate filter might qualify for a reduced pollution certificate (RPC), which has some financial benefits.

This list may appear to be lengthy, but it is by no means exhaustive. These days, vehicle manufacturers are able to use computing power to aid the decision-making process. They can feed the details of vehicle dimensions, weights and terrain into computerized models, which then produce anticipated performance figures for the proposed vehicle. These might include the ability of the vehicle to turn in a given area, potential fuel economy for different-sized engines and driveline combinations and potential axle loading under different load situations.

Figure 29.7 Articulated vehicle with a triaxle trailer equipped with aerodynamic mouldings to reduce drag and thus improve fuel economy



SOURCE Mercedes-Benz Classic

Load types and characteristics

The particular load to be carried is another vital factor to be taken into account when choosing a vehicle. Once again, it is essential to consider the alternatives with the prime objective of selecting the best chassis and the best body suitable for the load. The principal load features are described below.

Light (sometimes referred to as volumetric) loads are those loads that consist of lightweight commodities that are extremely bulky. For example, breakfast cereals or polystyrene products.

The important point is that light loads such as these require a large cubic capacity in relation to the weight of the goods being carried. Often this means that the truck is full before it is in danger of being overweight.

Where light loads are routinely carried it is important not to over-specify other vehicle requirements, as the use of a higher specification vehicle may not be necessary and will be more expensive.

Two additional points concerning the selection of vehicles for light loads are, first, that it is often possible to operate by using a large rigid vehicle coupled with a

draw-bar trailer (see Figure 29.5) and, second, that a double-decked semi-trailer could be used. This increases the volume capability.

Very heavy loads pose problems for vehicle choice because of the gross vehicle weight restrictions on roads and also because of axle weight restrictions. In the UK, vehicles specifically designed to carry loads heavier than the maximum permissible gross weight are covered by the special types general order (STGO) and fall into three categories, with a maximum of 150 tonnes permissible. Some loads are even likely to require special vehicle construction, although special low-loader vehicles are available (see Figure 29.8).

Figure 29.8 Heavy haulage tractor with an indivisible large load



SOURCE Mercedes-Benz Classic

Not all heavy loads are necessarily abnormal loads. For example, machinery that has a total weight within the legal limit can be carried on a standard trailer providing the weight is adequately spread over the axles.

The problem of mixed loads – where quite heavy products are mixed on the same vehicle as quite light ones – would not appear to indicate the likelihood of any constraining factors. The indication is that the mixture of light and heavy products would result in a balanced load where the total weight and the total cubic capacity are both about right for the vehicle, and this is indeed often true.

The problem that can occur, however, arises when a vehicle has to make a number of deliveries on a journey. What can happen is that the removal of parts of the load

can change the spread of weight over the vehicle and thus over the individual axle weights. These changes can mean that the vehicle suddenly has an illegally high weight on one of its axles – this is often referred to as ‘the diminishing load scenario’.

This effect can occur with any load on any delivery vehicle. When there is a mixed load of light and heavy goods, it can be much worse because of the variable spread of the load within the vehicle. Where this effect is likely to be a problem, it is important to select the most appropriate vehicle chassis and body from the outset, so that the problem can be overcome. A simple solution may be to equip the vehicle with a manual pump-up truck designed to move pallets within the vehicle to assist the driver in quickly redistributing the load.

All valuable loads represent some sort of security risk. Vehicle selection must, therefore, take this into account. There may be a need for a special chassis or body construction. It should be appreciated that valuable loads are not just the more obvious ones such as money or jewellery. Many consumer products, when made up into a large vehicle consignment, represent a very high value. Examples include wine and spirits, electrical goods, clothing and so on. Thus, it is very often important to select vehicles that can be easily but securely locked during the course of daily delivery work. There are many anti-theft devices available on the market, including satellite tracking, intruder alarms and immobilizers. Drivers need to be trained to deal with various situations where criminal activities may be a problem (see Chapter 41).

Liquids and powders in bulk have to be carried by road tankers that are specially constructed (see Figure 29.9). In the UK they are subject to construction and use regulations. They may also be subject to other specific regulations such as the Pressure Systems Regulations or Dangerous Goods Regulations (ADR). These regulations are related to the type of commodity that is to be carried. It is also important in vehicle selection to ensure that the correct input and output mechanisms are provided. For example, some products may be handled by gravity alone, while others require a variety of loading and discharging mechanisms for pumping products on to and off the vehicle. These mechanisms can create a lot of noise, so consideration needs to be given to noise attenuation and ear defence for the drivers.

The bulk movement of hazardous goods by road is often carried out by road tanker, so the particular considerations for liquids and powders mentioned above apply automatically. In addition, the fact that hazardous substances are of a high risk means that care must be taken to select the correct material or lining for the tanker so as to avoid any potential chemical reaction. Another point to note is that special fitments may be necessary in order to prevent electrical flashes from the vehicle's engine igniting flammable goods. Some vehicles also need to be equipped with earthing points to neutralize the adverse effects of static electricity. The appropriate Hazchem information plate may also be required.

Figure 29.9 Rigid bulk powder tanker with a draw-bar powder tanker trailer

SOURCE Phil Croucher

Main types of vehicle body

Decisions regarding the selection of the most suitable body type for a vehicle should be based on both the operating and the load requirements. Various body types have particular advantages and disadvantages according to the work to be undertaken and the products to be carried. Nearly all of the different vehicle bodies considered below may be fitted to either a rigid or an articulated vehicle.

A box is an enclosed body that normally has a sliding door at the rear, often known as a box van (see Figure 29.10). As an alternative, some box vans may be fitted with side doors instead of, or as well as, doors at the rear. One common feature is the hydraulic tail-lift. This enables the load to be moved from the vehicle-bed height to the ground mechanically by lowering the tail-lift.

Box vans are by far the most common body type for urban delivery vehicles, especially for those delivering consumer products, food and packaged items. Their advantage lies in the protection to be gained from all types of weather, and also from the reduced risk of pilferage, because they are enclosed and so can be made secure. Increasingly, curtain-sided bodies are being used because of the ability to gain side access to the load if required. Large box vans are also now in very common use for primary transport (trunking or line-haul) operations (see Figure 29.1). The reasons are similar to those given for urban delivery vehicles. This additional popular usage has come about because of the great increase in the use of the wooden pallet as a unit load, and the fact that box vans with reinforced floors can be readily loaded by fork trucks.

The platform or flat-bed is the traditional body type (see Figure 29.11). It consists merely of a wooden or metal floor above the skeletal chassis, with a possible range

Figure 29.10 A 4×2 rigid vehicle equipped with a box body

SOURCE Mercedes-Benz Classic

of heights. It is sometimes fitted with drop sides and rear to help secure the load. It is, of course, uncovered. It is still in common use for many raw materials and products that are unaffected by inclement weather. The majority of loads need to be roped and sheeted: a skilled but time-consuming occupation. It is for this reason that curtain-sided bodies are used more extensively than flat-beds.

The road tanker is another very common vehicle. The tank body can be used to carry a variety of liquids and powders (see Figure 29.9). The different requirements for loading and discharging tankers, and the problems of hazardous goods in terms of selecting the correct material for lining, were indicated previously in this chapter.

The tilt body is a curtain-sided vehicle that broadly consists of a fabric cover over a framework secured to the platform of a lorry. This fabric cover can be drawn together to cover the load completely and is then fixed by lacing or strapping down the length of each side of the vehicle. A cord may be fed through all of the securing buckles and sealed by customs officials.

In appearance, a tilt body is very much like a box van, although the sides of the tilt van are made of a combination of drop sides and flexible curtain fabric (see Figure 29.12). The introduction of the tilt body was to eliminate the need for loads to be roped and sheeted and facilitate faster customs clearance under Transports Internationaux Routiers (TIR) regulations. If the tilt superstructure has to be stripped

Figure 29.11 Platform or flat-bed 6×2 rigid vehicle with drop sides and HIAB crane to assist loading



SOURCE Mercedes-Benz Classic

down to allow loading from above by crane, or even from the side, this can be very time-consuming as compared to the curtain-sided vehicle.

Curtain-sided bodies have become very popular in recent years. They are different from tilt bodies in that they have a rigid roof, and one movable curtain each side of the body (see Figure 29.13). This is a very flexible and effective vehicle body that eliminates roping and sheeting and the problems associated with stripping out tilt bodies.

‘Tipper’ is the description that applies to vehicles that have the capacity to tip loads directly (see Figure 29.14). These can be open-topped bulk carriers or tankers. They are normally worked hydraulically and are used to discharge a variety of bulk materials. Typical loads include grain, gravel, sand, cement and plastic pellets. They may be covered, depending on the particular characteristics of the product carried. The inherent dangers of tipping tankers falling over are being overcome through the introduction of non-tipping tankers that use bottom discharge systems. These vehicles have the added advantage of being able to carry a higher payload (see Figure 29.15).

As previously indicated, the low-loader is used for the carriage of specifically large or heavy loads.

Figure 29.12 Articulated vehicle with a triaxle trailer fitted with a tilt body



SOURCE Mercedes-Benz Classic

Figure 29.13 Curtain-sided trailer giving ease of access for loading



SOURCE Mercedes-Benz Classic

Figure 29.14 Vehicle showing tipping bodies. Note the fact that the vehicle is tipping one container to the side and the other container to the rear of the vehicle



SOURCE Mercedes-Benz Classic

There are several other vehicle bodies used to carry certain types of product. These are basically self-explanatory, but in their construction they do reflect the special needs and requirements of the products concerned (see Figures 29.16 and 29.17). Typical examples are those bodies used for livestock, furniture, hanging garments, transportation of cars, trees and refrigerated products.

The final vehicle body to be considered is also a fairly recent alternative: the demountable box van or body, which is used in a similar way to a standard container. The demountable body can be carried directly on the platform or flat-bed of the vehicle or can be mounted on the skeletal chassis. In direct contrast to the container, however, the body is removed by the use of jacks, which are positioned at each corner of the demountable body and then raised, allowing the vehicle to drive away (see Figure 29.18).

There are a number of ways of removing the body. These may include screw-type jacks, power- or hand-operated hydraulic jacks, electrically operated portable jacks or power-operated lifting equipment fitted to the chassis of the vehicle. Demountable systems provide an increased flexibility to distribution operations by improving vehicle utilization and fleet economy.

Figure 29.15 Triaxle Feldbinder bottom discharge tanker. The discharge pipe may be seen under the middle of the rear bumper bar



SOURCE Mercedes-Benz Classic

Figure 29.16 Eight-wheel rigid vehicle equipped with a cement hopper



SOURCE Mercedes-Benz Classic

Figure 29.17 A post trailer designed to carry trees and logs, Oulu, Finland



SOURCE Phil Croucher

Figure 29.18 Demountable body system



SOURCE Mercedes-Benz Classic

The swap-body is a vehicle body used by intermodal operators. It combines the features of a tilt body but it is detachable like an ISO container. These swap-bodies conform to standard sizes and may be used by both rail wagons and road vehicles (see Chapter 28, 'Rail and intermodal transport').

Figure 29.19 How to get the most from your vehicle: somewhere in sub-Saharan Africa



SOURCE Daimler AG

The wider implications of vehicle selection

There are several additional points that should be considered when choosing a vehicle. Some of these are clearly associated with those factors and features that have already been discussed, some reflect quite clearly the wider implications of vehicle selection, and others show how it is possible to use knowledge and experience to help in decision-making. These associated factors can be summarized as follows.

Is there a proven model or make of vehicle that is known from experience to be good at the job in question? This knowledge may be obtained from looking at other vehicle operating centres and their fleets from within the same company, or it may be available from studying similar types of operation that are undertaken by other companies, or by reference to the trade press.

Also, it may be possible to assess the reliability of certain models and types of engine, as well as other vehicle components, by analysing the history of similar vehicles. Thus, various measures of performance can be produced and studied to give useful data on fuel economy, breakdowns, cost of maintenance and other useful information. Where information is not available from own-company records, it is still possible to use a variety of published data, which is available from the commercial press and other sources. Some companies now use fleet management computer packages to provide this historical information.

In selecting a vehicle, it is important to be aware of the need to undertake maintenance and repairs. If a vehicle operating centre has its own maintenance facilities available then this is not a big problem. The likely difficulties can and do arise for companies that do not have their own facilities and discover that the nearest dealer or maintenance facility with appropriately trained mechanics for their brand of truck is situated at a great distance from the operating centre. With the new levels of vehicle technology, it is becoming increasingly difficult for own-maintenance facilities to justify the investment in the necessary equipment needed to maintain these modern vehicles. Manufacturers' geographical spread and level of support have major implications for vehicle selection and should be carefully studied before a choice is made.

One area that is difficult to cater for, but must nevertheless be borne in mind, is that of likely future transport legislation that might affect the choice of vehicle. There are a number of factors that may be of importance, such as the construction and use regulations, drivers' hours, maximum vehicle weights, environmental issues and new levels of vehicle technology.

Another point concerns drivers: it should be remembered that it is drivers who have to work with the vehicles every day of their working lives. They will understand many of the particular operational problems involved with the work that they have to do, and they will undoubtedly have an opinion on the 'best' type of vehicle from

their point of view. It makes good sense to listen to this viewpoint. At least, it is important to consider the safety and comfort of drivers at work.

The final factor for which allowance must be made is, in many ways, one of the most important. It has been emphasized that there is a need to balance a variety of operational and economic aspects to ensure that the truck is efficiently run. Another vital factor to take into account is that, as well as loading at the distribution centre or warehouse and travelling legally on the roads, the vehicle also has to access the delivery points. Thus, the accessibility at the delivery interface is a very important consideration. It is essential to be able to provide a vehicle that is fit for purpose.

Vehicle acquisition

It has been shown that the process of vehicle selection is one that requires a good deal of thought and analysis to ensure that the most suitable vehicles are acquired. Having determined the vehicle requirements, the next task is to ascertain the most appropriate means of acquiring the vehicle. There are several options available: outright purchase, rental, lease or contract hire. Vehicles may also be acquired by outsourcing the whole operation to a third-party contractor. Indeed, it is often when large numbers of vehicles need to be acquired and large amounts of capital have to be approved that outsourcing is considered.

The traditional means of vehicle acquisition is that of outright purchase. This gives the operator unqualified use and possession, together with the choice of when and how to dispose of the vehicle. Discounts for cash may well be available, and possibly tax allowances for capital purchases. A major problem is likely to be the lack of capital available for purchases of this nature. Other ways of obtaining finance include bank overdrafts, bank loans, hire purchase and lease purchase. These have a clear cost associated with them and in some countries capital expenditure may be set against tax. Investing capital in rapidly depreciating assets such as vehicles rather than in other investments with higher rates of return is a major concern for business managers. This has helped fuel the trend towards outsourcing transport operations to third-party providers.

The leasing of vehicles is a popular alternative. Here, operators do not actually own the vehicles. With fixed-term leasing, operators make regular payments over an agreed period and have full use of the vehicles. The payment covers the cost of borrowing the capital (to purchase the vehicle) and may cover maintenance if required. Finance leasing means that operators cover the full cost of the vehicle over the leasing period and so may be given the option of extending the period of use at a significantly lower lease cost. The main advantages of leasing are that the standing (fixed) cost of vehicles is known and that the company does not use its own capital

to purchase the vehicle; the disadvantage is that operators must keep the vehicles for a prescribed period during which time operational requirements may alter. In addition, accounting practice in the UK (SSAP 21) means that vehicles acquired on finance leases have to be shown in the balance sheet, so the rate of return on capital employed is reduced.

Owing to the changes in accounting practice previously mentioned, the contract hire of vehicles has become a much more attractive option. Contract hire arrangements can vary from the supply of the vehicle alone, through maintenance, insurance and drivers to the provision of a complete distribution service. Thus, there has been a rapid growth in third-party distribution companies offering a range of contract hire services. The financial advantages of contract hire include the release of capital and the easier, more predictable costing of operations.

Vehicles may also be acquired via rental agreements. The vehicle does not become the user's property, but can be operated as required. Agreements may include maintenance and driver. Costs are generally higher than for the other alternatives, but rental periods are often very short-term, allowing the user greater flexibility, particularly providing the means to accommodate temporary peaks of demand. Costs are predictable and can be treated as variable for specific jobs.

Road freight transport: vehicle costing

30

Introduction

In this chapter detailed consideration is given to the key aspects of road freight transport costing, which are essential to the effective running of a fleet of road vehicles. The chapter begins with a discussion of the reason that road vehicle costs need to be assessed separately from the costs found in most companies' annual financial accounts. The fundamental elements of road freight transport costing are reviewed, showing how these costs should be considered and what can be gained from this type of information. The importance of the detailed and accurate measurement of vehicle and fleet costs and performance is emphasized, as is the need to determine this information in good time.

The major vehicle costs are categorized as standing costs, running costs and overhead costs. The detailed make-up of these costs is explained and examples show how these costs are calculated. All of this information is drawn together to demonstrate how the total transport operation is costed.

The concepts of whole life costing and zero-based budgets are explained. Direct product profitability (DPP) activity-based costs are also described. Some simple comparisons of different vehicle costs demonstrate the relative importance of the different types of transport cost, and show how this cost relationship can vary according to the size of vehicle.

Why use road freight transport vehicle costing?

At the end of every company's financial year, the company has to produce a number of financial statements that show how well or how badly it has performed during that year. One of these is known as a profit and loss (P&L) statement. This statement is useful in a broad context because it can show whether or not the company has performed satisfactorily. It may also be possible to ascertain a good picture of the

overall performance of the company's transport operation for that year from this information, but it does not provide a detailed account of exactly where any profit or loss is made within the operation itself. In short, it fails to give sufficient details of each vehicle and its operation to enable appropriate control of the transport fleet.

There is another problem. The final P&L statement is produced after the financial year has ended. Because of this, it is too late for management to make any effective changes to the transport operation if the results show that its performance is not acceptable. The P&L statement, therefore, fails to provide its information in sufficient time for any useful changes to be made.

In summary, there are two main reasons why a special form of cost reporting is beneficial to a manager running a transport operation. These are: 1) the need to know the details of the vehicle and fleet performance in order to control the operations; and 2) the need to know in sufficient time to make any necessary changes. Outlined in the following box is one example of how such a reporting system can be used for the monitoring and control of transport operations.

EXAMPLE How a monitoring and control system for a road freight transport operation can be used

A weekly system of reports for every vehicle in a fleet can show, among other things, the distance that each vehicle has travelled and how much money has been paid out for fuel for this vehicle. For many weeks the fuel costs for one particular vehicle are very similar week on week. In the most recent week, however, the fuel cost increases considerably. This should raise a number of questions in the mind of the transport manager. What has caused this cost increase? Is it significant? What can be done about it?

There are a number of reasons why this might have happened:

- The cost of fuel might have increased.
- The vehicle might have travelled above average miles/kilometres in this week and so used more fuel.
- The vehicle might not be performing properly, so its fuel consumption per mile/kilometre has increased.
- Figures have been incorrectly recorded.
- Fuel is being stolen.

It is important to know the real reason for this increase, so that any problem can be corrected. In this example, it might be found that:

- The cost of fuel has not changed.
- The vehicle distance has not altered – the vehicle has not run significantly more miles/kilometres than usual.
- A check shows that figures have been recorded correctly.
- Measuring the amount of fuel used against the mileage travelled (which gives the vehicle miles per gallon/kilometres per litre) shows that the vehicle is travelling fewer miles/kilometres per gallon/litre than in previous weeks.

It can be concluded that the reason for the increase in the money paid out for fuel is neither a rise in the cost of fuel nor an increase in miles travelled by the vehicle. It is because there is a fault with the vehicle or with the driver's behaviour – the vehicle is not operating cost-effectively. With this knowledge, the necessary steps can be put in motion to remedy the problem.

This example demonstrates how useful an efficient costing system can be. In particular, it illustrates four important aspects of a good costing system:

- 1 To be able to identify that something is wrong.
- 2 To get this information in good time.
- 3 To be able to identify what the problem is.
- 4 From this information, to be able to take some form of remedial action and solve the problem.

This example has shown one major reason for developing a good transport costing system – to make effective use of and keep adequate control over transport resources. Another important use for a costing system concerns the need to ensure that customers are being charged a sufficient price to cover the cost of the transport provided. This is clearly important for third-party contract operations. This type of costing system allows for costs to be budgeted in order to be able to determine an adequate rate at which to charge for the use of vehicles. For own-account fleets, this will enable a company to determine an appropriate cost to add to the price of the product or order to ensure that all own-transport costs are covered.

Two key aspects of a good costing system have thus been identified:

- 1 the recording of actual costs and performance in order to monitor and control the transport operation
- 2 the measuring of costs to identify the amount that will cover costs and budget for a job

Road transport costing: key information required

Both of these key aspects of a good costing system, identified above, require the detailed collection of the same information – the resources that are used in the transport operation. The types of transport resources that need to be considered can be classified as the ‘5 Ms’. They are:

- manpower: the drivers of the vehicles
- machinery: the vehicles themselves
- materials: associated resources, such as tyres, fuel, etc
- money: the respective costs of the resources
- minutes: the time when these resources are used for different purposes

In order to be able to understand how costing systems are developed and used, it is important to know the common costing terminology that is used in transport. The main cost categorizations in a transport costing system are:

- Cost unit: this is a unit of quantity in which costs may be derived or expressed. Examples include: cost per distance travelled (miles/kilometres run), cost per tonne per mile, cost per carton delivered.
- Cost centre: this is a piece of equipment, location or person against which costs are charged. Examples include: a vehicle, a fleet of vehicles, a driver, a depot.
- Direct cost: this is a cost that is directly attributable to a cost centre. For example, if a vehicle is a cost centre, then direct costs would include: fuel, the vehicle road licence, vehicle insurance.
- Indirect costs: these are the general costs that result from running a business. They are also referred to as overhead costs, administrative costs or establishment costs. These costs have to be absorbed or covered in the rates charged to the customer. Thus, they need to be spread fairly among the vehicles in the fleet. Examples include: office staff wages; telephone, computing and other office charges.
- Fixed costs: these refer to the cost centre itself (i.e. the vehicle). These costs will not vary over a fairly long period of time (say, a year) and they are not affected by the activity of the vehicle, i.e. the distance that the vehicle runs over this period. They are very often, in transport, referred to as standing costs. Examples include: depreciation of the purchase cost of the vehicle, Vehicle Excise Duty (a tax levied on vehicles in the UK for access to the road network), vehicle insurance.
- Variable costs: these are the opposite of fixed costs in that a variable cost varies with respect to the distance that the vehicle travels. Thus, it varies according to the amount of work that the vehicle undertakes. It is sometimes known as the running cost. Examples include: fuel, tyres, maintenance.

It should be noted that some cost factors can be defined as direct costs and then classified once again as either fixed or variable costs. In the examples above, fuel is both a direct cost (it is directly attributable to the vehicle as its cost centre) and a variable cost (the amount used varies according to the distance that the vehicle travels).

Transport costs are broken down into three main types, and each of these will be considered in detail in the remainder of this chapter. These types are:

- vehicle standing or fixed costs
- vehicle running or variable costs
- overhead costs

Vehicle standing costs

In this section, consideration is given to the different resources that are included as vehicle standing costs or fixed costs. Each of these resources must be paid for, regardless of the extent to which the vehicle is used. Thus, these resources are a cost that must be borne whether the vehicle is run for five or for 500 miles in any working week. Fixed costs, therefore, remain the same, independent of the level of activity.

The key vehicle standing or fixed costs are now discussed. They are:

- depreciation
- tax and licences
- vehicle insurance
- driver's minimum guaranteed wages
- interest on capital

A vehicle is an expensive piece of equipment that in most companies is expected to have a useful and reliable life of about five to eight years. The working life of a vehicle is, however, dependent on the type of job that it has to do. A local delivery vehicle may carry relatively light loads and travel only 40,000 miles in a year. A long-distance primary (line-haul) vehicle may be pulling heavy loads and may be running for 80,000 miles per year or more.

Whatever the working life of the vehicle, it is necessary to take account of the original purchase cost over the period of its expected useful life. One reason for this is so that appropriate costs can be recovered for the service that the vehicle performs. Failure to do this might affect the ability to run a profitable operation.

The method of taking account of the original purchase cost of a vehicle is known as *depreciation*. This is a means of charging the P&L annually a proportion of the original purchase cost of a vehicle over its expected lifetime. This is often referred to as 'writing down' the fixed asset. There are a number of different methods used for

calculating depreciation, the two main ones being the straight-line method and the reducing balance method.

The straight-line method of depreciation

The straight-line method of depreciation is the simplest method of assessing the annual apportionment of the original purchase cost of a vehicle. It requires three figures:

- the initial purchase cost of the vehicle (usually, but not always, less tyres, which are then treated as a running cost rather than a capital cost)
- the anticipated resale or residual value of the vehicle (i.e. the amount for which the vehicle might be sold at the end of its expected useful life – often set at about 10 per cent of the original cost of the vehicle)
- the expected operational life of the vehicle in years

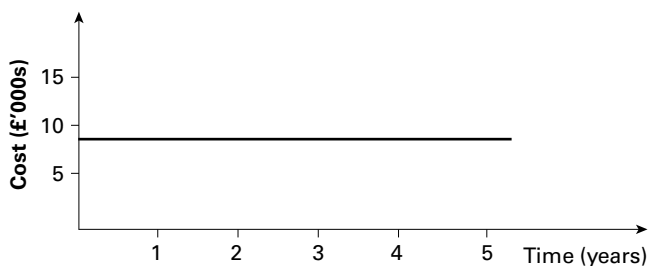
The annual depreciation of the vehicle is calculated by subtracting the residual value of the vehicle from its initial purchase price, and then dividing the result by the expected operational life of the vehicle.

Example:

	£
Purchase price of vehicle	53,000
Less cost of tyres	3,000
	50,000
Less anticipated residual value	5,000
	£45,000
Expected vehicle life = 5 years	
Annual depreciation	£9,000
(£45,000 divided by 5 years)	

This is illustrated graphically in Figure 30.1.

Figure 30.1 Depreciation: straight-line method



The reducing balance method of depreciation

The reducing balance method is slightly more complicated, but probably more realistic. The method assumes that depreciation is greater in the early years of a vehicle's life and becomes less severe in later years. This approach reflects the fact that assets lose a greater proportion of their value in their early years and also mirrors the fact that repairs associated with a vehicle's early life tend to be few and inexpensive, but tend to increase as the vehicle gets older.

The principle for the reducing balance method is to write down the vehicle to its expected residual value at the end of its operational life. This is calculated by reducing the value of the asset by an equal percentage each year. The same data requirements are needed as for the straight-line method.

Example:

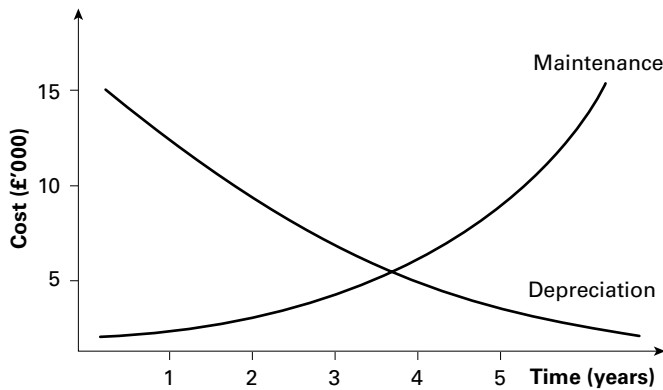
£50,000 to be written down at 36 per cent per annum.

	£
Initial value	50,000
Year 1 @ 36%	18,000
Written-down value	32,000
Year 2 @ 36%	11,520
Written-down value	20,480
Year 3 @ 36%	7,373
Written-down value	13,107
Year 4 @ 36%	4,718
Written-down value	8,389
Year 5 @ 36%	3,020
Residual value	£5,369

This is shown graphically in Figure 30.2. This figure also shows the relationship of the reducing balance method of depreciation with maintenance costs over time. Note that repair and maintenance costs normally increase dramatically in the latter end of a vehicle's life – often a strong indication that an old vehicle should be replaced by a new one.

There are a several different types of *tax and licences* that need to be costed against a vehicle. The main ones are:

- 1 Vehicle Excise Duty, which is based on the 'revenue weight' of the vehicle or tractive unit (e.g. in the UK, the confirmed maximum weight, which for plated vehicles is the permissible gross or train weight shown on the DfT plate).
- 2 The operator's licence: an indirect cost for the whole fleet, plus a cost per vehicle. (In the UK the operator's licence is a legal requirement for a transport operator running a business.)

Figure 30.2 The reducing balance method of depreciation

- 3 The driver's licence required for individual drivers: if paid for by the company.
- 4 The cost of training for the driver licence to drive large goods vehicles (where applicable): this is required for individual drivers (in the UK: the *Certificate of Professional Competence*).
- 5 Travel charges: these include such costs as congestion charges and toll charges for tunnels, bridges and roads.

The cost of *vehicle insurance* is also a fixed or standing cost. The actual amounts can vary for a number of reasons, such as:

- the area or region of operation
- the number of vehicles in the fleet (i.e. a discount might be available for a large fleet)
- the type of loads carried
- the value of the products carried
- the accident history
- the driver's age
- the excess paid by the company (e.g. the first £500 paid by the insured and not the insurance company on each transport-related insurance claim)

The sources for these costs are from company records or directly from an insurance broker.

Most companies treat *drivers' basic wages* as a fixed cost because they are payable regardless of whether or not a driver is actually 'on the road'. In addition to basic wages, allowances must be made for National Insurance contributions, holiday pay and pensions (where applicable). Although basic wages are treated as a fixed cost,

any additions, such as overnight subsistence, incentive bonuses and overtime, are classified as a running (or variable) cost, because they vary in relation to the amount of work that is done. Wages and other related costs can be found from payroll records.

An allowance for *interest on capital* is frequently omitted from cost calculations, being included, in the main, when assessing the overall performance of the company. It is an allowance that indicates one of two possibilities: either the cost of borrowing money (that is, the interest repayable on a loan used to purchase a vehicle); or the lost opportunity cost of forgoing the profitable use of a company's own capital (that is, the potential that is lost because the capital is used by the company to purchase a vehicle and therefore cannot be invested more profitably elsewhere).

Because each individual vehicle is treated as a cost centre, the 'interest' can be included as a standing cost. This cost should be related to the rate at which the company can borrow money or the rate at which it did borrow money to purchase certain vehicles.

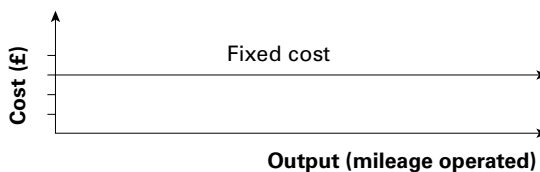
Vehicle standing costs are summarized in Figure 30.3.

Figure 30.3 Vehicle standing (fixed) costs

Fixed costs do not change with the level of activity. They accrue on a time basis rather than with the activity level. 'The costs incurred in having a vehicle standing ready and available for work in the depot yard.'

Fixed costs include:

- licences: driver's licence; vehicle excise duty; operator's licence
- vehicle insurance
- drivers' costs: wages; National Insurance contributions; pensions; holiday pay; etc
- vehicle depreciation
- notional interest



Vehicle running costs

This section concentrates on the second major category of transport costs – vehicle running or variable costs. A variable cost is said to vary in relation to the activity of the particular asset with which it is concerned. The cost centre for a transport operation is the vehicle. The activity of the vehicle is the amount that it is used, which is the same as the distance that it travels. Thus, we can see that the running cost is directly related to, and can be measured by, the distance covered by the vehicle.

Vehicle standing costs were defined as the fixed costs that had to be accounted for before a vehicle could be used 'on the road'. Vehicle running costs are the virtual opposite, being the costs that are incurred as a result of the vehicle being used on the road.

The key vehicle running or variable costs are now discussed. They are:

- fuel
- oil and lubricants
- tyres
- repairs and maintenance
- drivers' overtime, bonus and subsistence

The cost of *fuel* is normally the largest of all the variable or running costs. There are two reasons why fuel is a particularly significant cost: first because of the high fuel consumption of commercial vehicles (i.e. low miles/kilometres per litre); and second because of the constant rise in energy costs due to periodic shortages and heavy taxation. Because the cost of fuel is such a significant portion of running costs, it is important that its usage is regularly monitored. Excess use of fuel can be the result of a number of factors, such as:

- fuel leaks
- a worn engine
- poor vehicle maintenance, i.e. binding brakes
- under-inflated tyres
- poor aerodynamics
- bad driving
- theft of fuel

Running costs are related to an activity (i.e. the distance, in miles or kilometres, that a vehicle travels), so they are generally measured in pence per mile or pence per kilometre.

Example:

Price of diesel = 145 pence per litre

Vehicle's average number of miles per litre = 2 miles per litre

Cost of fuel, in pence per litre: $145/2 = 72.5$ pence per mile

The use of engine *oil and lubricants* is a very small variable cost. It is important to be able to measure usage, however, because high consumption may be a pointer to some mechanical problem. The costs of oil should also be measured in pence per mile (e.g. 0.5 pence per mile).

Tyres are classified as a running cost because tyre usage is directly linked to the distance the vehicle travels. Tyre usage is recorded as a variable cost in pence per mile as follows.

Example:

6×4 drive-train tractor

Cost of tyres	£500 each
Estimated tyre life	40,000 miles each
Total cost of tyres:	
(10 × £500)	£5,000
Tyre cost per mile:	
£5,000 × 100	
40,000 miles	= 12.5 pence per mile

Repairs and maintenance costs (including spare parts) tend to be the second highest of the variable costs and are again related to distance, because vehicles are (or should be) regularly maintained after a given number of miles/kilometres (e.g. every 6,000 miles). There are three principal factors that make up these costs: labour (fitters, mechanics, supervisors, etc); spare parts; workshop or garage premises.

Records should be kept for each vehicle in respect of the work that is done. This is a legal requirement in the UK. Other information sources include mechanics' time sheets, suppliers' invoices, parts requisitions, vehicle defect reports, etc. Costs are again in pence per mile/kilometre. Many companies now outsource their repair and maintenance operations to third-party transport companies that specialize in vehicle maintenance.

Drivers' overtime, bonus and subsistence costs are also included as running costs. As indicated in the section 'Vehicle standing costs', these are the costs that are associated with drivers but are variable or running costs.

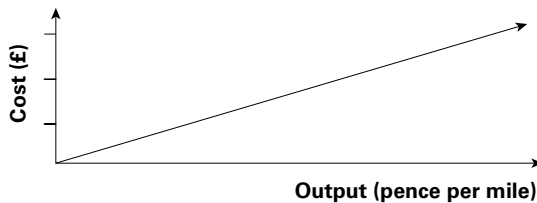
Vehicle running costs are summarized in Figure 30.4.

Figure 30.4 Vehicle running (variable) costs

Variable costs vary with the level of activity or output. When there is no output there are no variable costs.

Variable costs include:

- fuel
- oil and lubricants
- tyre wear
- drivers' overtime, subsistence and other expenses
- repairs and maintenance



Overhead costs

The two cost elements considered in the previous sections, vehicle standing costs and vehicle running costs could both be classified as direct costs that relate directly to an individual vehicle. Vehicle overhead costs are indirect costs because they do not relate directly to an individual vehicle but are costs that are borne by the whole fleet of vehicles. There are fleet overheads and business overheads.

Fleet overheads consist of the costs of all the 'back-up' or 'reserve' equipment and labour required to run an efficient fleet of vehicles. As such, they cannot be costed directly to a particular vehicle. The main resources are spare vehicles and trailers, hired equipment and temporary (agency) drivers. These are over and above what are called the 'on-the-road' requirements. The spare equipment is necessary to cover for the other vehicles as they are repaired or maintained, or if there is a breakdown. The temporary (agency) drivers are necessary to cover for holidays and sickness during the year. These 'spares' are apportioned by taking the total cost over a period (e.g. a year) and then dividing by the number of vehicles in the fleet.

Business overheads can be subdivided into transport department and company administrative overheads. Transport department overheads consist of the charges and costs that are clearly concerned with the transport department but cannot be directly related to any one vehicle (e.g. salaries and wages for managers and vehicle schedulers, company cars and expenses, telephone, email and computing, rent and rates, utilities, such as electricity and water, and training). Company administrative overheads are those costs that are central to the running of a business and that have to be apportioned between all the different company departments. They include, for example, directors' fees, legal fees, bad debts and bank charges.

Costing the total transport operation

This section draws all the previous information together, so that it is possible to determine how to cost the total transport operation. The first step that must be taken is to estimate the likely vehicle utilization. This is essential so that vehicle costs can be divided according to the activity of the vehicle. The estimate should be based on the history of vehicle usage and on any likely increase or decrease in this usage that might be foreseen.

For a transport operation, there are two areas of utilization that need to be determined. These are for days worked in the year and distance driven per year. Days worked can provide the basis for covering vehicle standing cost, and distance travelled can be used for assessing vehicle running cost. Historical data will indicate what the figures might be.

EXAMPLE Total transport operation costing

Number of working days per year,
eg 52 weeks $\times$ 5 days = 260 days/year
Estimated annual mileage = 80,000 miles

It is possible to determine the costs for the three main cost elements, as the following calculations illustrate:

Standing cost

Annual standing cost = £9,000

Therefore, $\frac{£9,000}{260 \text{ days}} = £34.62 \text{ per day}$ or $\frac{£9,000}{80,000 \text{ miles}} = 11.25 \text{ pence per mile}$

So the standing cost can be expressed on a daily basis or on an average distance (miles/kilometres) basis.

Running cost (pence per mile/kilometre)

Fuel	20.0
Oil and lubricants	0.5
Tyres	4.0
Repairs and maintenance	6.0
Total	<u>30.5</u>

Running costs should be calculated on an average distance (miles/kilometres) basis.

Overhead cost

Apportioned vehicle overhead = £1,200

Therefore, $\frac{£1,200}{260 \text{ days}} = £4.62 \text{ per day}$ or $\frac{£1,200}{80,000 \text{ miles}} = 1.5 \text{ pence per mile}$

As with the standing cost, the vehicle overhead cost can be expressed on a daily basis or an average mileage basis. With this breakdown of costs, it is possible to derive in detail the costs of different elements of the delivery operation that is being undertaken. If this is achieved, accurate and realistic charges can then be made to customers to ensure that transport costs are adequately covered. If vehicles are allocated as a whole to a particular operation, it is easy to identify the appropriate standing, running and overhead costs and to make the necessary charges or allowances.

Where vehicles are multi-user, and deliveries are made for a number of different customers, a further breakdown is required to reflect the extent of usage by the different customers. This is likely to be related to the number of cartons that are moved (or pallets, kilogrammes or cubic metres, depending on the measurement in use) and to the number of deliveries (drops) that are undertaken.

Whole life costing

This approach to assessing the cost of owning and operating an asset has become accepted as a particularly good way of identifying the true cost of a vehicle. It is especially useful when trying to compare quotations from different companies. In this section, whole life costing is considered in the context of commercial vehicle acquisition and operation.

The idea is to include in the analysis all the cost elements that are involved in a vehicle's life, or at least that part of its life when it is owned by a particular organization. The major cost elements are:

- 1 the initial purchase price of the vehicle
- 2 *plus* the total operating costs incurred by that vehicle during its life, i.e. maintenance, tyres and fuel
- 3 *less* the achieved/guaranteed residual value of the vehicle

One obvious problem is that some of these figures will not be available until after the vehicle has been sold. This is true where companies purchase their vehicles outright and then manage them throughout their life until disposal. If these same companies change their vehicles every three years, whole life costing provides them with a valuable way of comparing not only how different makes of truck perform but also how different configurations of engine and drive-train perform. This can be invaluable when the time comes to make decisions about replacement vehicles. Armed with information such as fuel consumption and cost over a given distance, cost of repair and maintenance and the value placed on this type of vehicle by the second-hand market, a transport manager can make discerning judgements about which trucks best suit the operation.

Before the adoption of whole life costing, decisions about truck purchase tended to concentrate solely on the initial purchase price of the vehicle. By looking at the costs incurred throughout the life of the vehicle it may emerge that it is better to pay a higher purchase price for the vehicle at the outset, as the achieved economies in operating costs more than compensate for the initial extra outlay.

Manufacturers are now offering whole life packages to commercial vehicle operators. This involves a purchase price, a cost for maintenance over a given mileage and a guaranteed residual value in the form of a buy-back price. Therefore, it becomes possible for a potential purchaser to make a whole life comparison between manufacturers' offerings before the choice is made. Of course, this will not include the performance on fuel consumption.

Information about achieved fuel performance may be obtained from the trade press, which often conducts vehicle road tests and publishes the results. Another good way of gaining a view about fuel economy is to ask the manufacturer for a demonstration vehicle that can be tested on the company's operations for a couple of weeks. This will provide useful practical information to aid decision-making.

When making comparisons between different manufacturers' quotations, a further sophistication may be introduced. This is to create a discounted cash flow (DCF) for each of the quotes. This is especially useful when pence-per-mile figures are quoted over different total distances, purchase prices are different and residual values are also different. It becomes very confusing to try to gain a true picture of which offering is the best, unless systematically laid out in a DCF. The discount factor is applied to each successive year's figures in order to represent the decline in the real value of money over time. By calculating a net present value (NPV) for each quotation, comparison becomes much easier. It is not absolutely essential that a discount factor is used, because when the costs are laid out in this way a straightforward addition will allow the quotes to be ranked in order of best value. The advantage of the NPV is that it provides a more accurate picture of the whole life cost of each quotation in today's money.

Table 30.1 demonstrates what a practical example will look like. The vehicles being purchased are 6×2 articulated tractive units, which will be operated on a 24-hour basis at maximum gross vehicle weight. The life of the vehicles will be four years at 120,000 miles per annum. The manufacturer offered maintenance either on the basis of a fixed price, which is described as inflation-proof, or on an annual review basis. In order to make allowance for this it has been assumed that an annual review would involve approximately a 3 per cent increase each year. It is worth noting that the guaranteed residual value is very generous because this manufacturer was attempting to increase its market share at the time. The resultant NPV appears to be better for the inflation-proof option but there is very little in it and the 3 per cent annual review figures are speculative. One very important aspect of this deal is that the guaranteed buy-back price is not only generous but it also insulates the operator from the vagaries of the second-hand truck market by transferring the risk to the manufacturer. When five or six of these DCF calculations are placed side by side for comparison, it is a powerful way of judging which deal is the best.

Table 30.1 A practical example of whole life costing

	Purchase Price of Vehicle	Inflation-proof Maintenance	Annual Review 3%	10% Discount Factor	Inflation- proof Option Result	Annual Review Option Result
	£	£	£	£	£	£
Year 0	68,362.00	0.00	0.00	0	68,362	68,362
Year 1		3,515.04	3,515.04	0.909	3,195	3,195
Year 2		3,515.04	3,620.49	0.826	2,903	2,991
Year 3		3,515.04	3,729.11	0.751	2,640	2,801
Year 4		3,515.04	3,840.98	0.683	2,401	2,623
					79,501	79,972
Less residual value	18,780.00			0.683	12,827	12,827
				NPV	£66,674	£67,145

NB Vehicle life is four years at 120,000 miles per annum

Whole life costing is widely used, not only in the field of commercial vehicles but also in the field of company car fleet-management, because it is such a reliable indicator of the true cost of ownership.

Vehicle cost comparisons

It is important to be aware of the relative importance of the different elements of vehicle costs. This can be illustrated by the consideration of a typical heavy goods vehicle, in this instance a 44-tonne GVW articulated tractor and trailer. Figure 30.5 demonstrates that the driver costs, at about 25 per cent, and the fuel costs, at about 37 per cent, are by far the most significant costs for such a vehicle averaging about 85,000 miles per year.

Figure 30.5 A comparison of vehicle costs, emphasizing the difference in importance of some of the main road freight vehicle costs

Standing costs	£pa	%	Running costs	£pa	%
Vehicle Excise Duty	1,200	1.0	Fuel	46,283	37.2
Insurance	3,408	2.7	Tyres	3,020	2.4
Depreciation – tractor	10,515	8.4	Maintenance – tractor	6,366	5.1
Depreciation – trailer	2,249	1.8	Maintenance – trailer	3,571	2.9
subtotal	17,372	14.0	subtotal	59,240	47.6
Driver	31,471	25.3			
			Overhead costs		
			Transport	8,196	6.6
			Business	8,196	6.6
			subtotal	16,392	13.2
Total	£pa	pence per mile			
	124,475	1.46			

It is also important to be aware that these comparative relationships may well change according to the type and size of vehicle. In a second example, a comparison is made between a large articulated vehicle and a smaller 7.5-tonne vehicle. Here, the relative importance of the driver of the vehicle, in cost terms, is much higher for the smaller vehicle (39.6 per cent) than the larger vehicle (25.3 per cent), while the running costs are much lower (30 per cent compared to 47.6 per cent). This is shown in Table 30.2.

Table 30.2 Typical operating cost breakdown showing the relative cost difference for two different vehicle types

	Percentage Breakdown	
	7.5-tonne	44-tonne
Depreciation	10.0%	10.3%
Driver	39.6%	25.3%
Running (fuel, oil, tyres, and repairs and maintenance)	30.0%	47.6%
Licence/insurance and overheads	20.4%	16.9%

Zero-based budgets

In most companies, part of the annual cycle is to prepare the next year's operating budgets. Very often this is nothing more than an exercise by which last year's budgets are increased incrementally, usually by the rate of inflation. For most operations, this approach will produce a workable budget, but where questions about cost-effectiveness have been asked, then another approach may be required. One such approach is known as zero budgeting.

This form of analysis requires a return to first principles. It is almost as though the operation had never existed and is being planned for the first time, hence the name 'zero' or back to the starting point. Each element of the operating budget must be analysed line by line. For example, the cost of fuel will be calculated by examining the fuel consumption of the different types of vehicle in the fleet according to the manufacturers' technical figures, which will be divided into the annual mileages for this type of vehicle and finally multiplied by the cost of fuel.

Example:

38-tonne GVW 4x2 tractor should achieve, say, 8.5 miles per gallon

There are six similar vehicles in this fleet

Their combined annual mileage is 480,000 miles

The current cost of fuel is, say, £6.50 per gallon

$480,000 \text{ miles} / 8.5 \text{ miles per gallon} = 56,471 \text{ gallons} \times £6.50 = £367,061.50 \text{ pa}$

This process will have to be repeated for all the different types of vehicle in the fleet in order to achieve the final budgetary figure. Unless the operation is already in excellent shape, the chances are that the figure arrived at will be less than the current cost of fuel used. This is because part of the process entails using the best possible achievable figures such as the manufacturers' fuel consumption figures or the best bunkered price for fuel.

The object of the exercise is, first, to have managers take a fresh look at their operations. Second, because the best possible figures are used to formulate the budget, it highlights areas for improvement. Perhaps the drivers are not achieving the best fuel consumption achievable and require training? Maybe more can be done to achieve a better price for the fuel used?

The exercise will cause managers to ask many uncomfortable questions about their area of responsibility. Some will find this so uncomfortable that they will simply attempt to replicate the current system by using their current fuel consumption figures and fuel purchase prices. This should be avoided, as the best results accrue from an honest line-by-line re-evaluation of the operating budget. If diligently undertaken, the resultant budget can be accompanied by a number of action points that will serve to improve the overall operational cost-effectiveness of a road transport fleet.

Direct product profitability

As indicated in Chapter 2, direct product profitability (DPP) is a technique of allocating all of the appropriate supply costs and allowances to a given product, rather than using average costs, which is the approach adopted in standard budgetary procedures as previously described in this chapter. This is not a criticism of the budgetary approach. DPP is used under different circumstances, with different objectives.

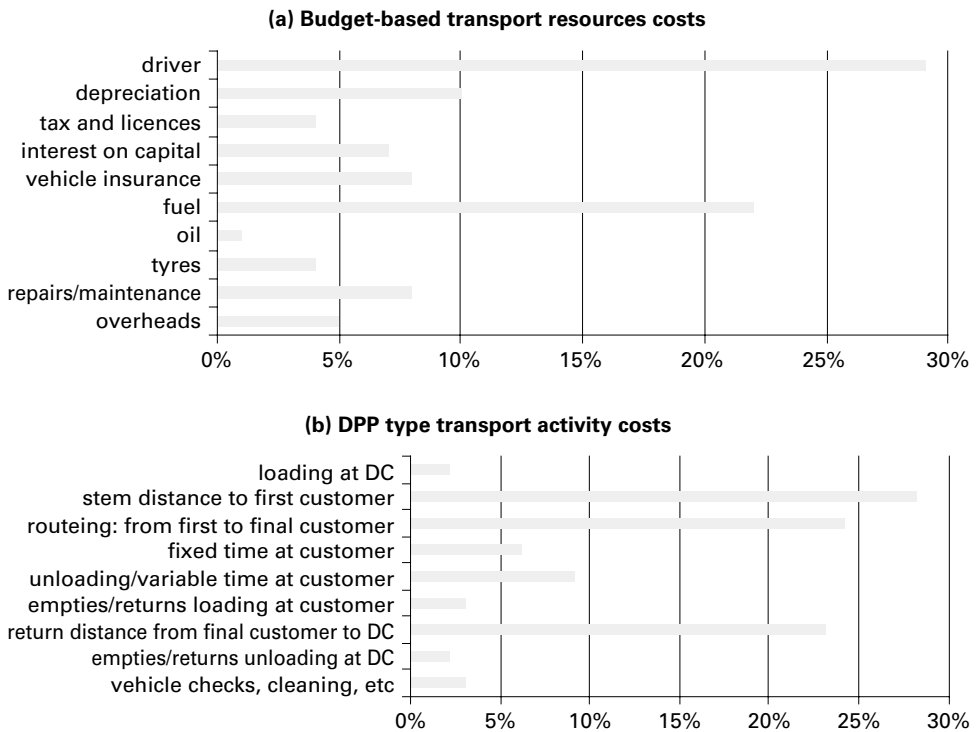
Budget-based costs are used in all businesses, are continually reported and so are often the 'best' costs immediately available for detailed costing purposes. DPP-type activity costs are not normally reported via classical costing systems, but they give a much more appropriate cost at the detailed product and customer level.

DPP is thus an activity-based system where costs are allocated according to the actual activity that is used in the logistics process to enable a product to reach its market/customer. DPP is, for example, used in retailing, particularly in the grocery industry, to measure a product's actual handling and transport costs from the time it arrives at the distribution depot to the time it is delivered to a customer or store. DPP takes into account every aspect of a product's cost: receiving, moving to storage, storage, picking, checking, loading, delivery and paperwork. DPP can help improve retail store profitability by identifying all of the costs associated with a particular product. Unprofitable products can be highlighted and reduced or withdrawn, while profitable ones can be given additional shelf space for direct promotion.

In the same way that a budgetary system operates, the actual costs of distributing a product are monitored and compared to a standard cost determined using DPP rather than a budget-based average across all products. In this way, areas of inefficiency related to individual products can be identified. Products are viewed as 'consuming' logistics resources in differing ways. For example, if a product is a non-standard size it may require different handling systems or 'consume' more transport space due to its odd shape.

DPP can also be used to identify high-cost logistics elements for a given product so that some logistics operations and processes can be streamlined or altered to improve effectiveness. DPP techniques can identify the costs of specific products to individual customers and so provide invaluable information for effective marketing and pricing strategies.

The two different approaches are illustrated in Figure 30.6. This shows how delivery transport costs are represented in a budget-based system compared to how they can be represented in an activity-based DPP system.

Figure 30.6 Comparison of budget-based and activity-based delivery transport costs

See Chapters 38 and 39 for alternative methods of collecting and measuring transport and logistics costs.

Road freight transport: planning and resourcing

31

Introduction

The emphasis of this chapter is on the means of planning and resourcing for road freight transport. The key planning aspects are discussed in the first section.

Road freight transport operations can be broken down into two main types – primary transport and secondary transport. It is noted that primary transport operations are commonly single delivery (sometimes called ‘single-drop’) journeys and the focus is usually one of cost reduction. Secondary transport operations generally involve multiple delivery (sometimes called ‘multi-drop’) journeys and are ‘customer-facing’ and can therefore be an important part of the customer service element of logistics strategy. Thus, customer service rather than cost is the major criterion for secondary transport operations, although cost remains important.

It is also shown that road freight transport resources need to be assessed from two different aspects – planning and operational. Planning is where the basic resource requirements for transport are determined by the identification of the appropriate number and type of vehicles and drivers that are needed for the fleet to undertake an operation in the medium or long term. Operational is where the aim is to maximize the utilization and effectiveness of existing resources on a daily basis. However, both of these objectives can be achieved using the same method, which is by vehicle routeing and scheduling either manually or using a computer package. Vehicle routeing and scheduling is discussed in detail in Chapter 32.

High vehicle and fleet utilization are fundamental to successful road freight transport planning and operations. Different ways of measuring vehicle utilization are reviewed and the problems that cause poor vehicle utilization or make it difficult to introduce improvements are identified. Various approaches that can be pursued in order to raise vehicle utilization levels are discussed.

Various fleet management information systems are outlined. These are aimed specifically at assisting the transport manager to monitor, control and administer fleet operations. Finally, the main developments and uses of vehicle telematics in road freight transport are outlined.

Key planning areas for road freight transport

There are some very specific areas for planning and managing road freight transport operations. As has been discussed in previous chapters, one of the real keys to creating an effective logistics operation is to get the right balance between customer service and costs and this also applies when considering the transport component of logistics. For road freight transport, some of the key planning elements include:

- **Assets:** road freight transport fleets consist of some very high-value assets, ranging from the tractors, trailers and rigid vehicles themselves to the drivers who operate the vehicles. It is important that these assets, particularly the vehicles, are worked to their maximum. This can be achieved through the development of efficient schedules that keep the vehicles and drivers on the road and active, and through the introduction of double- and treble-shifting of vehicles, which maximizes their use. Computer routeing and scheduling packages play a major role in helping to identify the most appropriate vehicles that make up the fleet and also in using these chosen vehicles most effectively. A discussion of the key characteristics of routeing and scheduling is therefore very important, and this is provided in Chapter 32. In addition, fleet management packages offer real opportunities to monitor very closely the costs and utilization of these assets. Both vehicle time utilization and vehicle space (or load) utilization are important considerations for road freight transport.
- **Service:** delivery transport acts as the main physical interface with the customer, so it is important that all customer service requirements are met. For transport, important requirements involve delivering within set delivery windows and meeting specific delivery times. Once again, computer routeing and scheduling packages and information systems are key tools for achieving these goals.
- **Costs:** as well as the major assets discussed above, there are also other costs associated with the operation of the vehicle, specifically the running costs such as fuel and tyres. Good scheduling can also help to keep these costs to a minimum.
- **Maintenance:** it is important to ensure that vehicles are maintained on a regular basis to reduce the occurrence of breakdowns, which can lead to both a loss of service and a higher operational cost. Fleet management packages can be used to help plan for regular maintenance. In some countries regular maintenance is a mandatory requirement to fulfil operator licensing obligations.

- Driver management: this can be significantly improved by the use of appropriate tachograph analysis, which is discussed below. As well as providing a better and more accurate picture of fleet efficiency, tachograph output can be used to monitor the detailed effectiveness of individual drivers.
- Vehicle replacement: a key decision for any transport manager is to be able to identify when vehicles need to be replaced and also which type of vehicle is the most effective for the particular type of operation that is being undertaken. A good fleet management system will be able to provide this information.
- Security and tracking: modern technology allows for the real-time tracking of vehicles. This enables up-to-the-minute information to be provided to schedulers and to customers, so can help to improve operational effectiveness, security and service (see Chapter 41 for more details).

Main types of road freight transport

Road freight transport operations can be broken down into two main types. These are primary transport and secondary transport. It is important to be aware of the major difference between these two, because they should be considered quite separately for both planning and operational purposes. The key difference can best be viewed within the context of the supply chain as a whole. This is illustrated in a domestic transport network in Figure 31.1. This supply chain consists of two manufacturing points that feed finished products into a national distribution centre (NDC) as and when product is available. The NDC then feeds four regional distribution centres (RDCs) with regular full vehicle loads. Retail outlets (sometimes called retail stores or shops) are then delivered selected orders on a daily basis from the RDCs.

The primary transport element is the movement of full loads on large vehicles with a single delivery point. This may be from plant to NDC, or from NDC to RDC. These are sometimes called trunking or line-haul operations.

The secondary transport element is the movement of loads on smaller delivery vehicles from the RDC to retail stores. Deliveries are typically made to several drop points during one vehicle journey. Orders are pre-selected for each delivery point and may be packed on to some type of unit load (a wooden pallet or a roll-cage pallet). These are often known as multi-drop or local deliveries.

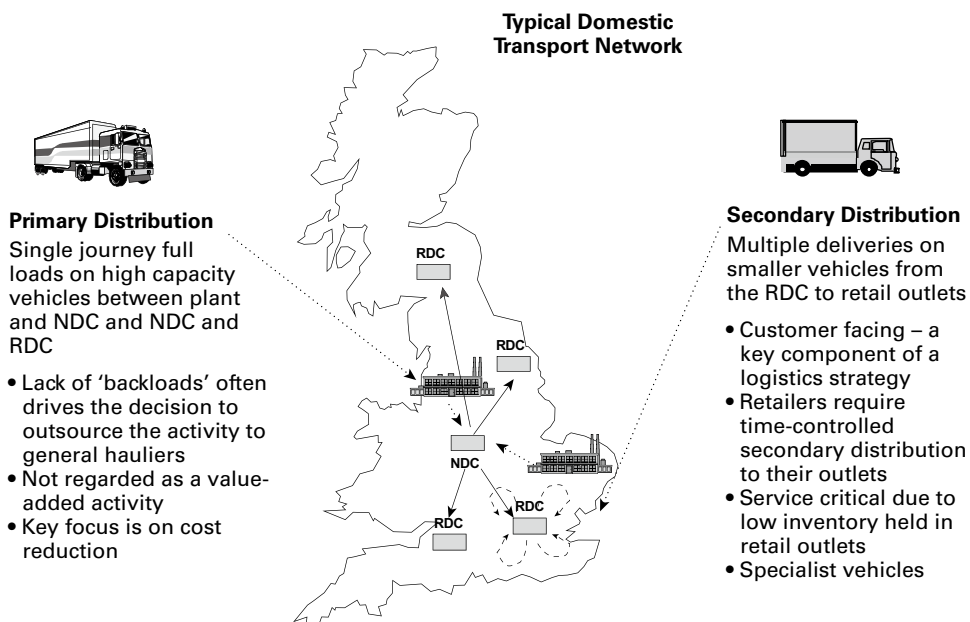
Primary transport/distribution

The focus on primary transport is often one of cost reduction. It is seldom regarded as an activity that ‘adds value’ to an operation, because there is no direct link to the final customer or, as illustrated in Figure 31.1, with the retail store. Primary transport is all about moving the product at minimum cost, which generally involves

using as large a vehicle as possible and making sure that the vehicle is filled to capacity. These movements usually consist of delivery to a single delivery point. Other key aspects include:

- Vehicles are operated for as long as possible, sometimes on a 24-hour, three-shift basis, to maximize vehicle time utilization.
- Providing return loads is important in order to achieve the maximum load utilization of the vehicle. The lack of return loads or 'backloads' often drives the decision to outsource the activity to general hauliers who are more likely to be able to find return loads.
- Additional vehicle specification, for example special on-vehicle handling equipment, is less important than for secondary transport operations because loading and delivery sites are likely to have suitable equipment.

Figure 31.1 Typical road freight transport operations consist of 'primary' and 'secondary' transport or distribution



Secondary transport/distribution

Secondary transport and delivery operations usually involve direct contact with the customer or end user (or, as with retail operations, the key end user interface). These are, therefore, what are known as 'customer-facing' logistics operations, and they can be an important part of the customer service element of logistics strategy. Because

of this, cost reduction is not the main operational criterion as it is with primary transport (although it is important). Customer service is the major criterion. In addition, secondary delivery generally involves multiple delivery journeys which are much more difficult to plan than the single delivery journeys that are common to primary transport operations. Important related factors include:

- Many customers have very restricted delivery time windows (the time in which a delivery may be made). This makes the accurate time scheduling of secondary vehicles very important.
- Service is usually critical. In particular, inventory reduction in retail stores together with the increase of store selling space and elimination of stockrooms makes timely delivery essential. This is to ensure that the store does not run out of stock.
- Specialist vehicles have been developed for secondary delivery, e.g. grocery multi-temperature compartmentalized trailers. These are used to maximize the opportunity to make frequent and full deliveries of essential stock shelf-ready to the stores.
- The last or final mile delivery is now of major significance for home delivery where customer expectations for speed, time and perfect order delivery are extremely high and crucial for successful service (see Chapter 5 where this is discussed in more detail).

In the first instance, it is vital to understand the difference between primary and secondary transport; the methods used for the planning and management of these types of operation and the selection of appropriate vehicles can and often do vary. This is because of the different emphasis on service and cost, and because primary transport tends to be single delivery journeys with return loads while secondary transport generally involves multiple deliveries.

Other transport/distribution operations

There are other types of road freight transport operation that are also used for delivery operations. Customer service and cost minimization are also relevant for these. They include:

- Stockless depot operations, which involve a single stockholding base plus additional stockless distribution depots which are supplied by large vehicles from the stockholding depot. Orders are then delivered to customers using local delivery vehicles.
- Demountable body operations, where one or more demountable boxes are loaded onto a vehicle and are driven and dropped at a dismount point in the delivery area. A suitable small vehicle then uploads each box and undertakes the local delivery operation.

Transport resources: planning and operational requirements

Transport resources need to be assessed through two different approaches.

The first is to identify the basic requirements that are needed (*planning*). Basic resource requirements for transport are determined by the identification of the appropriate number and type of vehicles and drivers that are needed for the fleet to undertake an operation in the medium or long term.

The second is to maximize the utilization and effectiveness of existing resources on a daily basis (*operational*). Thus, on a day-to-day basis, the existing fleet of vehicles and drivers needs to be used as effectively as possible. The use of these assets needs to be optimized and costs need to be kept to a minimum.

Interestingly, both of these objectives can be achieved using the same technique, which is by effectively routeing and scheduling either manually or using a computer package. Thus, both manual and computer routeing and scheduling can be used for the initial determination of transport resources (planning) and for the subsequent optimization of resources as they are used on a daily basis (operations). It is worth noting that manual routeing and scheduling can be undertaken for quite small operations, but that computer routeing and scheduling is essential for most medium and large delivery operations because the mathematical calculations required are enormous.

For *planning* requirements, the general approach is to identify the requisite base data for delivery demand and vehicle types, and use the manual or computer method to determine specific delivery route requirements (routeing) and then calculate from these how many vehicles and drivers are required to undertake the operation (scheduling). This is described in detail in Chapter 32.

For *operational* requirements, the approach is different. Secondary delivery (local delivery) operations require the efficient organization of road transport delivery to the final customer or retail outlet normally from a single depot. These operations are usually undertaken by an existing fleet of delivery vehicles that may vary in size and capacity. Also, the level of demand for products from the depot is likely to vary day by day and week by week. The two main problems are, therefore, to try to minimize the number of vehicles that need to be used to achieve this, and to deliver this variable amount of goods and products as efficiently as possible. 'Efficiency' in this instance is to maximize the amount of product moved on the vehicles and minimize vehicle mileage (thus keeping costs to a minimum). It is principally about providing a balance between supplying the agreed level of service to customers on the one hand and doing so at an acceptable cost on the other.

From the viewpoint of a depot manager or transport operator, objectives for a local delivery operation can be stated quite simply as follows: to plan cost-effective

journeys for vehicles operating from a single depot, delivering known loads to specific customers and returning to the depot after completing the journey. Although this sounds relatively straightforward, there are a number of additional constraints that must be considered. Some examples are:

- the weight or volume capacity of the vehicles
- the total time available in a day
- fixed delivery times or delivery windows
- vehicles unavailable due to maintenance or repair
- any legal restrictions to drivers' hours of work
- insufficient drivers with the correct licence
- loading and unloading times
- different vehicle speeds
- traffic congestion
- access restrictions

A fairly general definition of the aim of operational road transport delivery has been given above. For an existing fleet, this can be summarized as the 'best' use of vehicles when providing a particular delivery service (known as the 'optimization' of vehicle usage). There are, however, a number of different ways in which optimization can be achieved, and any or all of these may be acceptable objectives depending on the particular transport operation concerned. Some examples of these different objectives are:

- to maximize the time that vehicles are used (i.e. make sure they are working – productively – for as long as possible)
- to maximize the capacity utilization of vehicles (i.e. ensure that all vehicles are as fully loaded as possible within legal limits)
- to minimize distance travelled (i.e. complete the work by travelling as few miles/kilometres as possible)
- to minimize the number of vehicles used (i.e. keep the capital or fixed costs to a minimum)
- to ensure that customer specific delivery requirements are met (i.e. timed deliveries or vehicle type restrictions)
- a combination of (some or, where possible, all) of the above

The means of planning and operating efficient and effective transport operations are generally undertaken by using the same approach – that is, by vehicle routing and scheduling. The various methods that are available, ranging from manual to very

sophisticated computer methods, are the subject of Chapter 32. Before considering these, it is useful to understand some of the key issues related to how best to utilize vehicles, because high utilization is of fundamental importance to successful road freight transport planning and operations.

Vehicle utilization

Vehicle and vehicle fleet utilization can be measured in a variety of different ways. The most obvious approach and the one that is probably most usually associated with road freight transport is that of the distance travelled by vehicles. The greater the distance travelled by a vehicle in a given period, the better might be thought the vehicle has been utilized. This is, of course, only useful if the vehicle has travelled by the most efficient routes. In addition, it is important that the vehicle is carrying a reasonable load. But how should this be measured – in terms of the weight or the space that is used? In short, it is necessary to be aware of the different ways of measuring road freight vehicle utilization and to choose and use the ones that are the most appropriate.

What can vehicle utilization mean?

Different ways of assessing vehicle utilization are as follows:

- *Distance-related*: as already indicated, the most common view of vehicle utilization in the context of how much work a vehicle is achieving is probably distance-related – the judgement often being that the greater the distance travelled by a vehicle the better the vehicle has been utilized. Typical measures might be miles or kilometres travelled per week or per annum. For freight vehicles one other element is also key – the amount of goods being carried over this distance.
- *Weight and distance*: this approach takes into account the amount that the vehicle is carrying as well as the distance travelled. It is often used in national statistics as a measure of the work undertaken by vehicle groups as a whole. Typical measures are tonne-kilometres or tonne-miles. Although it takes account of the weight carried by a vehicle, which is crucial to many operations, it does not take account of the capacity in terms of space utilized where this, rather than weight, is the key constraint on a vehicle. Also, it is problematic in some instances as it does not include the actual carrying capacity of the vehicle, which is important in ascertaining the actual utilization of the vehicle.
- *Weight utilization*: this approach does take account of capacity as it is the ratio of the actual weight of the goods carried and the maximum payload weight of the vehicle. As noted above, it is useful where weight is the key constraint but not where space is the key constraint.

- *Space or cube utilization:* goods and products, such as paper tissues, that are low in density very often fill the vehicle space before reaching the maximum weight of a vehicle. Thus space or cube utilization rather than weight can be the important measure for some vehicle operations.
- *Deck utilization:* many logistics operations are based on the use of a specific unit load for storage and/or for transport operations. Classic examples are the wooden pallet and, in the grocery industry, the roll-cage pallet. In a freight/delivery transport context, operations such as these are constrained by the number of unit loads that can be placed on the vehicle rather than by weight or cube constraint. This is sometimes known as deck or unit load utilization. The consequent lack of good cube utilization from using unit loads for transport has led to the introduction of 'double-deck' trailers that offer a much better cube utilization.
- *Vehicles running empty:* another view of utilization or, perhaps, underutilization that is now used as a key indicator for national road freight transport statistics is that of vehicles running empty. This has significant implications for both primary and secondary road freight transport. For primary transport in particular this has led to the search for return loads for vehicles undertaking medium- and long-distance deliveries. For delivery transport also there has been a move to arrange for delivery vehicles, once they have completed their final delivery to collect supplier loads that can be brought back directly to the depot.

See Chapter 6 for a discussion on the implications of product characteristics when planning for logistics – particularly volume-to-weight ratio and value-to-weight ratio.

Why high vehicle utilization can be difficult to achieve

There are several issues that can cause poor vehicle utilization or make it difficult to introduce improvements. These include:

- *Demand variability:* demand can fluctuate quite considerably according to the time of day, the day of the week, the time in the month or annually. These different cycles can make achieving consistent high utilization very difficult. If vehicles are bought with a view to achieving peak demand levels then this means that for the majority of the time they will be underutilized. Seasonal/annual peaks can be levelled out to a certain extent by hiring in vehicles at peak periods. But daily and often weekly peaks are much more difficult to cater for with this approach.
- *Different product constraints:* different products impose different constraints on vehicles. Low-density loads can fill the space in a vehicle before reaching the maximum weight constraint. Very heavy loads reach the maximum weight constraint but will not fill the vehicle space that is available.

- *Unit loads:* many logistics operations use unit loads such as wooden pallets and roll-cages for the transport of products from DCs to retail outlets or end users. These can fill the vehicle in terms of deck utilization but not necessarily in terms of space/cube or weight utilization. There can be an acceptable loss of vehicle utilization providing there are reduced handling times and costs elsewhere in the retail supply chain.
- *Unreliable schedules:* the arrangement of return loads for delivery vehicles can be problematic if vehicle schedules are prone to finish outside set times. It is understandably necessary to be able to guarantee on-time collection for return loads, especially where the return load must be delivered within a reasonable delivery window. Schedule times can be compromised for many reasons: traffic congestion, breakdowns, delivery delays at drop points, unloading difficulties.
- *Just-in-time:* the move to just-in-time delivery has resulted in smaller order quantities delivered more frequently with shorter lead times. This has led to reduced vehicle utilization which companies are prepared to accept provided customers and, to a certain extent, suppliers are seeing cost savings through dramatically reduced stock levels.
- *Specialist handling requirements:* the complete supply chain of some products can be undertaken using specialist handling and storage systems which can lead to restricted space for the product in road transport vehicles, thus impacting on vehicle utilization. Hanging garments and composite (ambient/chill/frozen) grocery operations are examples of this.
- *Poor information:* it can be difficult to identify appropriate return loads due to the lack of knowledge of suitable opportunities. This can be less of an issue for third-party companies who may find it easier to identify opportunities from within their own broad set of operations. Some web-based freight exchanges can provide useful information for identifying potential return loads.

How to improve poor vehicle utilization

There are several different approaches that can be pursued in order to improve vehicle utilization levels. Not unexpectedly, these are directly related to many of the problems that were discussed in the previous section. It is also worth noting that some of the issues come as a direct result of the move to companies taking an overall supply chain view of their operations and are a result of introducing some of the classic logistics trade-offs. While resulting in a reduction in the effectiveness of one logistics element (in this case transport efficiency and vehicle utilization) the result is usually an improvement in other logistics activities and an overall supply chain saving (see Chapter 2 for a discussion of the integrated supply chain and the total logistics concept). The main opportunities for improvement are:

- *Choice of vehicle:* companies operating road freight transport fleets, whether own account or third party, need to ensure that they are selecting the most appropriate vehicles for their delivery requirements. This specifically involves a clear understanding of the key constraints on vehicle utilization – whether it is related to weight, space or deck size. When this is understood, a company is better able to choose the most appropriate vehicle mix for the fleet, with the maximum vehicle weight or size as appropriate to enable full or high utilization. As discussed later in Chapter 32, this is best achieved through the use of routeing and scheduling packages (see Chapter 29 for more information on vehicle selection).
- *Return loads:* the problem of vehicles running empty could be improved by an increase in the use of return loads for vehicles that have completed their initial runs. A number of developments in logistics might help:
 - Reverse logistics is now a key requirement in many operations, involving product returns, waste packaging recovery, recycling, etc (see Chapter 42).
 - Freight exchanges and freight procurement services are more readily available on the internet, where it is possible to identify return load opportunities.
 - Vehicle tracking systems allow for ‘live’ information on vehicles on the road so that it is easier to identify real-time vehicle availability and also to monitor likely collection and delivery times for customers offering return loads.
 - Internal information systems allow companies such as grocery operations to link all of their transport operations so that back loading opportunities can be successfully coordinated.
- *Improved space efficiency:* additional space can be created on vehicles by the development of more appropriate and more space efficient packaging and handling systems. Some companies have already identified opportunities such as redesigning product and package dimensions, the use of slip sheets in place of wooden pallets, loose loading on vehicles, thus eliminating wasted space in unit loads and double-deck trailers for use where stacking height is an issue (see Chapter 42).
- *Order cycles:* lumpy demand can result from the monthly payment cycle which can lead to bunched ordering at the beginning of the month (to take advantage of interest-free credit) or the end of the month (to spend all available credit). Also, better load consolidation can be created by using nominated day delivery in different areas on different days of the week so that higher levels of load consolidation, drop density and vehicle utilization can be achieved.
- *Use of fleet and vehicle planning and operational software:* appropriate transport software packages are available that can significantly improve vehicle utilization through better fleet planning and vehicle monitoring and control (see examples discussed in Chapter 32).

Fleet management

There are a number of fleet management information systems that are aimed at assisting the transport manager to monitor, control and administer their transport operation. These are specialized database packages that are aimed specifically at fleet operations. The main functions covered are:

- **Maintenance scheduling:** this includes the monitoring of the service life of vehicles in a fleet and the scheduling of routine and non-routine maintenance and repairs. Package features include:
 - service history
 - maintenance schedule reports
 - workshop costs analysis
- **Vehicle parts control:** this is the stock control function of spare parts requirements. Features may include:
 - stock enquiry
 - maintenance of supplier information
 - stock location
 - stock reports
 - generation of purchase orders
- **Fleet administration:** fleet administration packages are used to ensure that vehicles are legal and roadworthy. Package features may include:
 - vehicle licence renewal
 - reports required by government regulations
 - insurance lapse reports
- **Fleet costing:** these packages provide detailed information relating to vehicle and fleet costs. They assist the manager by providing analyses and information concerning individual vehicle and overall fleet profitability. Features include:
 - vehicle cost analysis
 - driver cost analysis
 - overall fleet costs
- **Tachographs and tachograph analysis:** in many countries, goods vehicles over 3.5 tonnes gross vehicle weight must be fitted with a tachograph. The tachograph is used to record the driver's hours of driving, rest and other work as well as vehicle speeds and distance travelled. Tachographs can be manually operated but are now generally digital, based on a vehicle monitoring unit with a driver smart card.

- Although used primarily for guarding against legal infringements such as excessive driver hours, tachograph recordings can also be very useful in providing the input data for an analysis of driver/vehicle performance. A number of systems are available that can take tachograph information and produce itemized information on rest time, driving time and break time, as well as details of legal infringements. Typical package features are:
 - infringement reports
 - driver and vehicle utilization reports
 - fleet reports
- Tachograph analysis packages or modules can be stand-alone, or can be integrated with other transport management systems. Tachographs provide a useful source of management information and can be used to achieve:
 - more economical driving habits, which will lead to improved fuel consumption and reduced maintenance costs
 - improved planning and routeing of vehicles, as real data on journey times and average speeds may be calculated
 - reduced vehicle accidents where drivers are aware that their driving performance and speed are being monitored
 - and improved productivity from drivers

There are a number of fleet management software packages available. Information on features and product reviews can be found on the internet (Capterra, 2021), and there are more details in Chapter 40.

Vehicle telematics

There are various in-vehicle intelligent transport systems, of which the major subsection is telematics. Telematics has been defined as ‘the remote use of computers to control and monitor remote devices or systems’. Telematics systems in vehicles help to support sustainable mobility and distribution by providing tools and mechanisms to enable improved network management, safer vehicles and more effective driver utilization. Many of these have both planning and operational benefits for road freight transport. Examples of some of these additional road freight transport information systems applications include:

- Driver and vehicle performance data, enabling reduced fuel consumption through the monitoring of fuel consumption rates and driver performance. Also, maintenance costs may be reduced through improvements in driving techniques.

- Vehicle tracking systems whereby a vehicle's geographic position can be monitored using global positioning systems (GPS). These can provide a variety of different benefits, from improved vehicle, load and driver security to better customer service, with the provision of accurate delivery times to lower costs through reduced waiting and standing time as exact vehicle arrival times are available.
- Trailer tracking allows for vehicles and their loads to be monitored in real time using satellite GPS technology. This can be particularly beneficial for the security of vehicles, drivers and loads – many of which can be high value. Trailers can be tracked automatically, and 'red flag' warnings can be issued if there is any divergence from set routes. In addition, these systems can be used for consignment tracking to provide service information concerning delivery times, and load temperature tracking for refrigerated vehicles so that crucial temperature changes can be monitored and recorded – essential for some food chain and pharmaceutical products.
- In-cab/mobile terminals enable paperless invoicing and proof of delivery. These are used by parcels and home delivery operators, based on electronic signature recognition, and also by fuel companies for the immediate invoicing of deliveries where delivery quantities may be variable.
- On-board navigation systems are common in many private cars, but are also used in many commercial vehicles. They can provide driver guidance to postcodes and addresses – very beneficial for multi-drop delivery operations where the final customer location may be new or unfamiliar. They can result in significant savings in time, fuel consumption and redelivery and can, of course, greatly improve customer service.
- Linked with on-board navigation systems are traffic information systems. These provide real-time warnings of traffic congestion and road accidents, allowing drivers to avoid these problem areas and considerably reduce delays and the associated additional costs. In tandem with routeing and scheduling software, this information can be used to enable the immediate rescheduling of deliveries and re-routeing of vehicles.

Understandably, many of these systems can be expensive, but for many large fleets and operations the cost saving and improved service makes a compelling case for their adoption (see also Chapter 40).

Road freight transport: routeing and scheduling

32

Introduction

In the previous chapter it was indicated that both the planning and the operational aspects of road freight transport are best addressed using the same method, which is through the use of vehicle routeing and scheduling. This can be achieved either manually or by using a computer package. This is outlined and explained in this chapter. Routeing and scheduling problems are shown to be categorized in four different ways. Three of these are planning-related (resource planning, 'what if' planning and planning fixed route schedules) and one is operational (variable/daily route schedules).

Routeing and scheduling algorithms are briefly discussed, the most common one being known as the savings method. A great deal of data is required to undertake a successful routeing and scheduling study. This includes the basic demand data as well as data that reflects the different characteristics of road transport delivery. The major data requirements are identified. The manual procedure typically followed by a load planner for daily scheduling using pigeonhole racking is described. Then a manual approach to scheduling for strategic planning purposes is outlined.

The use of computer routeing and scheduling packages is then discussed. These systems use digital mapping and complex algorithms to work out realistic schedules that meet all the constraints for the most complicated operations. Some typical output is shown.

Vehicle routeing and scheduling issues

Vehicle routeing and scheduling problems are relatively complicated. There are several reasons for this: first, there are many different types of problem that can

arise, each of which needs to be understood and approached in a different way; second, there are a number of different methods or algorithms that can be used to produce solutions; and, finally, there are many detailed aspects that need to be taken into account, especially the detailed data requirements which are essential for a successful outcome.

Different types of routeing and scheduling problem

As already indicated, vehicle routeing and scheduling can be used to solve a variety of different problems. There are three main planning-related problem types and one that is operational. These are:

- 1 resource planning
- 2 ‘what if’ planning
- 3 planning fixed route schedules
- 4 determining variable/daily route schedules (operational)

Resource planning

Resource planning is the identification of the basic requirements that are needed for a transport fleet. These include the appropriate number and type of vehicles and the number and type of drivers that are needed for the fleet to undertake an operation in the medium or long term. Resource planning methods are described in detail later in the chapter.

‘What if’ planning

‘What if’ planning involves the identification and measurement of the effects of change. It is a way of analysing possible future alternative scenarios in a calm and considered environment, enabling suitable plans to be made and carried out in good time. The development of computer-based modelling techniques, including routeing and scheduling, has significantly increased the opportunity for companies to plan for the future of their operations. Computer routeing and scheduling models can be used to test or simulate the effect of different aspects, such as changing demand, new vehicle availability and legislative changes. This is often known as ‘what if’ planning. Some examples include:

- Third-party contractors typically use routeing and scheduling packages to help them respond to invitations to tender for business. The packages allow them to identify fleet and driver requirements and thus cost out the operation accordingly.
- A large manufacturer of soft drinks has used a routeing and scheduling package to help it to identify the implications of adopting different minimum order/delivery sizes for its various products to its many different customer types. Any

reduction in minimum order size may bring an increase in revenue for product sales, but is likely to be associated with an increase in delivery costs, because many smaller orders have to be delivered. A routeing and scheduling package was used to test and identify these potential cost implications.

- Road transport operators use routeing and scheduling packages to help them identify the implications of changes in transport legislation. An increase in maximum vehicle weights is a case in point, as this impacts on various aspects, such as the size of loads that can be carried and the buying policy for the fleet.
- Many fleet operators use routeing and scheduling packages to test the performance and cost implications of introducing different vehicles into a fleet, such as those with a different carrying capacity.

Planning fixed route schedules

Planning fixed route schedules involves the mid- to longer-term aspects of vehicle routeing and scheduling, in particular where there is a regular delivery of similar products and quantities to fixed or regular customers. Typical examples include some retail delivery operations, bread delivery and beer delivery to outlets contractually tied to the brewery, known in the trade as ‘tied’ houses. The main characteristic is that of a fairly regular demand being delivered to virtually the same locations. Thus, it is possible to derive vehicle schedules that can be fixed for a certain period of time (e.g. three to six months). Some changes will be necessary as shops open or close, or as new products come on to the market, but in general the schedules can be maintained for a reasonable length of time. Fixed schedules are good where consistent, regular deliveries suit the customer type. These schedules are drawn up on the basis of past or historical data.

Planning variable route schedules

Variable route schedules involve the preparation of operational routes that have to be scheduled on a weekly or a daily basis. This type of scheduling is typically undertaken by retail operations, by parcel delivery companies, by companies supplying spare parts and by contract haulage companies that work for a number of different clients. The key factors are that either the demand (quantity) of goods cannot be estimated (e.g. it is ‘random’ demand) or the location of delivery points can vary, or that both of these occur. However, what *is* normally fixed is the catchment area of the distribution centre (DC).

As indicated, for variable scheduling of most delivery operations it is impossible (or very difficult) to plan efficient delivery schedules based on historical information. It is necessary to look at each series of orders on a daily (or weekly) basis, and plan vehicle routes and schedules according to this ever-changing demand. For very small operations, this type of scheduling is often still undertaken manually by a load planner in a DC; for larger operations, routeing and scheduling packages enable this

to be undertaken as a 'live' interactive scheduling exercise. An example of such an advanced package is given later in the chapter.

Most complex delivery operations are now planned on an interactive basis that allows the scheduler to use the computer to derive the most effective routes. Actual demand data are used rather than historical demand, and these 'real-time' data provide the basis on which routes are scheduled. Thus, much more accurate routes can be formulated. A rather obvious question might therefore be asked: why aren't all sets of routes derived in this way? The answer is that the cost of setting up and using a routeing and scheduling package on a daily basis can be very expensive – because of the cost of buying the package, the cost of trained personnel and the time and cost of providing the demand data every day.

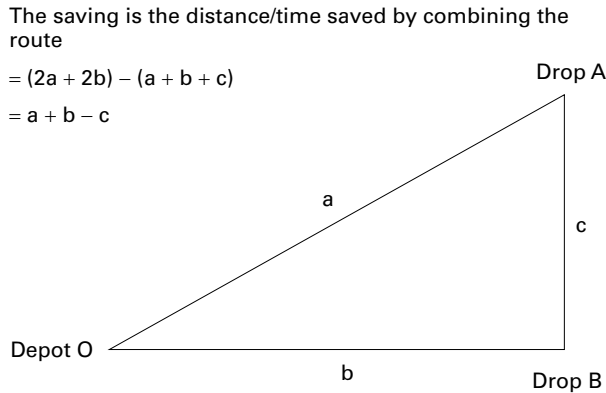
Schedules produced interactively can result in very varied routes day by day. This is because the computer is able to reappraise demand requirements and come up with a completely original result each time it is used. One of the major benefits of an interactive approach is that the scheduler is in a position to make changes to routes as they are required. For example, should an urgent order be received after the initial routes have been planned using the computer, the scheduler can manually input the order into the package and assign it to an existing route. The computer will then check the route to see if the new order can be accepted. It may be rejected for a variety of reasons – insufficient capacity left on the vehicle, insufficient time available, etc. Thus, the scheduler can use the package to ensure that the order is only placed on a vehicle that is in a position to complete the delivery both legally and within the allotted service constraints.

Some software packages also allow for multi-DC routeing so that deliveries are made from the DC that has the available resources. Thus, resources at all DCs can be utilized more effectively, enabling the maximization of asset utilization.

Different algorithms

The actual method used for routeing and scheduling varies according to the nature and difficulty of the problem, and whether a manual or computer-based approach is used. Each different method is known as a routeing and scheduling algorithm. The most common algorithm is known as the savings method. This can be explained by a relatively simple example, as indicated in Figure 32.1. Distribution centre O services two delivery points, A and B. The distances between these two delivery points OA, OB and AB are a , b and c respectively. If each delivery point is served by a single vehicle from the depot, then the total distance is $2a + 2b$. If only one vehicle is used in a single trip then the total distance covered is $a + b + c$. The savings achieved by linking together the two delivery points A and B are thus:

$$(2a + 2b) - (a + b + c), \text{ or } a + b - c$$

Figure 32.1 The savings method: a heuristic scheduling algorithm

The distance between every delivery location is recorded. A ‘savings matrix’ is then generated, recording the savings made by linking together each of these pairs of locations. Taking the link with the highest potential saving first, and then adding successive links, a route is put together, measured against the vehicle capacity and driver and delivery time constraints. Eventually all delivery points will be allocated to a vehicle route, and the schedule will be complete.

In any problem with a significantly large number of delivery locations, the advantage of using a computer is quite obvious – it would not be feasible to test all possible different routes manually. As indicated earlier, other algorithms have been developed and are used in the many different computer packages available.

As discussed in the previous chapter, there are several objectives that can be ‘optimized’ when routeing and scheduling a fleet of vehicles – from minimizing distance travelled to maximizing vehicle capacity utilization. Different algorithms and different computerized routeing and scheduling software enable these various objectives to be addressed by the scheduler. It should also be noted, however, that there may be practical implications that are difficult to represent appropriately when scheduling both manually and when using a software package. While distance-related savings may be derived from reliable map-based data, time-based savings are calculated using average travel speeds for different types of vehicles on different classes of roads and can be quite subjective. This is because they may be unrealistic when set by the operator of the routeing and scheduling package or, *in practice*, may be inappropriate due to unforeseen traffic problems or adverse weather conditions. As a general rule, these possible drawbacks are not a major issue and computerized routeing and scheduling software enables significant cost and service advantages to be achieved.

Data requirements

It has already been noted that there are many different factors that need to be taken into account when planning the delivery operation of a road transport fleet. These factors require a great deal of data and information to be collected and collated.

The major areas for data are:

- demand data
- distance factors
- customer and service constraints
- vehicle restrictions
- driver constraints
- route factors
- product/unit load constraints

Demand data

Demand data should ideally be for daily, weekly or annual demand by customer at the point of delivery. This can often be difficult to collect, is usually time-consuming and will often require the most manipulation and clarification prior to use. It may be necessary to undertake additional analyses (and collect additional data) to take account of peak demand periods, because they are likely to require different schedules.

There are several ways in which demand data can be *represented*. The key requirement is for the data to be representative of the main measure of vehicle capacity constraint. This might be weight-, volume- or unit-related. Examples include:

- weight (per product type delivered or as a total delivered tonnage figure – in kilogrammes or tonnes)
- cubic capacity or volume (in, say, cubic metres or cubic feet)
- carton/case/parcel (numbers to be delivered – common in retail distribution)
- unit load (e.g. numbers of pallets or roll-cages – again common in retail distribution)
- value in revenue or sales (rarely appropriate because of the problem of interpreting value as a physical measure)
- product item (generally too detailed)

Demand data must also be *classified by location*, and this can be represented in a variety of ways, although the most common by far is by postcode (zip code). The best (and often only) option is the classification that is in general use within the company. This will usually be drawn from electronic files of customer orders that

should record the customer delivery address and postcode (zip code) as well as the order size (care needs to be taken to distinguish between the customer's invoice address and the *actual* required delivery address).

A demand data file might look like this:

Name	Town	Postcode	Demand	Type
Cannons	Redditch	B97 4YR	32	delivery
Broomfield	Nantwich	CW5 5LW	8	delivery
Nash's	L Eaton	NG10 1JA	14	delivery

Distance factors

For routeing and scheduling analysis, there are several methods for estimating or measuring distance factors, specifically the distance travelled by the vehicles as they go about the distribution operation. Distances include those from the depot to the many delivery locations and those between the different delivery locations.

The most common method for measuring distance is by digitized road network. All reputable computer scheduling systems use a special digitized road network of the country or area concerned, which as a minimum consists of the major roads and junctions of the national road network. These provide a very accurate representation of travel distances. They also make allowances for different road types (e.g. motorway, major and minor roads) and for land use (e.g. city centre, town centre, rural, etc), which allows for variable speeds to be used when calculating the time taken to travel.

Alternatives include the true distance method (where all the actual distances are physically measured on a road map – this is very time-consuming and could not be undertaken for large applications) – and the coordinate method (where the depot and customer delivery points are located on a map by grid reference), and the straight-line distances are measured and factored up to an approximate road distance. Typically, the factor that is used is 1.2.

Customer and service constraints

There are a number of customer and service constraints that may need to be taken into account during the scheduling process. These relate to the ability to make a delivery to each destination point. They may be concerned with physical aspects or be time-related. Some of the more detailed ones cannot be used for manual routeing because of the difficulty of taking so many variables into account at the same time, but they are catered for by most routeing and scheduling packages. The most common customer and service constraints are:

- specified times for delivery (e.g. 8.00 am)
- specified delivery windows (e.g. between 10.15 and 11.00 am)
- early closing days
- lunch breaks
- access restrictions (e.g. only vehicles of a certain size can deliver)
- unloading restrictions (e.g. no fork-lift truck available to unload pallets)
- drop-size limitation (e.g. only a certain number of packages/pallets can be received)
- parking problems (e.g. cannot park or unload in the main road)
- paperwork problems (e.g. all goods must be checked by the driver and signed for)

Vehicle restrictions

Certain vehicle restrictions also need to be taken into account. Typical examples might include:

- the type of vehicles available
- the number of vehicles available
- the need to pre-load trailers
- mixed fleets (i.e. rigid and articulated vehicles)
- vehicle capacities (in weight or volume)
- use of compartmentalized vehicles

Driver constraints

Driver constraints are also relevant, the major ones for consideration being:

- drivers' hours legislation
- shift patterns and hours of work
- the number of drivers available
- different types of licence and training
- the need for a second person to assist with deliveries

Route factors

Route factors refer to the different constraints that apply to the make-up of individual vehicle routes. These include:

- the road infrastructure
- maximum number of calls per route
- multiple trips (i.e. more than one journey in a day by one vehicle)

- two-day trips (i.e. the vehicle and driver do not return to the depot every night)
- simultaneous delivery and collection requirement

In addition, the road infrastructure must identify the different road types that are available, together with the appropriate average road speeds.

Product/unit load constraints

There is a variety of factors that may need to be considered with reference to the product or unit load that is being distributed. Typical examples are:

- the weights and dimensions of the different products
- the weights and dimensions of the different unit loads
- variable unloading times (different products or unit loads may vary in the time it takes for their unloading)
- separation of products within a vehicle because of potential contamination or fire hazard
- the need to collect empty containers
- the diminishing load problem, which can lead to the overloading of specific axles if the load is not redistributed evenly after one or more deliveries have been made
- a requirement for special handling equipment

Manual methods of vehicle routeing and scheduling

In this section, a manual system for day-to-day scheduling and a manual system for long-term planning are described. It is useful to understand how these are undertaken, especially the planning exercise, as the key steps are broadly the same as those used for a computerized system, albeit far more simple and straightforward! Because of the detailed nature of such an exercise, only a broad picture will be painted of what actually takes place.

A daily (manual) scheduling system

This example describes the *daily routeing and scheduling system* and procedure undertaken by a load planner for a DC situated in London. The company is a contract haulier with a few large and several small clients for which it undertakes delivery. This particular DC covers London, East Anglia and the south-east of England. Although some locations are visited quite often, there are no regular deliveries made and new locations occur quite frequently.

Procedures at the DC are relatively straightforward. The majority of orders are received from the head office by electronic transfer (via EDI), although some may come directly to the DC from customers. The orders give information relating to the delivery address, deliver-by date, product, quantity, packaging, gross weight and any special delivery instructions. The deadline for receipt of orders is midday for delivery the day after tomorrow. This leaves the afternoon for the load scheduling and preparation of order picking notes for the following day's load preparation work. It also provides for some time allowance for the adjustment of the existing planned loads to take account of urgent orders that are required for delivery the next day.

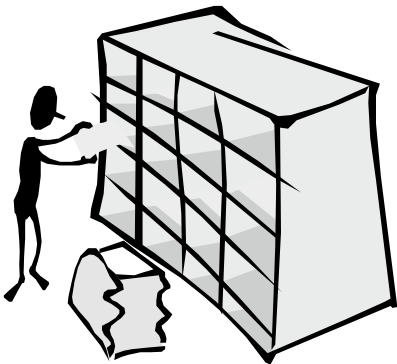
On the day following the receipt of order, the goods will be picked and marshalled by the warehouse staff and then loaded on to a vehicle by the driver on returning in the late afternoon. Delivery takes place the next day.

A copy of every order is date-stamped, and then order types are categorized according to delivery status. There are:

- *Forward orders* (i.e. delivery required at a later date): these are placed in a forward-order tray one week ahead, two weeks ahead, etc.
- *Normal orders*: these are to be delivered according to the company's standard service level (for example, within five days). These orders are used as the prime basis for making up loads.
- *Urgent orders*: these occasional orders might be for delivery within 24 hours. They are also used for making up full vehicle loads, but outside contractors are brought in if this is not feasible.

Orders are accumulated in a system of pigeonhole racking, which is arranged on the basis of geographic areas in a formalized layout. The aim is to have a number of main delivery areas spread around the depot. The depot should be near the centre of the system. For an east London depot, the pigeonhole racking is arranged as shown in Figure 32.2.

Figure 32.2 Pigeonhole racking



	Beds	Cambs	Norfolk	
Oxford	E Bucks	W Herts	E Herts	Suffolk
W Bucks	NW	N	NE	N Essex
Berks	W	C	E	S Essex
	SW	S	SE	
N Hants	W Surrey	E Surrey	W Kent	E Kent
	S Hants	W Sussex	E Sussex	

After the orders are placed in the pigeonholes, the manual load scheduling and routeing exercise takes place. As already indicated, the loads are assembled with urgent orders as a priority when forming the basis of a load. The planner schedules so that the furthest drops from the DC in each area are chosen first. The full load is then made up from other drops within that pigeonhole that are relatively close, and from drops that can easily be made en route from or to the depot. These additional drops can be readily selected using the pigeonhole system because of its geographical format. Using a method such as this, it is easy, on a daily basis, for a load planner to develop ‘petal-shaped’ routes that have the depot as their central point. This method can give very efficient vehicle routeing.

Manual scheduling for strategic planning purposes

In this example, the aim of the exercise is *to determine overall fleet requirements for a delivery transport operation*. This is undertaken using a detailed strategic manual routeing and scheduling exercise and the necessary steps are described. Routes are created from the required orders (routeing) and then appropriate vehicles are scheduled to these routes (scheduling). The overall vehicle requirements are then calculated and costed at the end of the exercise. The key elements are shown in Figure 32.3 and are described in the remainder of this section.

Figure 32.3 Steps taken to undertake a manual routeing and scheduling exercise

DETERMINE DELIVERY DATA

- Establish delivery parameters
- Establish delivery constraints

DETERMINE DEMAND DATA

- Identify demand in suitable units for each customer location
- Identify customer drop constraints

IDENTIFY SPATIAL DATA

- Determine geographic area (map/grid)
- Identify appropriate distance measurement process

FOLLOW THE PLANNING PROCEDURE

- Allocate demand to geographic locations on the map
- Form clustered trips
- Combine trips into routes
- Calculate vehicle requirements and distance travelled

COST AND MEASURE THE OPERATION

- Calculate the delivery cost
- Calculate vehicle utilization



Determine delivery data

The basic delivery data describe the operational parameters and constraints that apply for deliveries from a depot near Northampton in the UK. The depot is used by a fast-moving consumer goods (FMCG) distribution company, and deliveries are made from the depot to customers in an area largely to the north of Northampton. The depot closes at the weekend. All deliveries in this very basic example are to be scheduled for a single day. The unit load used is the roll-cage pallet, but the case is the main measurement unit. The parameters and constraints are:

- Two vehicle types are available. These are 16-tonne rigid vehicles each with a carrying capacity of 700 cases, and 32-tonne articulated vehicles each with a carrying capacity of 2,100 cases. Volume capacities are not used.
- Order sizes are represented as the number of cases.
- The acceptable times at which deliveries can be made vary among customers. There are six groups of delivery time window codes:

Code

1	All day	9.00 am – 6.00 pm
2	Lunchtime closing	9.00 am – 1.00 pm and 2.00 pm – 6.00 pm
3	Early closing	9.00 am – 1.00 pm
4	Early am only	9.00 am – 11.00 am
5	Lunchtime only	12 noon – 2.00 pm
6	Late pm only	4.00 pm – 6.00 pm

- Drivers work a maximum 10-hour day. Drivers must take a 45-minute break after driving for 4 hours and 30 minutes. Maximum driving time is 9 hours per day. There is an average 48-hour working week.
- The average road speeds are:

	Urban	Rural
Motorway	44.0 mph	56.0 mph
Dual carriageway	27.5 mph	35.0 mph
A roads	22.5 mph	31.0 mph
B roads	17.5 mph	25.0 mph

- The time taken to unload goods at customers’ premises varies as a result of access problems and unloading equipment available. There are three main groups. Each group has a fixed time (which is incurred regardless of the quantity delivered and takes account of paperwork, etc) and a variable time related to the size of the delivery in terms of cases delivered via roll-cages. The groups are as follows:

	Fixed (minutes per drop)	Variable (minutes per case)
1	10	0.025 (1.5 seconds)
2	20	0.050 (3 seconds)
3	25	0.075 (4.5 seconds)

- The drivers are able to leave the depot at any time after 6.00 am. The latest return time of a vehicle to the depot is 7.30 pm.
- Vehicles are pre-loaded for delivery.
- Second/multiple trips in a day are allowed. If a vehicle does multiple trips in a day, the time required to reload vehicles at the depot is 10 minutes fixed time and a variable time of 0.015 minutes (0.9 seconds) per case. The minimum time that must be available for a further trip is 2 hours.

Determine demand data

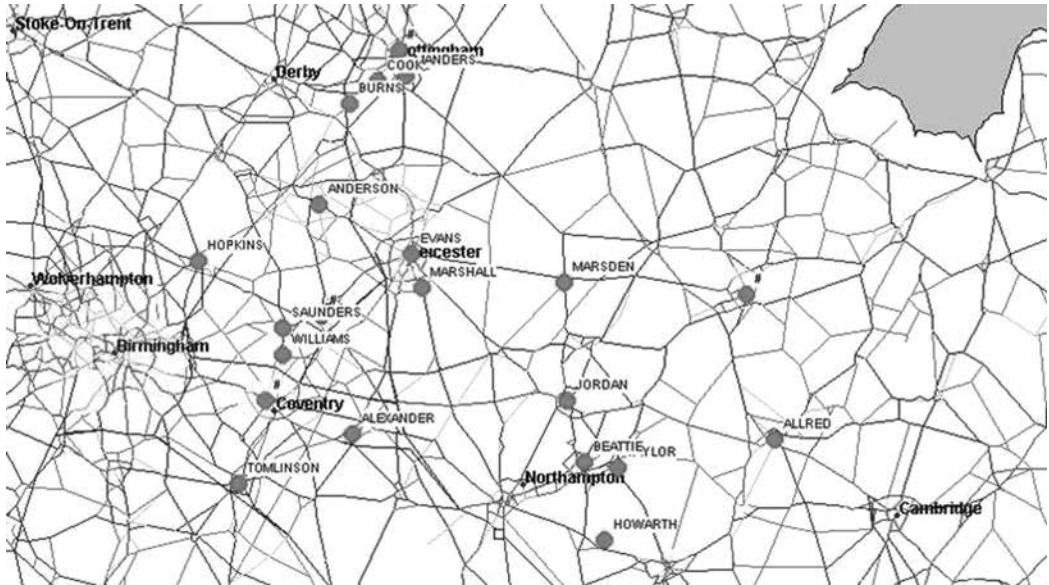
Demand data is given for each of the locations to which a delivery is to be made. These may be actual orders for daily/weekly scheduling or a set of average orders for resource planning purposes. Demand and delivery constraints are identified for each customer to include:

- location
- cases to be delivered
- fixed unloading time
- variable unloading time
- any vehicle size restriction
- delivery time window

Identify spatial data

A suitably detailed map should be used and the drop points indicated accordingly. An example of a computer-generated map is given in Figure 32.4.

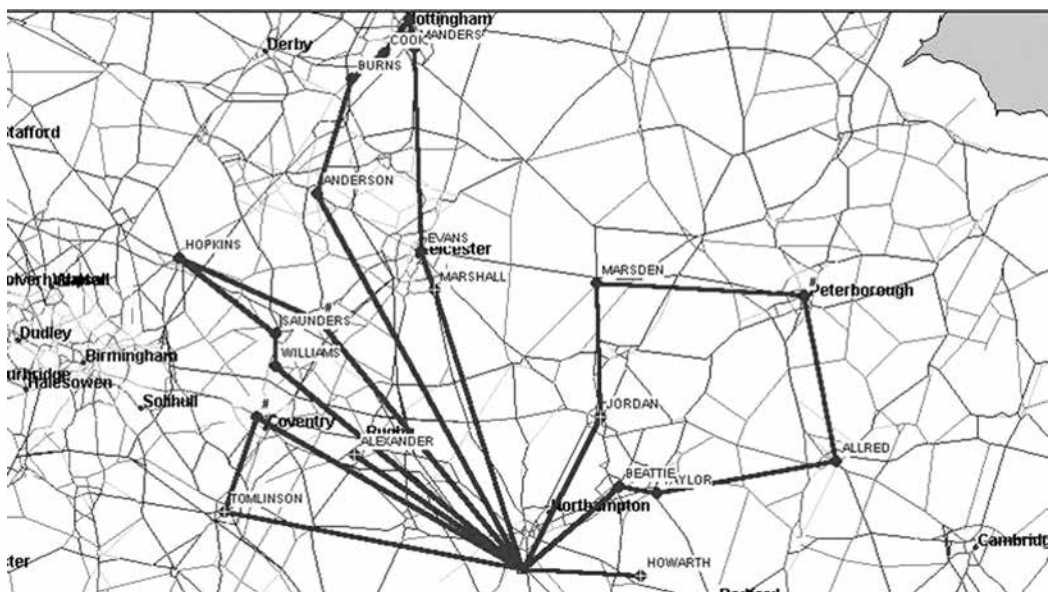
A process of measuring distances needs to be established. This might be according to the actual roads that are used during the delivery run, although this is very time-consuming if there are some complicated routes developed. A simplified approach is to measure any distance as a straight line and then multiply this by a 'wobble factor' that is representative of the way that roads twist and turn. A factor of 1.2 is appropriate. Sometimes motorways are measured directly and other roads estimated using the straight-line approach.

Figure 32.4 Digitized map of drop points and depot

Follow the planning procedure

Once the basic data is identified and recorded, then the actual planning procedure can take place. The overall objective for such an exercise is likely to be to ‘find the best routes that will minimize the numbers of vehicles and minimize delivery distance travelled – within the set demand and delivery constraints’. Routes are planned based on what are known as the principles of ‘maximum drop density’ (deliveries or ‘drops’ that are close together are scheduled on the same vehicle) and the full use of vehicles (use as much vehicle load capacity and vehicle time as is possible). The basic steps are thus:

- identify delivery points on the map
- identify demand and constraints by delivery point
- identify deliveries that can provide a single delivery trip and schedule these
- form clustered trips as follows:
 - start with the drop that has the most constraints or that is the furthest from the depot
 - select a suitable vehicle (by its capacity)
 - form trips by combining adjacent deliveries until there is a full vehicle load
 - record the total time taken (travel time plus delivery time)

Figure 32.5 Map showing final routes

- final trips are short ones near to the DC
- combine trips into routes where possible (i.e. the vehicle route consists of two trips by the vehicle on the same day)
- determine fleet requirements (total number and type of vehicles) and distance travelled

The procedure is straightforward, but very time-consuming if there are a large number of vehicles to be scheduled. Examples of the routes are shown in Figure 32.5 – although these have actually been derived by using a computer routeing and scheduling package!

Cost and measure the operation

The final stage is to cost the operation by calculating the fixed cost, based on the number of vehicles used, and the variable cost, based on the mileage travelled by the fleet. In addition, the respective utilization factors can be calculated. For the small problem outlined here, the results are as follows:

Costs and utilization factors for the vehicle fleet:

Vehicle costs (calculated on a daily basis)

2 rigid vehicles @ £75 per day		£150
634 kilometres @ 20 pence per kilometre		£127
3 articulated vehicles @ £146 per day		£438
662 kilometres @ 31 pence per kilometre		£205
Total cost per day		£920
Annual cost		£220,800
Cost per case delivered	(£920/9,863 cases)	9.3 pence/case
Cost per kilometre	(£920/1,296km)	71.0 pence/km

Vehicle utilization

Time utilization:	actual hours	44 hours 13 minutes	80%
	available hours	55 hours	
Load utilization:	actual cases	9,863 cases	88%
	maximum cases	11,200 cases	

Computer routeing and scheduling

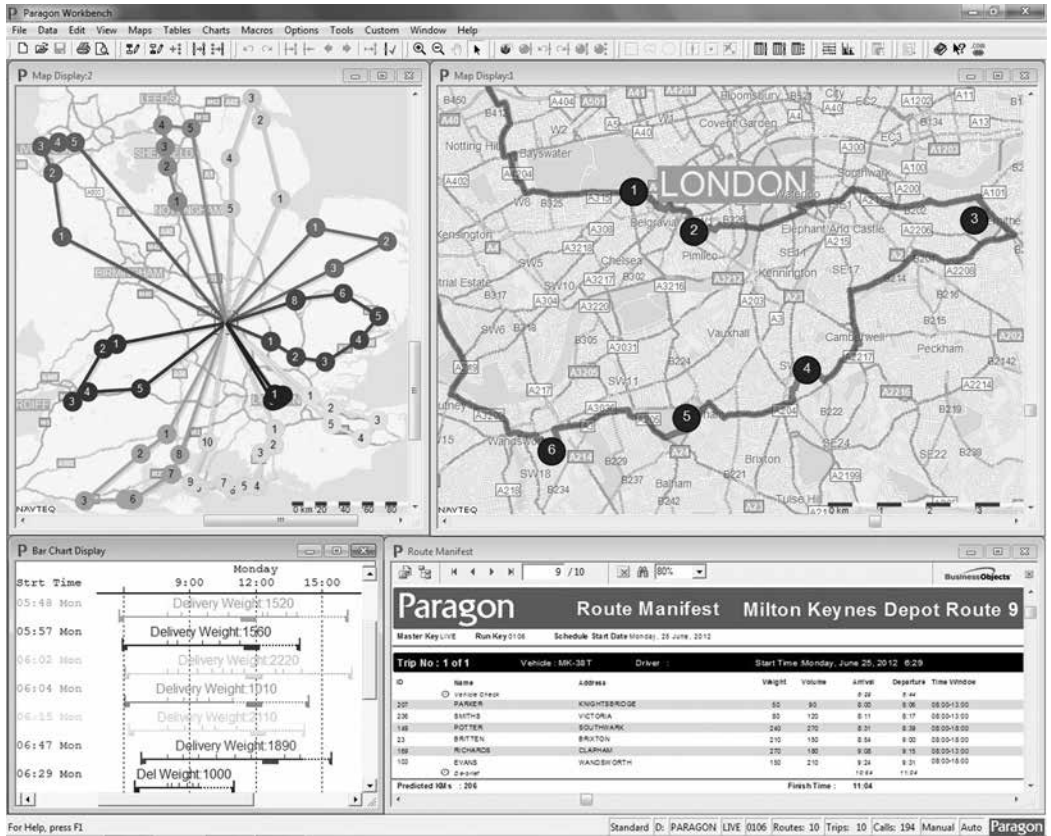
What these packages can do

As discussed earlier in this chapter, there are several different types of problem that routing and scheduling can be used to solve. These are basic resource planning, 'what if' planning, planning fixed route schedules and operational variable/daily route schedules. All of these problems can be tackled with significantly greater accuracy by using a computer vehicle routing and scheduling package. Some computer packages are designed to address one particular aspect, but most cover more than one.

The general aim of computer routing and scheduling is similar to that indicated for manual routing and scheduling. Note that *computer routing and scheduling packages do not, in fact, provide an optimum solution to a problem. They provide the best answer within a given set of constraints and demands.* Computer packages provide the transport planner with the ability to go into much greater detail than is possible with a manual system, because they can undertake many more calculations and many more alternatives can be investigated than when using a manual system.

The scheduling procedures used in computer packages vary according to the nature of the answers that are required, but the basic system is again similar to that described for manual scheduling, albeit substantially more complex. These computer systems use digital mapping and incorporate advanced scheduling methods (algorithms) to work out realistic schedules that meet all the constraints for the most complicated operations. They can be relied upon to produce very efficient solutions. Used interactively and in real time, a computer package can also enable the scheduler

Figure 32.6 Routeing and scheduling systems use digital mapping and complex algorithms to work out realistic schedules that meet all the constraints



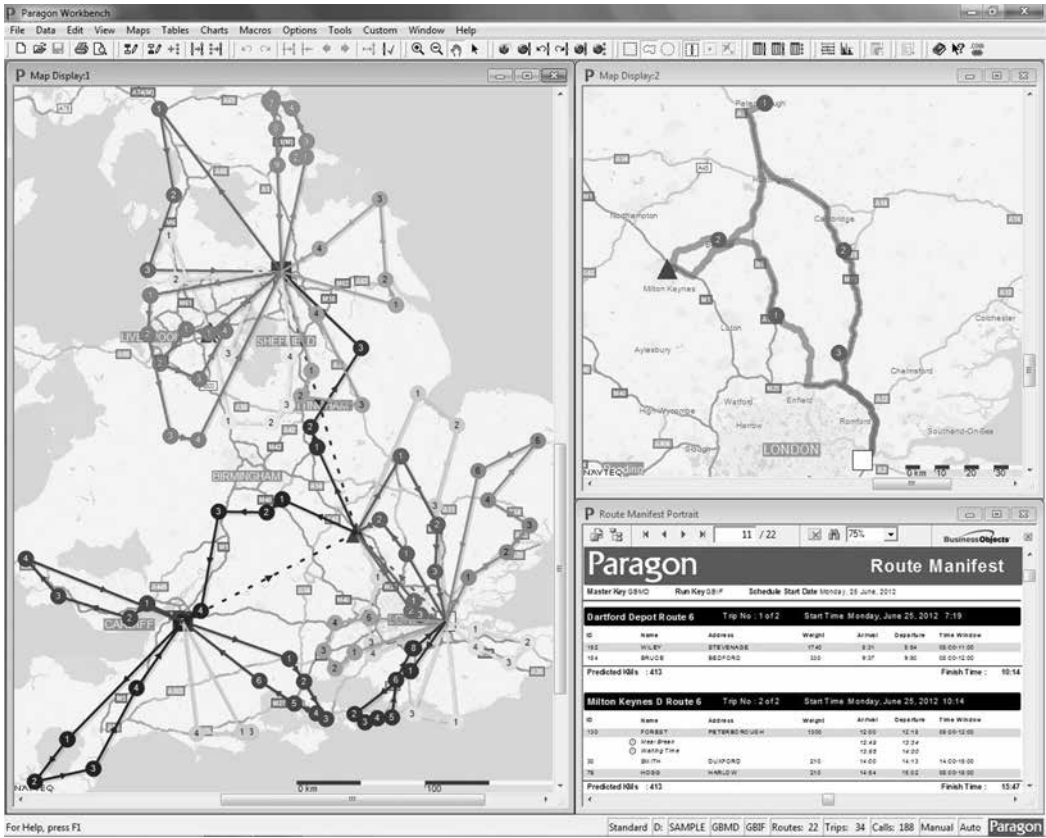
SOURCE Paragon Software Systems plc

to make fundamental changes to existing routes to allow late or urgent orders to be planned into the schedule while the computer checks for any implications (missed delivery windows, legal infringements, etc).

Figure 32.6 provides examples of some typical output data, illustrating a map of the daily routes from a depot located at Milton Keynes in the UK, together with the detailed drop points of one particular route, a summary bar chart display and a detailed route manifest. The visual output makes it much easier to interpret and understand the results, and the detailed delivery schedules can be used by the drivers.

Most packages can be used to undertake the planning of very complicated operations across a broad spectrum of requirements. Today's most advanced systems can, for example, be used for the central planning of multiple depots with multi-shifted vehicles combining deliveries, collections, reloads and inter-depot transfers. Figure 32.7 demonstrates one such application, the large map illustrating the results of a multi-depot operation being supplied from a central stocking point in the heart of

Figure 32.7 Today's most advanced systems are used for central planning of multiple depots with multi-shifted vehicles combining deliveries, collections, reloads and inter-depot transfers



SOURCE Paragon Software Systems plc

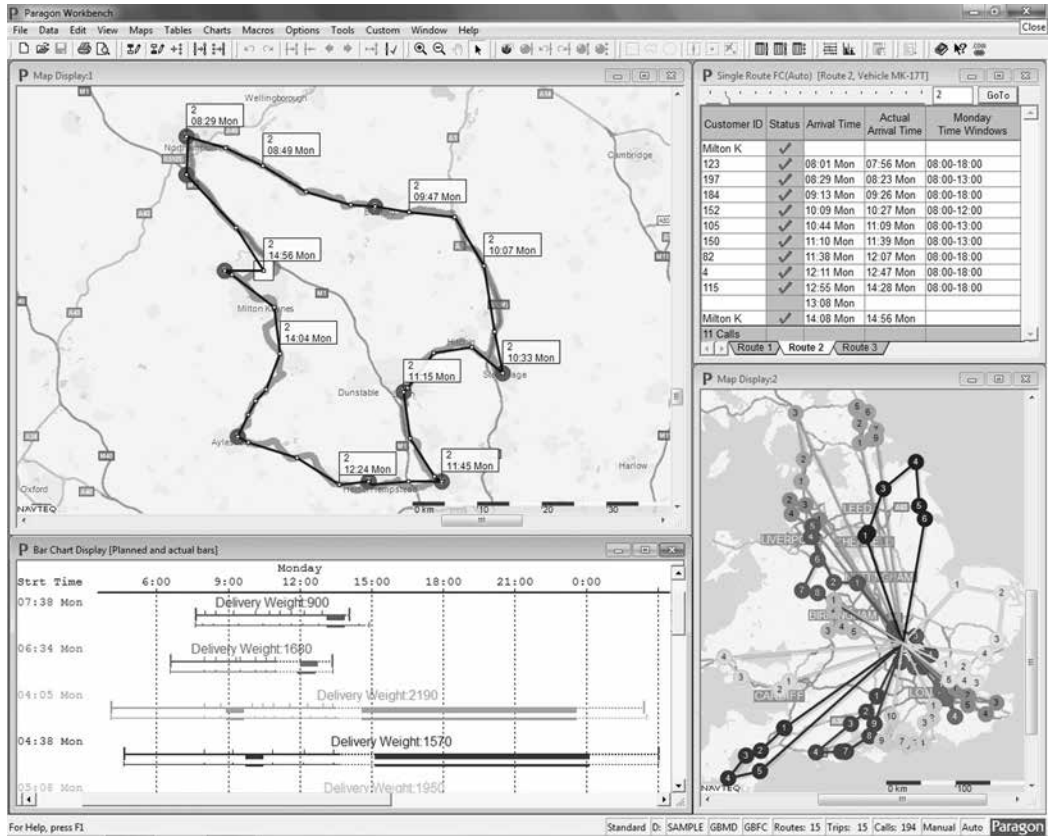
the Midlands in the UK. Also shown in the split-screen display is an example of one of the satellite depot routes together with the detailed manifest.

As well as being used for the initial determination of transport resources and for the subsequent optimization of resources, vehicle routing and scheduling systems can also be linked with live vehicle-tracking systems. This means that route plans can be monitored in real time so that discrepancies can be highlighted immediately. Figure 32.8 shows a map and bar chart display that allow this monitoring to be undertaken visually.

Routing and scheduling computer software

There are a number of different routing and scheduling computer software packages available. Various lists of the main ones can be found on the internet. Two useful places to use as starting points are:

Figure 32.8 The link with vehicle tracking means that route plans can be monitored in real time so that discrepancies can be highlighted immediately



SOURCE Paragon Software Systems plc

- Gartner.com, which provides a summary of several routeing and scheduling packages (Gartner, 2021)
- Commercial Motor, which provides a general discussion on routeing and scheduling packages including a list of key packages with a link to the supplier websites (Commercial Motor, 2021)

These lists may not be exhaustive, as new products are brought on to the market from time to time, principally from Europe and the United States, and existing ones are continuously developed and updated. As indicated earlier, computerized vehicle routeing and scheduling systems offer the opportunity for greatly enhancing the effective planning and management of road transport operations. In addition, some of the more specific advantages claimed for these systems are as follows:

- decreased standing costs as the number of vehicles required for a fleet can be minimized
- decreased running costs as efficient routeing reduces distance travelled by the vehicles
- less need to hire in vehicles
- increased customer service through consistent and reliable schedules
- less chance of breaking transport regulations through the ability to programme in legislative constraints
- savings in management time as schedules can be calculated quickly
- an increased level of control because more accurate management reporting is possible

International freight forwarding

33

We are capable of calculating quotations for three major projects, making bookings for five different shipments and answering twelve totally unnecessary calls per hour, all simultaneously. We do not require sleep and are at your service twenty-five hours a day, eight days a week. Our home numbers are your numbers.

ANON, *THE LIFE OF A FREIGHT FORWARDER*

Introduction

International freight forwarding, or freight management as it is sometimes known, is a complex and highly skilled business. Freight forwarders are called upon to move freight parcels of all sizes utilizing different modes of transport internationally. As the slightly tongue-in-cheek quotation above indicates, freight forwarders are constantly juggling the needs of their clients with the realities of the physical limitations of international transport systems. Their skill lies in the ability to integrate the actions of multiple logistics providers, customs authorities and government agencies as well as ensuring that all the required documentation is in perfect order. They often have offices based in airports, seaports, at land border crossings as well as in main industrial areas.

Freight forwarding companies range in size from small offices to very large global organizations but the scope of their operations is often global or at the very least international. Global coverage is achieved by establishing networks of offices that are either owned or provided by local forwarding companies who act as agents on their behalf. Many freight forwarders may specialize in certain regions of the world or in certain industries. Very few are able to offer a truly global service.

Many of the aspects of freight forwarding, such as specific modes of transport and elements of international trade, have been covered elsewhere in this book. Therefore the emphasis in this chapter is on the elements that have either not been covered

elsewhere or not covered in sufficient detail. In addition we examine those integrating activities performed by the forwarder in order to stitch together an international movement of cargo. In particular, cargo insurance is looked at in some detail. Basic documentation and its purpose is covered. The harmonized system used by customs authorities for identifying cargo is briefly explained. Some of the specialized services that forwarders offer such as crating for shipment, cargo tracking, consolidation of cargo and chartering are described. Project logistics is looked at in more depth and some common terms are explained.

The role of the freight forwarder

The uncertainties of global logistics activities were categorized by Bowersox and Closs back in 1996. They identified the '4 Ds' of uncertainty as: distance, demand, diversity and documentation. In practice what Bowersox and Closs were referring to were:

- longer transport distances
- increased uncertainty of demand
- diversity of culture and administration
- the wide differences in documentation required to facilitate international freight movements

However, in the 21st century we may add a fifth 'D' (4 Ds + 1) to this list which is the increasing desires of customers who expect both the lowest prices and the highest standards of service. Furthermore, they expect their goods to be moved with the minimum of impact on the environment. These are the circumstances within which freight forwarders operate.

Unlike an airline or trucking company, it is less easy to clearly define the activities of freight forwarding companies. There are certain activities such as dealing with customs clearance and documentation that all freight forwarders offer but the area is not exclusively theirs as some international trading companies undertake these activities for themselves. Very often freight forwarders act as the lead logistics supplier to a customer in that they coordinate the activities of various other specialist logistics suppliers who each play a separate role in fulfilling an international movement of freight for the customer. For example, the freight forwarder may organize the collection of the freight using a trucking company and then contract other logistics suppliers such as the airline for air freight and then another to collect and deliver the goods at the end of the journey. They may also arrange for the goods to be packed or crated prior to shipping as well as preparing all the necessary paperwork at both origin and destination ports of entry and departure. Freight forwarders are

often used to coordinate the activities of logistics providers in a project logistics scenario (see 'Project logistics' section in this chapter).

Freight forwarders own or lease logistics assets as it suits their business. It is impossible to describe a universal model that freight forwarders employ. Their business models are as varied as the forwarders' size and the industries they choose to service.

Some small freight forwarding companies operate on an asset-light basis. That is to say they own very few fixed assets as a company and lease or hire assets as they are required to fulfil freight operations when they arise. These companies may only own some information and communications technology (ICT) equipment such as laptop computers, printers and mobile phones. This allows them to be highly flexible. If such a company loses a major contract then they simply cancel any hire agreements they may have used to fulfil their obligations and move on to the next job. This is a very useful strategy in a very uncertain commercial world. However, these companies often suffer from reduced customer service as they are more frequently let down by the quality of the contractors they hire.

On the other hand, some very large freight forwarding companies may decide to own and operate certain fixed assets as it suits their business model. Many companies choose to own small vehicles to make collections and deliveries of small international consignments. There are some companies that own or lease aeroplanes to move freight, such as FedEx, Deutsche Post DHL and UPS. Other companies may lease and operate ships: for example, Pentagon Freight Services operate a small break bulk ship that it uses to deliver freight primarily for the oil and gas industry, as shown in Figure 33.1.

There is another large group of companies that would describe themselves as express courier companies that often have a worldwide network of offices and logistics facilities. These companies specialize in the fast and reliable collection and delivery of parcels and documents around the globe. Often these same companies have divisions that specialize in more general freight forwarding activities such as customs brokerage, air freight and sea freight. In many cases these companies are household names, such as FedEx, United Parcel Service (UPS), Deutsche Post DHL and so on. A cursory glance at the websites of these companies quickly demonstrates the worldwide scope and scale of their operations. They offer a 'one-stop-shop' approach to clients and offer industry specific logistics solutions in some cases.

It is becoming much harder to make a clear distinction between the activities of the express courier companies and those companies such as Panalpina, which would generally be recognized as a freight forwarder.

Figure 33.1 Pentagon Freight Services vessel *Charelle II* loading project cargo in Sharjah, UAE



SOURCE Paul Hayward

Specialized services

Many freight forwarders offer additional specialized services to their clients. Below are a number of the more common services available but the list is by no means exhaustive.

Packing and crating

Any cargo that is consigned on a long international journey needs to be appropriately prepared to ensure that it is protected against the rigours of multiple handling and extremes of weather, especially seawater.

Cargo loaded into a standard ISO container is protected from the elements by the container itself and the fact that the container is filled to capacity obviates the need for the cargo to be secured against movement in transit. However, this is not always the case. It is in these situations that freight forwarders provide the service of blocking and bracing cargo inside a container to ensure that it does not get damaged in transit. They provide personnel who cut timber to size and fix it in place.

In some cases, items may need to be protected by a wooden crate specifically produced for the purpose of moving the goods. Items may be wrapped in protective material such as wrapping paper or bubble wrap and then placed inside the bespoke wooden crate or cardboard carton. Hazardous goods need specialist labelling and packaging.

In Figure 33.2 some very specialized hydraulic lifting equipment is being used to manoeuvre and unload cargo from a truck trailer. The goods are extremely fragile and heavy. It was impossible to use a crane due to the constraints of the building and the nature of the cargo. These packing and crating services provide useful additional revenue for freight forwarders and additional cost for the consignor of the freight. However, without these services the goods may be subject to damage or deterioration in transit. Crating and packing also helps prevent pilferage.

Figure 33.2 Project logistics: a 95 tonne milling machine being unloaded from a road trailer. The load is being lifted and manoeuvred into position by a four-way gantry lift system with a total lifting capacity of 360 tonnes. The milling machine had to be accurately located on to 30 bolts



SOURCE Adrian New

Air cargo is often packed into unit load devices (ULDs) or onto air cargo pallets by freight forwarders in preparation for loading on to aircraft (see Chapter 27).

Groupage or less than container load (LCL) services

Many forwarders offer consolidation services on certain trade routes or to specific countries or regions. The service works by offering the benefits of containerized transport to clients with freight quantities that are smaller in weight and/or volume to fill a standard shipping container. The client is offered a competitive rate that is higher than the basic rate of a full container (on a cost per tonne basis) but lower than other methods of shipment. In this way the forwarder collects together parcels of freight from multiple clients and consolidates the shipment into one container.

This consolidation service may be offered for most modes of transport but most commonly for sea, air and road shipment or a combination of these modes. Containers with consolidated loads may be broken down and then consolidated with other cargo as the journey progresses. For example, a consolidated container may be shipped from Shanghai in China to Dubai where the container is unloaded and the various smaller consignments are then combined again with other consignments in consolidated loads for countries in the Gulf region. This process means that the cargo may not move very quickly but it does provide an economical service for clients that are less concerned with speed of delivery.

Non vessel-operating common carrier (NVOCC) services

The NVOCC term relates to maritime transport. Many freight forwarders are NVOCCs. It refers to a carrier who issues bills of lading for the transport of goods on ships that they neither own nor operate. These are called house bills of lading. NVOCCs purchase space on vessels at a discounted rate that they then sell on to clients at a higher rate. This is related to the consolidation services described above but not exclusively so.

The United States Customs and Border Protection Service (CBP) refer to organizations providing these services to air freight clients as 'air freight consolidators', while the International Air Transport Association (IATA) calls freight forwarders who provide consolidation services as well as other air cargo services 'IATA cargo agents'.

In the same way that NVOCCs issue house bills of lading for sea transport, air freight consolidators/IATA cargo agents issue house air waybills.

Freight tracking

Freight tracking and tracing is a service provided by many international express couriers. Where shipments have been barcoded it is relatively easy to scan the consignment as it reaches certain points on its journey such as a distribution centre, sea port, airport or delivery truck. Once the cargo is scanned the tracking system is

updated in real time and the client is able to access the system from anywhere in the world via the internet using the consignment number or some other unique identifier. In this way the client can satisfy themselves on the progress or otherwise of their consignment.

In a situation where the consignment is not barcoded the freight forwarder stays in contact with the various logistics providers being used to transport the goods. If the goods are being sent by sea then the forwarder knows when the cargo was loaded and when the vessel sailed. The forwarder is also aware of the progress of the vessel and passes this to the client as required. Once the ship arrives at its destination port an arrival notice is issued by the forwarder. This process, of course, requires effort on the part of both the forwarder and the client to communicate. This is clearly less easy than accessing a tracking system online. Naturally a similar process applies to goods sent by air, road, rail or inland waterway.

Ship's agency

Many freight forwarders act as ship's agents for major shipping lines (see Chapter 26) as they often have offices in major sea ports and are in a good position to service the needs of the shipping lines' vessels when they dock. This service may be in addition to selling cargo space on behalf of the shipping lines. This often leads to (understandable) confusion in the minds of inexperienced purchasers of freight forwarding services. There is a distinct difference between the role of a ship's agent and a shipping agent. The ship's agent takes care of the needs of the vessel and crew itself such as arranging fuel, water and so on, whereas a shipping agent sells maritime transport services on behalf of shipping lines. If that is not confusing enough then consider the fact that the two types of service may be sold by the same company!

Chartering

The chartering of ships or aircraft on behalf of clients is another service provided by freight forwarders. The forwarder finds a suitable available ship or aircraft and negotiates terms on behalf of the client. In turn the forwarder earns a profit margin for organizing the arrangements. Often referred to as a charter agreement or charter party there are two main versions of this legal arrangement. The first is known as a *gross charter* where the client leases the vessel from the owner for a fee complete with crew, equipment and other expenses such as port costs. The other is known as a *bareboat charter* where the client leases the vessel only without the crew and in effect becomes the owner for the agreed period of the charter. This is a very basic description of charters, and professional advice should always be sought prior to engaging in a charter agreement.

Cargo inspection

Cargo inspection services and cargo superintendents are often provided by freight forwarders (see Chapter 26).

Employee implants

In some cases where a freight forwarder has a large enough contract with a client the forwarder may offer to locate one of their employees in the premises of the customer. In practice the forwarder's employee works alongside the customer's staff, preparing goods for shipment or preparing and checking the required paperwork. This can be a mutually beneficial arrangement and dramatically help the communication between the two companies. Problems are more quickly resolved and not allowed to escalate. Obviously the volume of work has to be sufficient to justify such an arrangement.

Documentation

Most people who have not been professionally involved in the international shipment of goods either as a client or as a professional freight forwarder assume that the complexity of these movements derives from the coordination of multiple modes of transport over a long distance. While this is for the most part true, by far the most important aspect related to international shipments involves the documentation. Transport-related issues may incur delays, damage, and cost but documentation-related issues could result in the cargo being stuck in transit for a very long time, possibly years. It is vitally important that the necessary paperwork is fully understood and professionally prepared prior to despatching the goods. Some countries may require documents to be submitted online, with others requiring original physical paperwork and/or a combination of the two. It is not unusual to be required to submit documents in the language of the destination country. Some specific commonly used documents have already been discussed in Chapters 26 and 27. It is important to understand that international documentation is required whatever mode of transport is used.

Many different documents may need to accompany the goods, depending on several factors, some of which are outlined here:

- the destination country and its relationship to the originating country
- the characteristics of the goods shipped
- the customs status of the goods once imported into the destination country
- the destination country may require certificates of conformity to certain quality or safety related standards

These factors are examined in more detail below:

- *The destination country and its relationship to the originating country.* The relationship between the origin and destination countries is very important as it dictates the nature of the documentation required. For example if the destination country is part of the same trading bloc such as the European Union (EU) then the goods may be considered to be in 'free circulation' within the external borders of the EU. As such minimal paperwork is required. However, if the destination of the goods is in another trading bloc such as the United States–Mexico–Canada Agreement (USMCA) area then another set of documents would be required. At the time of writing USMCA and the EU do not have a free trade agreement, although it is being discussed. Another significant issue relates to politically motivated trade embargoes. These are often used as a way of resolving political disputes but cause considerable headaches for freight forwarders. For example, the United States imposed trade sanctions against Iran related to Iran's nascent nuclear programme. The sanctions restricted US companies in their business with Iran. The sanctions encompassed third parties, which meant that the embargo could not be circumvented by a US company using a company based in another country to do business with Iran on its behalf. This also included a prohibition of using Iran as a transit country en route to central Asia, for example.

- *The characteristics of the goods shipped.* Some types of cargo might include certain restricted politically sensitive technologies such as those related to the military, communications equipment and technology, aerospace and armaments. Specific licences may be required by the authorities for export and import of these goods. Hazardous cargoes would almost certainly require specific documents to accompany the cargo.

In other circumstances the goods being shipped may be legally acceptable in the country of origin but are either legally or culturally unacceptable in the destination country. These issues need to be correctly understood before any shipment is despatched. It is widely understood that both alcohol and pork products are very sensitive issues in Muslim countries but the importation of these goods is not always prohibited. Some strict Muslim countries choose to ban importation outright while others choose to allow importation but levy a significant import tariff. What may be less well understood is the status of religious texts in some Muslim countries. Once again some choose to ban the importation outright while others impose a tariff. This may present issues when an expatriate worker's personal effects are being imported.

- *The customs status of the goods once imported into the destination country.* Goods being imported into a country on a permanent basis would attract the requisite customs duties, which must be paid at the time of importation unless they are duty free. However, many countries allow some goods to be imported on

a temporary basis provided certain requirements are met by the importer. This is known as a temporary import. For example, if a trade exhibition is being held in a country then exhibitors from other countries may well wish to showcase their goods for the duration of the show but then re-export them soon after the end of the exhibition. Different jurisdictions deal with this situation in different ways but a common practice is to allow the temporary importation of the goods but require the importer or their agent to deposit with the customs authorities a sum of money equal to the duty that would otherwise be payable by the importer if they were permanently importing the goods. Once the goods are re-exported then the importer is refunded the duty. This is often referred to as duty on deposit. Care needs to be taken that all the paperwork is correct when reclaiming duty on deposit, or the money will be retained by the customs authorities in question.

This sounds very straightforward and indeed is straightforward when the example is as clear-cut as the one described above. The problems arise when matters are less clear and span a longer period of time. This may happen in the case of a project such as the temporary importation of an oil rig and all its associated equipment. The rig may be imported for a period of some years and at the time of importation not all the constituent parts of the rig achieve temporary import status. For example, spare parts and goods that may be consumed during the lifetime of the project may not be temporarily imported while other more durable parts of the rig would be granted temporary import. At the time of re-export it is vital that all the various duties on deposit are recovered or a very significant cost may be incurred. This requires the importer or their agent to maintain scrupulously accurate records, especially of the bills of entry. If this is not complicated enough it is not unusual for oil rigs to move from one location to another within the same country. This may mean moving from one customs administrative region to another *within* the same country. In Algeria, for example, such movements require customs documentation to be prepared to cover such internal movements.

- *The destination country may require certificates of conformity to certain quality or safety related standards.* For example, the EU requires certain imports to display the CE (Conformité Européenne) symbol. This is one example related to the EU but there are myriad other examples covering various countries, trading blocs and industries. Care should always be taken to ensure that these requirements are met. It is precisely because they are so specific to certain goods and industries that extra care needs to be taken prior to shipping any goods.

This list is by no means exhaustive but it gives a clear sense of the framework of complexity surrounding any given shipment.

One other point worth making is that it is not unusual in some parts of the world for customs regulations to be changed at very short notice. Given that some

sea voyages may take many weeks to complete, especially in the case of less than container load (LCL) sized shipments, this could present very real problems for all concerned. There is little that any consignor can do to alleviate this issue with the possible exception of ensuring that you contract reputable and professional freight forwarders to handle your shipments. They will have people on the ground in the location and will be best placed to resolve the issues that may arise.

Typical documentation

It is extremely hard to produce a complete list of documentation as requirements differ not only between modes of transport but also between different parts of the world. However, it is possible to highlight certain types of documents that are invariably required, such as a transport manifest, sometimes referred to as a freight document. If this is not confusing enough we then have to acknowledge that some standard documents may play multiple roles in certain circumstances and jurisdictions. For example, a sea freight bill of lading is both a contract for transport services as well as conferring rights of ownership upon the bearer and may be traded between different parties. By contrast, an air waybill does not confer rights of ownership and may not be traded between parties. A commercial invoice may also be sufficiently detailed to double as a packing list. What may be generalized is that shipments will always have some form of:

- transport or freight document
- commercial invoice
- packing list
- customs document
- freight insurance document (not necessarily always required)
- certificate of origin (not necessarily always required)

The transport document outlines the nature of the cargo and the origin and destination. This takes many different forms from an air waybill (air) to a bill of lading (sea); from a truck manifest (CMR in EU) to rail waybill (CIM in EU). It is often the contract for transport services between the consignor and the logistics service provider. In a situation where there are several freight forwarders sending consolidated loads containing many different consignments from different customers, then the freight forwarders may each have a master bill of lading or master air waybill that lists all the separate shipments they are loading on the ship or aircraft.

The commercial invoice is usually required by customs at both origin and destination. At destination it will help to determine any duties payable. The packing list is a very detailed list of the goods being transported. The customs document acts as the administrative document for customs authorities at both ends of the journey and

possibly any countries in transit. In the EU this is known as the single administrative document (SAD). The freight insurance document outlines the insurance cover in excess of the minima provided by different modes of transport (see ‘Cargo insurance’ section in this chapter).

ATA (Admission Temporaire/Temporary Admissions) carnets are used to facilitate the temporary importation of certain articles such as trade samples and trade exhibition materials. Although widely accepted, not all countries do accept them therefore it is important that this is established from the outset. It is wise not to mix items on documents that are being permanently imported with items that are being imported on a temporary basis. Ideally separate paperwork should be prepared for permanent and temporary imports.

TIR carnets are used primarily by road transporters to facilitate rapid transit through various countries en route that have signed the 1975 TIR Convention. Trucks and trailers must conform to specific construction requirements in order to avoid transit customs authorities opening and examining the cargo on board.

It is important to state that the documents outlined above are often the minimum, and other documents may be required. Advice should always be sought from professional freight management companies with specific expertise in the origin and destination countries.

Increasingly, wood used in international transport is required to be both treated and certified against certain pests. This includes many forms of wood use including crates, dunnage, reels, pallets, boxes and packing cases. There are some exclusions. The logic is that untreated wood may carry pests that could have a detrimental effect on the environment. In effect, if untreated, the wood acts as a mechanism for spreading unwanted pests around the world. Wood that has been treated should carry certain marks demonstrating that it has been treated. Currently acceptable treatments (known as phytosanitary measures) include heat treatment (HT) and methyl bromide (MB) fumigation, although alternatives to the latter treatment are being sought as methyl bromide is known to deplete the ozone layer. The regulations also apply to wooden packing that is reused, repaired or remanufactured.

The Harmonized System (HS)

The Harmonized Commodity Description and Coding System or Harmonized System (HS) was introduced in 1988 and is managed by the World Customs Organization (WCO) based in Brussels. According to the WCO this system is a ‘multipurpose international product nomenclature’, or put simply it classifies goods traded around the world. It is used by over 200 customs authorities in countries that have adopted the system and is thus virtually universal. The WCO claims that ‘over 98 per cent of the merchandise in international trade is classified in terms of the

HS'. The system is made up of roughly 5,000 commodity groups, each of which is identified by a six-digit code.

The system assists customs authorities to decide what duties may be payable, if any, on entry to their jurisdiction. It also helps them prepare trade figures. It is vital that consignors and their agents use the correct HS code when preparing documentation as the penalties for misrepresentation may be severe and lead to the cargo being impounded or at the very least delayed.

Cargo insurance

Carrier liability limits

Carrier liability for loss or damage to cargo in transit is limited by various international as well as commercial agreements. This applies to all modes of transport, although the method of limiting carrier liability varies. For example, air freight liability is limited by the Montreal Convention in 2019 to 22 special drawing rights (SDR) per kilogramme. A standard drawing right is a fluctuating international currency unit set by the International Monetary Fund (IMF) on a daily basis, with current values in local currency available on the IMF website (IMF, 2021). However, this only applies to countries that are signatories to the international agreement. This clearly demonstrates that the liability of the carrier to compensate the consignor or owner of the cargo in the event of loss or damage is set at a very low level.

There is a list of defences against carrier liability known as the 17 Hague-Visby/COGSA (Carriage of Goods by Sea Act related to cargo loading or discharging at a United States port) Defences, which include defences such as: act of God, act of war, insufficiency of packaging, or saving or attempting to save life or property at sea. The latter defence could be cited if your cargo was stowed on the weather deck of the ship and in a situation of severe weather the captain jettisoned your cargo to help stabilize the ship. In addition, COGSA limits the liability of the carrier to US \$500 per shipping unit and Hague-Visby limits liability to 2 SDRs; hence the need for additional insurance.

Therefore, it is extremely important that the consignor arranges additional insurance to cover the eventuality of loss, damage or delay in transit. In addition, it may be difficult on arrival of the goods to prove exactly where any damage occurred, especially if several modes of transport have been used. This is often referred to as goods-in-transit insurance. Insurance companies generally set the premium to be paid on a percentage of the value of the cargo. Insurance companies often increase the premium if the perceived risk of loss, damage or delay is higher. Cargo sent by sea freight in ships older than, say, 20 years may see a steep rise in premium in line

with the age of the vessel. If the routing of the cargo is to or through an area of political instability or war then this would also attract a higher premium.

Freight forwarding companies often act as brokers for insurance companies, which naturally earns them a commission, but at the same time provides a useful service to the client. They may also be able to obtain a better deal due to the fact that they purchase insurance on a regular basis. In addition, the forwarding company may be able to advise the client about some of the peculiarities related to cargo insurance. For example, the consignor is responsible for taking due care when preparing the cargo for shipment. When a package of freight is scheduled to travel a long distance and carried on various modes of transport it is imperative that the cargo is properly packaged. This will ensure the cargo is protected in such a way as to withstand being handled several times as well as protecting it from the weather or sea water. If the cargo is not professionally packaged then any potential insurance claim may be denied citing poor packaging as the reason. Your freight forwarder should be able to arrange for your cargo to be suitably packaged to withstand the rigours of international transport.

As mentioned earlier, goods-in-transit insurance can be quite baffling to those not experienced in its processes and procedures. The type of insurance purchased is extremely important if you wish to be covered for all eventualities. However, it must be understood that even the most all-encompassing insurance does not protect the consignor from absolutely every risk.

Types of insurance policy

The type of cargo insurance purchased may also vary. Essentially, goods-in-transit insurance is purchased to cover the possibility of loss, damage or delay. The most comprehensive policies cover 'all risks' although there are limits imposed by all insurance companies to what is covered.

Open cover policies may be arranged by companies who regularly transport goods internationally. Naturally these policies vary and reflect the variety of goods and companies involved. The policy may be valid for one year and cover goods in transit up to a certain value. The provisions of the policy remain the same for all the movements during the valid period. The general nature of the goods to be moved is disclosed at the time of agreeing the policy but the specifics of each movement may only need to be passed to the insurance company prior to despatching the goods or on a monthly basis. Naturally this avoids having to continually negotiate insurance deals throughout the year. As mentioned above, the insurance company may stipulate that the goods should only be carried on board ships that do not exceed a certain age, among other provisions.

For those consignors who do not ship goods internationally on a regular basis there are single voyage policies. These apply specifically for a given journey from a

named origin to a named destination, and once the goods have arrived safely then the policy ends unless, of course, a claim is made. The key point is that the policy covers a single journey only.

Insurance policies often include a provision known as the deductible (US) or excess (UK). A deductible/excess is the amount of money agreed between the insured and the insurance company that would be deducted from any claim made by the insured. Obviously the higher the amount of money deducted on claims then the lower the insurance premium would be. This can save money on the premium but the insured should be very clear that the amount of the deductible/excess agreed would have to be paid by them in the event of a claim being made.

General average

A general average is often hard for the uninitiated to understand and it is important that the insurance purchased covers for such an eventuality.

The fundamental logic of the general average may be traced back to a decision made in the British House of Lords in 1801 although the principle goes back to ancient times. The quotation below neatly summarizes the principle.

All loss which arises in consequence of extraordinary sacrifices made or expenses incurred for the preservation of the ship and cargo come within general average and must be borne proportionably [*sic*] by all who are interested. Natural justice requires this.

BIRKLEY V PRESGRAVE, 1801

The rules related to general average losses state that when losses are incurred by 'voluntary sacrifice' such as cargo being jettisoned at sea in order to save the vessel or the life of the crew or in an instance where expenses are incurred by one of the parties for the benefit of all the other parties involved in the sea voyage, then the costs would be apportioned between the vessel owners and the consignors who have cargo on the vessel. This might occur when a disabled ship requires to be towed into port.

For further clarification regarding general average losses see York–Antwerp Rules 2004, which are managed by the Comité Maritime International, Antwerp, Belgium.

If you have the right insurance then the claim from the carrier is passed to the insurance company concerned. Any repairs to the vessel may not begin until all the consignors or their insurers have agreed to pay their share of the costs. If your cargo is urgent then this would be a very difficult situation for you as you may have to wait not only for the repairs to be completed but also for all the communications with the various parties involved to be completed before repairs begin. However, in some situations the cargo may be released earlier if average guarantees are in place and alternative transport is available. The situation may be further complicated if some

of the cargo is not insured, in which case the general average adjuster (GAA) would seek cash securities.

Insurance and Incoterms®

The use of Incoterms® is an internationally agreed method for clearly delineating the risks and responsibilities between the buyer and the seller (see Chapter 25 for more details regarding Incoterms®). In the case of cost, insurance and freight (CIF) it is made very clear that the seller pays for the insurance of the cargo delivered to a named port of destination but is *only required to purchase insurance on minimum cover*. However, it is important to note that with CIF the point at which the risk of loss or damage transfers from the seller to the buyer is when the goods pass over the ship's rail at the port of loading, notwithstanding the seller's responsibility to purchase the necessary *minimum* insurance for the sea voyage. In addition, assuming the goods need to travel further from the port of entry to the final destination then the buyer would be responsible for insuring this part of the journey. The buyer is often advised by freight management companies to exercise prudence and buy insurance for the sea journey as well despite the fact that they are not strictly required to do so. Taking such action covers the buyer in the event that the seller's insurance is compromised in some way. This adds some cost but may provide peace of mind. Alternatively a different Incoterm® could be used.

Project logistics

This is a very broad term that may be applied to many operations in the supply chain. The planning and execution of the transport of a package of freight such as an oil land drilling rig would certainly fall into the category of a project. On the other hand, managing the receipt, storage and final delivery of a large number of purchase orders related to a given construction project would also fall into the same category. This is not often considered as project logistics so it is worth examining in slightly more detail.

In this scenario a client who may be ordering equipment for a project from multiple suppliers might hire a freight forwarder to manage the receipt, consolidation and onward shipment of these supplies. The forwarder would receive a copy of every purchase order raised by the client. The suppliers would be advised to deliver the goods to the freight forwarders' warehouses in different locations (and possibly countries). The forwarder would receive the goods, check the delivery for any damage, shortage or excess and then place the goods in storage. Once the client gives the instruction to deliver the goods to the final project location then the forwarder would consolidate all the different suppliers' deliveries for the said client into one

efficient load. The client would be able to access online the status of each individual purchase order as the forwarder updates the system as each exercise is completed: for example, goods received at warehouse; goods held in quarantine; goods delivered with proof of delivery scanned into the system. These are projects where certain large freight forwarders have the knowledge, skills, expertise and facilities to add real value.

Figure 33.3 Project logistics: a gas turbine skid weighing 137 tonnes being unloaded from a ship. The ship's cranes are not able to accommodate such a heavy load. The two mobile cranes both have a lifting capacity of 500 tonnes. The load is being transferred to a Goldhofer trailer with 12 hydraulic axle lines coupled to a MAN prime mover for the road journey. The freight forwarder arranged and coordinated all the logistics providers involved



SOURCE Adrian New

Any operation that may be categorized as a project would fulfil certain criteria:

- The project would have a *clear objective* such as transporting all the equipment that comprises a drilling rig including accommodation units from a given location in one country to another specific location in another country in a certain timescale.
- The project would be *time-bound*. In other words, it would have a specific start and finish date. Failure to meet the planned finish date may incur financial penalties.

- The project would be *unique*. Although many of the elements may have been undertaken before, the way that these elements combine together in this project have never happened before. In other words, it is not a routine exercise although many of the constituent elements may be routinely undertaken.
- The project would *involve complexity*. It may involve the use of multiple modes of transport, large volumes of goods, multiple stakeholders and many different countries all combined together in a complex way.
- The project might require the use of *highly specialized transport equipment* and information and communication technology. This could include specialist heavy-lift ships, road haulage or aircraft.
- Due to the complex nature of projects there is always an *element of risk*. Anything that can go wrong might well go wrong just at the time the team least expects it. This requires an *element of flexibility* not only in the thinking of the project team to solve the problem but also financial flexibility as there is almost always a financial implication.
- The project will always be subject to *constraints*. These may be straightforward constraints such as financial constraints on the amount of money available or the time limit for completion. There could also be some constraints that are not so obvious, such as completion prior to extreme weather conditions changing. For example, the ice roads used in Canada cannot be used after the ice begins to thaw and vice versa. Another example might be the trade sanctions imposed on Iran that does not allow US-based transport carriers to enter the country. The constraint may even be the fact that there is no suitable specialist transport equipment available in the country that would require the project team to source the equipment elsewhere and transport it to where it is required. This is often a problem in less well developed countries.

Common terms explained

As with all industries, freight forwarding has developed some terminology that requires further clarification. Some brief explanations are provided below.

Demurrage

Demurrage or detention is a term that often causes confusion and very often irritation on the part of users of freight forwarding services. The basic premise is that if transport assets are delayed for any reason beyond the control of the freight forwarder or logistics service provider then a charge would be levied on the client, often at prearranged rates. For example, if a truck is kept waiting beyond (say) two

hours without being loaded/unloaded or the loading is taking an unusual amount of time then the client may be charged a demurrage rate per hour. If the transport asset happens to be a ship then the detention charges could be very high.

The demurrage or detention charge is based on the principle that unnecessary or unforeseen delays cost the transport operator because they are not generating revenue when the transport asset is not moving. Some say that demurrage applies to cargo delays and that detention applies to delays of transport equipment. However, in practice the terms are often used interchangeably around the world.

In a similar fashion shipping containers that are not loaded/unloaded or customs cleared and collected within a certain permitted timescale may well attract a penalty charge from the shipping line. This is known as container detention charges.

Containers that require cleaning or repair once returned to the shipping line may also attract a charge.

Out of gauge cargo

Out of gauge cargo is cargo that exceeds the various specifications and dimensions of transport equipment. Naturally this varies according to the rules and regulations that apply in different territories.

In container shipping operations out of gauge cargo is cargo that exceeds one or other of the internal dimensions of a standard shipping container. That means any cargo that exceeds:

Length 12.024 metres

Width 2.350 metres

Height 2.387 metres

Please note that these figures may vary slightly depending on the type of container used. Shippers also need to be mindful of the maximum payload weight of a standard 40-foot container, which is 26,670 kilogrammes (this figure also varies slightly depending on the type of container used). The weight restrictions imposed on road haulage vehicles in different countries also need to be taken into account.

As a very general rule-of-thumb, any cargo that exceeds 12 metres length, 2.5 metres width and height, and weighs more than 20 to 25 tonnes may be categorized as out of gauge.

Out of gauge cargo often falls into the category of project logistics and may include heavy-lift cargo.

Shipper's load, stow and count (SLAC)

In a world where a very high proportion of cargo is shipped in ISO containers, shipping lines protect their interests by endorsing bills of lading with the term shipper's

load, stow and count. What it means is that the shipping line is accepting a container for sea transport but has no way of checking that the goods inside are what they are said to be on the bill of lading. They are also not in a position to check how the cargo has been loaded and secured inside the container. In the event that a discrepancy is found when the container is being unloaded and, provided that the security seal has not been broken or changed, then the shipping line will be absolved of responsibility. The bill of lading might read '1×40-foot container said to contain (STC) 100 tyres' and be endorsed with the term 'shipper's load, stow and count'.

Forwarder's certificate of receipt (FCR)

This is a document issued by freight forwarders when they accept the receipt of goods on behalf of a client. The FCR acknowledges receipt in good condition and responsibility for the goods. It is not a contract for transport services nor does it confer title to the goods and is not negotiable. The International Federation of Freight Forwarders Associations (FIATA) produces a standard form of FCR for use by members.

Abandoned cargo

This term is widely used to cover shipments that are not completed for many different reasons. For example, if the shipping line is not given instructions to deliver the cargo within a certain timescale then the cargo may be considered abandoned. It may be that either the consignor or consignee is unable or unwilling to pay outstanding charges and abandons the cargo. In other circumstances the consignee may have gone bankrupt or the cargo may have been damaged beyond repair. The shipping company holding the cargo may dispose of the cargo by auction or private sale after a fixed period of time or simply dispose of the cargo as waste.

PART SIX

**Outsourcing
logistics**

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Outsourcing: operations and services

34

Introduction

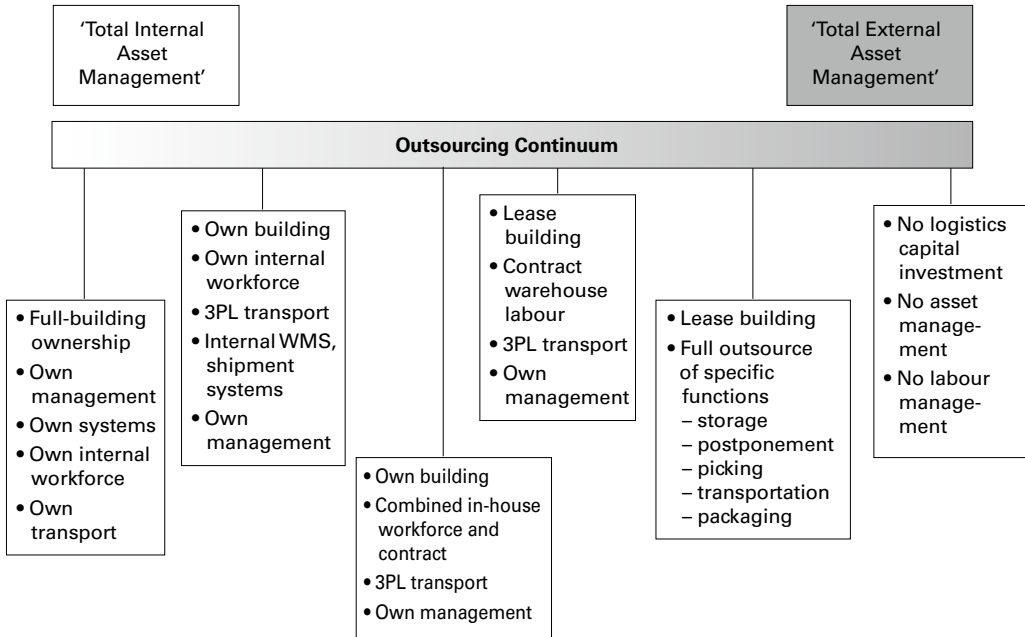
In the final section of Chapter 4 it was noted that probably the most important channel decision for those operating in distribution and logistics is whether to use an own-account (in-house) operation or whether to outsource to a third-party logistics (3PL) service. This chapter, and the following three chapters, are all concerned with outsourcing, beginning here with a review of the different outsourcing operations and services that are available. In Chapter 35 the key decision criteria for outsourcing are reviewed. Chapter 36 describes the detailed steps of an approach for the selection of a service provider. Chapter 37 considers the important question of contractor management. The concept of fourth-party logistics (4PL) was described in Chapter 5.

This chapter begins with a brief review of the breadth of outsourcing opportunities that are available based on a continuum of logistics activities ranging from total internal logistics management to total external logistics management. A summary of the most common activities that are offered by third-party logistics service providers is then given, including many elements of storage, inventory, transport and packaging. The key categories or types of available services are described. These cover the different approaches that may be considered for warehousing or depot outsourcing and the different attributes of the types of transport service that are available through outsourcing. Additional services offered by third-party logistics providers, over and above the more traditional functions of logistics, are also discussed. These are often known as ‘value-added’ services because they consist of those functions and services that add significant additional value to the product being distributed.

Breadth of outsourcing

There is a vast choice of different operations and services that can be outsourced. These include outward and inward physical flows and supporting processes. Indeed,

Figure 34.1 Continuum of logistics outsourcing showing some of the range of physical functions and services that might be outsourced



in distribution and logistics virtually every different function can be outsourced! The ultimate option is to outsource the whole operation, keeping in-house only those non-logistics functions that are deemed to be the core business of the company, such as retail shops for retailing companies. One useful way to understand the breadth of opportunities that are available for outsourcing is to view this as a continuum of services, ranging from total internal logistics management to total external logistics management. This is illustrated in Figure 34.1.

The continuum diagram illustrates just some of the different opportunities that are available across the whole scope of outsourcing physical logistics operations. Within the two extremes shown in the diagram there are a multitude of alternatives. One common approach is to outsource the delivery transport operation but keep the warehouse and storage operation in-house. However, no single solution is the 'right' answer. Any of the multitude of different combinations may suit one particular company, so the implications of all options should be explored. Also, this is by no means an exhaustive collection of possibilities, but should provide a particular perspective of what might be done.

The two ends of the scale are:

- 1 Total internal asset management:** this represents a company that has kept the entire logistics operation in-house and is not outsourcing anything. Thus, we see that it has, for example, full ownership of its logistics building facilities and has

its own management, systems, internal distribution centre (DC) workforce and transport operation.

- 2 *Total external asset management*: here the company has outsourced all of its physical logistics operations. Thus, it has no logistics capital investment, no asset management and no labour management but, importantly, retains responsibility for the actions of the service provider.

For any company that is contemplating outsourcing as an option, there are some important reasons for considering outsourcing opportunities using an approach based on the idea of the outsourcing continuum. Such an approach is helpful during the initial decision-making phase of outsourcing – trying to answer questions such as ‘should we outsource at all?’ and ‘what should we outsource?’ These aspects are discussed in more detail in Chapter 35.

So, the concept of the outsourcing continuum can help:

- to identify where the major benefits of outsourcing might be found
- to make clear exactly what is included and what is excluded as far as the contractor and the associated contract are concerned
- to make clear where the boundaries of responsibility change
- to identify the expected ‘gains’ or ‘wins’ from a contract, whether these are cost- or service-related

Logistics functions provided by 3PLs

There is a broad range of different functions or activities that are provided by third-party logistics service companies (3PLs). It is interesting to see the extent to which these offerings are taken up by their customers. A study by Langley (2020) identified the percentage of shippers outsourcing specific logistics activities across all the major geographic regions of the world. Perhaps predictably, transport and warehousing were at the forefront of those activities that were offered by 3PLs (see Table 34.1), but several less traditional activities were also significant: international transport, reverse logistics, cross-docking, order management and fulfilment and service-parts logistics. It should be noted that some companies may specialize in a certain type of operation, while others may offer all of the many alternatives that are available. The basic types of operation offered can vary in style and degree, for example, an outsourced delivery transport operation might cover just the contract hire of a single vehicle, the provision of a complete fleet of vehicles or even a fully dedicated operation including vehicles, drivers and complete transport management. A fully dedicated supply-chain-oriented package might include storage and warehousing, primary and secondary transport, management services, order processing and stock control, among others.

Table 34.1 Percentage of shippers outsourcing specific logistics activities

Outsourced Logistics Service	Percentage offering service
Domestic Transportation	73%
Warehousing	73%
International Transportation	65%
Customs Brokerage	54%
Freight Forwarding	52%
Cross-Docking	35%
Freight Bill Auditing and Payments	35%
Reverse Logistics (Defective, Repair, Return)	33%
Product Labelling, Packaging, Assembly, Kitting	25%
Order Management and Fulfilment	21%
Transportation Planning & Management	19%
Inventory Management	17%
LLP (Lead Logistics Provider)/4PL Services	15%
Information Technology (IT) Services	15%
3PL Provided Supply Chain Consulting Services	11%
Customer Service	11%
Service Parts Logistics	11%
Fleet Management	9%

shipper percentages for all regions

SOURCE Langley, 2020

A summary of the most common activities that are offered is basically a list of the key functions of most logistics operations. There is nothing original in such a list, so for anyone currently working in a logistics environment these will be well known. For those unfamiliar with all of the different aspects of logistics, some of the main ones are listed below, together with a brief comment on the operation. Note that this is not an exhaustive list, but should provide a flavour of the type of operations that can be undertaken. Also, note that there are many more sophisticated operations that are also provided and that these are reviewed later in this chapter under the heading of value-added opportunities.

Warehousing and storage

- **Distribution centre operation:** outsourcing can be undertaken for any of the common functions to be found in the operation of a distribution centre. Normally the complete set of functions is outsourced, including goods inward, reserve storage, pick, pack and consolidation for delivery. This is because it is difficult to outsource only partially such a physically intensive operation. However, the boundary between outsourcing and own operation can also be set with respect to asset ownership. Thus, as previously indicated, the ownership of the building could be kept in-house while all the other assets (people, equipment, etc) might be outsourced – or it may be vice versa (the ownership of the building outsourced and the operational assets kept in-house). Of course, a variety of alternative divisions of outsourcing and in-house ownership and responsibilities are possible within this continuum.
- **Excess storage:** this is probably the original form of outsourcing where externally owned general warehouses were used to store, in particular, goods that could not be stored in a company's own warehouse due to a lack of space. Typical examples are if large orders are received or if goods must be stockpiled for a particular event, e.g. Christmas or the summer season.
- **Cross-docking:** cross-docking operations can also be outsourced. Cross-docking is where customer orders need to be consolidated from a variety of goods that are sourced from a number of different supplier locations. As physical deliveries of the goods from these sources occur, they are unloaded and then sorted and assembled into customer orders. These orders are then loaded on to different trucks and the final customer deliveries are made. These operations use a lot of physical space and need to be carefully coordinated for both inbound and outbound movements. Some third-party companies have the facilities and expertise to undertake this.
- **Trans-shipment:** this is similar to cross-docking, but trans-shipment often refers to the sortation and onward delivery of ready-picked orders. Some third-party providers operate satellite depots in rural areas so that they can collect ready-picked small orders from different companies' distribution depots and then trans-ship these at their satellite depots to provide consolidated deliveries to local delivery points.
- **Break bulk:** examples of break bulk operations are where containers or full vehicle loads are received from abroad for final delivery in a country. The loads are broken down into individual orders by the operator and then dispatched as required to the appropriate delivery points. This might be for inward-bound raw materials for a company's manufacturing sites, or for finished goods that need to be delivered to retailers or end users. This is a classic opportunity for outsourcing.

NOTE: this should not be confused with break bulk ships, which is a different concept (see Chapter 26).

Stock and inventory

- Inventory management: linked very closely to the storage operations previously described, inventory management includes the additional responsibility of the management of all of the stock and inventory that is held. This might cover elements such as stock control, stock replenishment, stock rotation, obsolescence and other related activities.
- Specific stock responsibility: many companies like to have full control and vision of their finished goods inventory, but there are occasions when the control and management of certain types of inventory can be outsourced. Good examples are spares inventory, packaging and unit loads.

Transport

- Primary transport (trunking, line-haul): the focus on primary transport is often one of cost reduction. It is seldom regarded as an activity that ‘adds value’ to an operation, because there is no direct link to the final customer or retail store. Primary transport is all about moving the product at minimum cost, which generally involves using as large a vehicle as is legally possible and making sure that the vehicle is filled to capacity. These movements usually consist of delivery to a single drop point, and other key aspects include:
 - vehicles are operated for as long as possible, sometimes on a 24-hour, three-shift basis, to maximize vehicle time utilization
 - return loads for the vehicle are important so as to fulfil the criteria for maximum utilization
 - additional vehicle specification, for example special on-vehicle handling equipment, is less important than for delivery operations

The lack of return loads or ‘backloads’ and the difficulty of achieving these other key aspects often drive the decision to outsource the activity. This is because 3PLs have many customers, and are thus in a much better position to identify and create suitable opportunities for improved utilization and therefore lower costs.

- Secondary transport (final delivery): secondary transport and delivery usually involves direct contact with the customer or end user (or, as with retail operations, the key end user interface). These are, therefore, what are known as ‘customer-facing’ logistics operations and they can be an important part of the customer service element of logistics strategy. As such, cost reduction is not the main

operational criterion as it is with primary transport (although it is still very important!). Customer service is the major criterion.

Many customers have very restricted delivery windows (the time in which a delivery may be made). This makes the accurate scheduling of secondary vehicles very important. Service is usually critical. In particular, inventory reduction in retail shops and the increase of shop selling space and elimination of stockrooms makes timely delivery essential. This is to ensure that the shop does not run out of stock. Specialist vehicles have been developed for secondary delivery, e.g. grocery multi-temperature compartmentalized trailers. These are used to maximize the opportunity to make frequent and full deliveries of essential stock requiring different storage temperatures to the retail shops.

Secondary transport operations are thus both service- and cost-sensitive, and require particular skills for planning and management, as well as some fairly substantial financial investment. For these reasons, many companies outsource their secondary transport operations to medium and large third-party service providers.

Note also the development of horizontal collaboration (or 'grey' transport) where competitive companies in the same industry share transport space for the final delivery – because transport is regarded as a commodity and therefore not a basis for competition. This obviously may or may not involve a 3PL (see Chapter 5).

- Collections and returns (reverse logistics): normally, distribution operations are planned and designed to provide a one-way flow of physical product that is delivered to customers. The nature of the delivery vehicle, the unit load, the handling equipment available, or tight delivery schedules, may make it inappropriate for items to be collected via the outbound delivery system. Thus, many types of collection operations (damaged product, packaging, unit loads and returned goods), often known as reverse logistics, are outsourced.
- Fleet management/mobile asset management: many companies see the day-to-day management of a vehicle fleet (sometimes described as mobile asset management) as a specialist technical operation best undertaken by specialist 3PLs. Thus, although the company may schedule and manage the vehicles and drivers to give them control of their delivery operation, they can choose to outsource the management of the fleet (maintenance, legal responsibility, etc) to a third-party company.
- Contract hire: a classic opportunity for third-party providers is the provision of vehicles and/or drivers to supplement own-account fleets when they require additional resources. This might be to cover breakdowns, holidays or seasonal demand increases. The contract hire of vehicles can also be used to enable companies to avoid capital investment in new vehicles.

Packaging and unitization

- **Packaging:** there are various opportunities for companies to outsource packaging operations. These will normally be where special requirements make it difficult for the packaging to be undertaken in-house. A typical example is packaging product for export, which might be undertaken more cost-effectively if a specialist export contractor is used (see Chapter 33).
- **Labelling and product preparation:** many products are delivered to retailers from their suppliers without specific price information as an integral part of each individual item. This information often needs to be added before the goods are displayed in-store.

Also, some products may need to be presented in a special selling unit in the shop. Although shop staff can undertake this work, there has been a move to ensure that all products are sales-ready before they enter the store in order to simplify the shop replenishment operation so that all effort is concentrated on selling items rather than preparation work. Thus, many companies (and this may be the suppliers or the retailer) may now outsource these types of operations to a third party.

- **Unit loads:** for operations that use a large number of unit loads (pallets, roll-cages, etc), it is important to have close management and control. This is often for reasons of both cost and supply. The cost reasons are to minimize costs by reusing the unit loads as often as possible (thus keeping down the capital costs by reducing the need to purchase new units). Supply reasons are to ensure a reliable availability of units at the end of the production process. This is an operation that is sometimes outsourced.

Others

- **Product inspection:** all products that are bought in, especially from abroad, are likely to need to be physically inspected to check for quality. This can be heavily labour and space intensive, and so is an operation that can be outsourced, providing this does not create additional movement of the goods to an unnecessary location. It is possible to have this undertaken at the country of origin prior to the export of the shipment or in the importing country as part of the delivery process (see Chapter 26).
- **Merchandising:** similar to labelling and product preparation, merchandising is another operation that can be outsourced. This involves the preparation of the product for display and sale, and here also involves the review of stock levels in the shop as well as the arrangement of the goods on the shelf in the shop.

- Telesales and call centres: this is another discrete specialist area that can be outsourced. Although not always classified as a logistics operation, very often telesales, or call centres for catalogue sales, ultimately involve order-taking into a system that is linked to the warehouse management system. The operation is, therefore, specifically oriented to logistics.

Types of services available

This section of the chapter concentrates on the many different categories or types of services that are available. The major category, and the initial decision that needs to be made by a potential user of third-party logistics services, is whether to have a dedicated solution or a multi-user solution. A dedicated operation is where an exclusive logistics or distribution operation is provided by a third-party company for its client company. In other words, the operation is set up and run for just a single client. A multi-user operation is different to a dedicated operation because a group of client companies is catered for, within the service provider's operation, rather than just a single client. The key factors concerning the decision to choose either a dedicated or a multi-user operation are discussed in Chapter 35.

Once again, the categories described in this section are organized around the two key logistics components of warehousing and transport. Also considered, however, are some alternative opportunities for the occasional use of outsourcing.

Warehousing

The categorizations of service in this section describe the different approaches that may be considered for warehousing or depot outsourcing. These are not all mutually exclusive of each other. For example, a satellite operation may also be part of a national operation. They are:

- Specialist distribution operations: these distribution operations are used for the storage of products that require special facilities or services, and the distribution operation run by the third-party company is especially tailored to suit these needs. Specialist operations can be either dedicated or multi-user, including areas such as frozen food and hanging-garment distribution. In addition, in the grocery industry, for example, many of the grocery multiples will outsource a specialist depot for particularly low-demand items and for very large items that require specialist storage, handling and picking and so do not fit well with their normal logistics operations.
- Regional multi-user distribution operation: these multi-user operations are provided for any number of clients, and for most product types. They are usually

provided by a 'general' third-party distributor that has probably started as a very small operation and grown into a regional operation concentrated in a specific small geographic area.

- National multi-user distribution operation: this category is very similar to the previous one, a service being provided for any number of clients and product types. The main difference relates to the size of the operation. This is country-wide, and would probably include a number of depots linked by a primary transport (trunking, line-haul) operation between these depots. Thus, a client company can have their products delivered to anywhere in the country. A client company's products might be located in just a single depot, a number of depots or in all of the depots in the third-party network structure.
- Satellite operations: these are operations where the operator is not involved in the storage of any products, but is only providing a break bulk and delivery service. Thus, no unordered stocks are held, although in practice some minor stockholding may occur for a limited number of product lines. Many manufacturers and suppliers now use satellite depot operations to enable them to minimize their inventory-holding requirements (perhaps to a single central depot) but to achieve a very large delivery 'reach' to a wide geographical area through overnight distribution of picked orders from the central depot, which are trans-shipped at satellite depots for onward local delivery the next day. This type of service is most commonly undertaken by third-party service providers.
- Cross-docking: as described earlier in this chapter, cross-docking is often used to enable customer orders to be consolidated from goods that are sourced from a number of different locations. As physical deliveries from these sources occur, orders are immediately assembled and, on completion, the final customer deliveries are made. These operations use a lot of physical space and need to be carefully coordinated for both inbound and outbound movements. Some third-party companies have the facilities and expertise to undertake this, so it is a commonly outsourced activity. Also, third-party companies are used for this type of service when manufacturers or suppliers do not have their own depot in a particular geographic area.
- Joint venture: a limited number of operations have been set up whereby a third-party operator and a client company form a separate distribution company called a joint venture. This may occur where a manufacturer with its own distribution operation has some underutilized resources. It will then link up with a third-party operator and offer the services on a wider basis. This has occurred in the hanging-garment and the hi-tech sectors.
- International distribution operations: these may be dedicated but are most likely to be multi-user, enabling a client to achieve international movements between sites and delivery to final customers over a broad international area. It is still

difficult in a European context to find a single third-party operator that can provide such a universal service across the breadth of the European continent.

- **Composite depots:** these are really a specific area of specialization in the grocery industry. Over many years, the logistical structure of grocery multiples has varied from depots where only a single product type is stocked and distributed (frozen food, chilled food, fruit and vegetables or ambient) to what is known as a composite depot in which all product types are held. A mixture of goods from these different product types is also transported together on what are known as composite delivery vehicles for delivery to superstores and hypermarkets. These are all dedicated operations and usually consist of extremely large and sophisticated depots with expensive delivery transport fleets. Once again, it is an area where the biggest logistics service providers are prevalent.

Transport

The various types of transport service that are available through outsourcing are here classified in a different way from that used for warehousing. There are four main attributes that can be used to differentiate these broad service types. These are:

- **Asset dedication:** this is determined by whether or not the assets are dedicated to the client (either a multi-user or a dedicated operation).
- **Speed of delivery:** this is a key service feature. The range includes same day and next day delivery, or any agreed service level.
- **Size of consignment:** the size of consignment obviously has a big impact on both service and cost. Size can be represented in weight, cubic volume or number of items/units.
- **Contractual basis:** the basic difference here is whether the arrangement is a 'one-off' transactional agreement (sometimes called 'spot hire') or whether a specific (generally medium- to long-term) contract is drawn up and signed. The nature and type of contract can also vary quite significantly.

The key question of cost is negotiable according to the services that are required, although, of course, many transport operators have distinct tariffs that they work within. As a general rule, costs will be higher the larger the load and the faster that the delivery is required. A summary of this very traditional breakdown of broad third-party transport service types is given in Table 34.2. This is a very broad attempt at categorization and there are undoubtedly several elements where some overlap occurs. Nevertheless, this classification is useful in clarifying some of the main attributes of the options that are available. Note also that different cargo or product characteristics (such as frozen, liquids, powders, hazardous, out of gauge) may restrict the use of some of the different services offered.

Table 34.2 A breakdown of the broad third-party transport types, showing some of the different attributes

Broad Service Type	Asset Dedication	Speed of Delivery	Size of Consignment	Contractual Basis
Express	Shared	Same/next day	Small parcel-size	Transaction (could be contract for such as mail order)
Groupage/LTL	Shared	Slower than express/several days	Larger than express/pallet-size plus	Transaction
General haulage	Shared (but could be contract)	Slower than express/48 hours plus	Any size	Transaction ('spot') or contract
Multi-user	Shared	Slower than dedicated/next day or longer	As required	Contract
Dedicated	Dedicated	As required	As required	Contract

The main service types indicated in Table 34.2 are:

- **Express:** usually this will be a parcels operation or an express courier service where the emphasis is on the speed of delivery. Non-urgent parcels are often sent via the national or international parcel post where both the costs and the speed of service are lower. Express services are normally transactional, but for some large-scale operations, such as mail order, contracts will be used.
- **Groupage or consolidation services,** sometimes referred to as less than truckload (LTL): this is a very traditional style of transport service. The major attraction is the ability to send small orders via a low-cost transport option. Thus, small orders from any number of companies are consolidated together into full vehicle loads. The main drawback with groupage is that orders may take a long time before the final delivery is made. This is because time is lost as orders are collected together to create a full load. These options are very much shared rather than dedicated.
- **General haulage:** this is another very traditional means of outsourcing transport – one that was in existence for a long time before third-party distribution became established. General haulage is now commonly used by manufacturers and suppliers that need to have non-standard products moved – typically those that cannot be easily unitized. General haulage can be shared or dedicated, dependent on the size of the load and the length of time that a relationship is expected to be required between user and contractor. Transactions are typically of two types, as described above: either transactional (known as 'spot hire') or contractual. The

former is used for small and occasional loads, and the latter if there is a particularly large load or movement required, because a more formal arrangement is preferable.

- **Multi-user:** this type of service can be used for both transport and warehousing. Asset dedication is shared as this is the basis of a multi-user environment. Multi-user services are generally contract-based (though occasionally transactional), consignment size is variable and speed of delivery is also negotiable, but is likely to be slower than that for dedicated operations.
- **Dedicated:** this type of service can be used for both transport and warehousing. Assets are dedicated, size of consignment is variable and speed of delivery is negotiable.

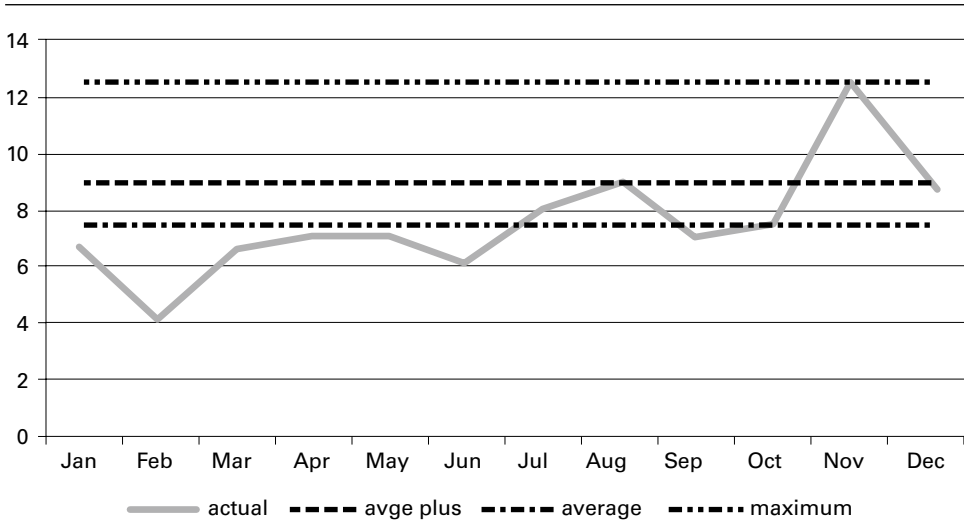
Multi-user and dedicated services are compared in the next chapter.

Occasional use

Many companies use third-party services on an occasional basis or as a supplement to support their own-account operations. There are a number of different opportunities available and these services represent an important input to shared and multi-user operations. Examples include:

- **Seasonal peaks in demand:** most own-account operations should only be resourced up to a level that will allow the company to run the business for somewhere between average and peak demand. If a business has resources that allow it to operate at peak levels, then it is likely that many of the resources will be under-utilized for much of the year. Thus, for a correctly resourced operation it will be necessary to outsource at seasonal or peak periods of demand. This is demonstrated in Figure 34.2. The graph illustrates that the company should resource its fleet to the level of either the lower or the middle straight line (at average demand or average plus 10 to 20 per cent). Thus, outsourcing is required before December – the Christmas peak – and in August – the summer (using the average demand resource level).
- **Weekly demand peak:** similar to the previous example of annual demand, many own-account operations may only be resourced up to a level that will allow them to run the business for somewhere between average and peak demand during the week. Thus, it may be necessary to outsource for peaks of demand that occur during the week.
- **Non-standard products (abnormal or ‘uglies’):** many distribution operations are designed to cater for standard palletized products. Those products that are not easily palletized, ‘ugly’ or abnormal products, may be outsourced to a third-party operation – often one that specializes in distributing these types of product. Good examples of this include very small or very large products (in the retail grocery industry), or hazardous products.

Figure 34.2 Annual demand, showing that the fleet should be resourced between average or average plus 10 to 20 per cent, and so some transport should be outsourced at the two peaks



- **Peripheral geographic areas:** the demand for many companies' products will be concentrated in certain geographic areas – for retailers this is likely to be in highly populated areas of the country. In rural areas, for example, where there is only limited demand for their products, it is often uneconomic for retailers to run their own distribution operation, so they use a regional third-party company to undertake the distribution for them.
- **Non-standard operations:** certain non-standard operations are not easily undertaken within a typical distribution operation. These may be outsourced to third parties who specialize in those elements of logistics. A good example is ice cream. This may be retailed with other confectionery products but cannot be transported with these products in ambient transport vehicles. Thus, a specialist refrigerated multi-user transport operation must be used for the ice cream.
- **Pallet distribution via networks:** some companies operate their own transport fleets but these are not set up to deliver small quantities of pallets to a wide area. Other smaller companies may require pallet distribution but do not have their own transport. Thus, there are a number of pallet distribution providers that offer specific pallet delivery systems for small companies that operate across regional or national boundaries.
- **Spot hire:** there are often occasions when additional resources are needed over and above the normal operating requirements. This may be due to additional one-off demand (an unexpected order or an exceptionally large order), an urgent order, or through sickness or vehicle breakdown. This may necessitate the hiring

of extra vehicles and drivers. Resources are then hired from third-party service providers (or general hauliers) on what is known as a spot basis.

- Promotions and product launches: for many businesses, the introduction of special offers, promotions or new products is a means of stimulating additional sales. It is not always possible to forecast the exact impact of such activity. For any really successful promotion or product launch it may well be the case that the existing distribution operation is unable to cope with the increased demand on its resources. Thus, third parties are called in to provide any additional resource requirements.

Specialist value-added services

There are also many additional services offered by third-party logistics providers, over and above the more traditional functions of logistics. These are often known as 'value-added' services because they consist of, in particular, those functions and services that add significant additional value to the product being distributed:

- Niche services: these are where the complete operational package is specifically designed for the distribution of a particular product type. There are many examples in a number of different market sectors – automotive, electrical/electronic, hanging garments, high tech, etc.

The development of hanging-garment distribution is typical – here the entire distribution operation, from production point through finished goods warehouse, primary transport, distribution centre, delivery transport and into the retail store, is all provided on hanging rails. Products are thus stored and moved as 'sets' of garments on hangers. Some of the storage operations use very sophisticated automated systems.

- Time definite services/sequencing centres: time definite outsourcing services have been set up to support the just-in-time operations of major manufacturers. Typical examples are the sequencing centres that have been developed in the automotive industry to support line-side production. All of the major automotive companies use this approach and several different third-party companies provide this type of service. These centres allow for line-ready production modules to be supplied directly to the production line so that the relevant components can be introduced into the manufacturing process at exactly the appropriate time. This is probably one of the most complex logistics operations there is, as an automotive production line may have different models moving down the line and each of these models will have a large number of different components. Ensuring that the correct item reaches the correct point of fit on the production line at the right time requires considerable computing power and logistics expertise. Sequencing centres are usually co-located with the production facility.

- Production and assembly: in some instances, the final manufacturing or assembly of products takes place outside the manufacturing environment but within the logistics operation. The computer industry offers a number of examples where basic products, such as PC monitors, PC processing units or laptop computers are initially distributed to the relevant market before being finally made ready for the end customer. This is likely to include the ‘badging’ of the equipment with the appropriate name and the installation of the final language software, keyboard and power pack. This is often undertaken by the third-party distributor (see the section on ‘flexible fulfilment’ in Chapter 13).
- Inbound logistics: the provision and movement of goods into a manufacturing company is also seen as an area for additional value-added service. This involves the coordination of the collection of the raw material, component and packaging products that a manufacturing company requires. It typically might include not just the collection and transport of all these different products, but also the stock control, ordering and order progress chasing. It offers a good opportunity for cost saving and improved stock and supplier control, and is a service that several 3PLs offer.
- Repacking for sales: for some product offerings it may be necessary for goods to be repacked before they are ready for selling. A typical example is the need to blister-pack two different items that are derived from separate manufacturers or suppliers but are to go out as a distinct retail product – a torch together with a battery, for example. This is another niche operation favoured by a few specialist distribution companies.
- Pre-retailing: this refers to products that are prepared for immediate use in the retailing environment. This may involve removing goods from their outer packaging, labelling, etc. In the clothing industry, particularly for boxed items, additional services will include cleaning and pressing to make the garments shop-ready.
- Retailing point-of-sale material: another example of a retailing value-added opportunity is that of point-of-sale (POS) material. Many POS requirements cannot be easily identified and distributed through standard order and physical systems. Thus, this has become an area of specialization for some third-party operators. For example, in the UK, a third-party logistics services provider operates a system for a major supermarket chain that allows them to identify, for individual shops, exactly what POS items and printed materials are required. The 3PL provider can then print and produce the appropriate requirements based on shop size and profile, and then deliver them to the shops.
- Aftermarket or service-parts logistics: the supply of many products is supported by the subsequent provision of service-parts to enable the continued use of the

initial products. For many logistics operations, the physical structure and processes of the original distribution methods are inappropriate for providing the spare parts. Aftermarket supply involves many parts from many suppliers to a wide range of customers. Eventually, this process involves non-current parts, minimum batch sizes and obsolete items. Added to this can be the time criticality of parts with a global geographic coverage. Outsourcing to a specialist service-parts logistics company is, thus, a very attractive solution to a very difficult problem.

- Traditional home delivery: for some time now, third-party contractors have developed and run home delivery operations for products such as white goods and brown goods, covering delivery, installation, return and repair, refurbishment or disposal. They typically provide nationwide fulfilment of consumer electronic goods for manufacturers, retailers, insurance companies and service providers. Also, parcels operators have specialized in the home delivery of small orders for a variety of different clients, such as mail order companies.
- E-fulfilment: internet shopping is now very common and there is a corresponding demand for the fulfilment (or e-fulfilment) of internet orders. Although internet access provides a direct and instantaneous link from the customer to the selling organization, the actual physical fulfilment must still be undertaken by more traditional physical means, with the notable exception of digitized products such as music, films, books, photos, training courses, etc, where the internet is in this sense the method of distribution. For small product items that need physical distribution, this is usually undertaken using postal or parcel services. For larger items, new means of physical distribution for home delivery are necessary because traditional channels are inappropriate.

Many e-fulfilment operations require a specialized approach, and most of these approaches have been developed by 3PLs. Those companies involved in grocery home delivery have, for example, developed specialist small vehicles that have compartments for the different types of grocery products: ambient, fresh, chilled and frozen. A number of different logistics solutions are still used for the storage and picking elements. One option is to build specialist home delivery depots or e-fulfilment centres. Some operations, however, pick from large retail hypermarkets while some stock and pick within designated areas of existing DCs (see also Chapters 5 and 21 for further discussion).

- Returns or reverse logistics operations: there are many instances when goods need to be returned to the distribution depot or, eventually, back to the manufacturer. These are called returns or reverse logistics operations where products or packaging have to travel the reverse journey back up the supply chain. It is often very difficult to organize this effectively on outward-bound delivery vehicles because it may, for example, affect set delivery times to stores or customers. Many companies now use third parties to undertake these reverse flow movements. For

larger companies full-scale dedicated operations are now used – again, particularly by the grocery multiple retailers and internet retailers such as Amazon.

The main reverse logistics operations undertaken by 3PLs include:

- **E-returns:** one area of significant impact has been the e-returns arising from home-delivered items that customers do not want due to size, style or damage issues. These need to be sent back by post or collected from customers' homes and returned to the seller. Many parcels' operators have developed reverse logistics or returns operations that enable collection from homes and return to suppliers.
- **Packaging returns:** linked to environmental legislation, 'producers' of packaging waste in the EU are legally responsible for the collection of packaging and packaging waste for reuse or disposal (see Chapter 42). As already indicated, this type of reverse logistics is difficult to perform through traditional outward-looking logistics operations; thus, a number of third-party operators have set up specialist reverse logistics systems, in particular for the large grocery multiples. Examples include the development of recycling centres for the disposal of waste, and the repair and washing of reusable containers in the grocery industry. Examples include the cleaning and reuse of some containers in the fruit and vegetable industry.
- **Product returns:** another issue that has arisen due to environmental concern is legislation for the return of consumer products that have reached the end of their working life. In the EU, this is reflected in the Waste Electrical and Electronic Equipment (WEEE) Directive (see Chapter 42). The objective of this EU directive is to reduce the amount of WEEE being produced and to encourage its reuse, recycling and recovery. Organizations that manufacture, supply and use electronic and electrical equipment are all covered by this legislation and there are significant implications for their operations. Due to the difficulty of undertaking this through existing logistics structures, it is a prime opportunity for third-party service providers to set up and run reverse operations to fulfil these legislative requirements.
- **Refurbishment:** in the light of current environmental legislation many manufacturing companies have endeavoured to re-engineer their products so that parts from some used products can be reused in new products. For cars in the EU it is a legal requirement. It is necessary to return these parts through the supply chain to the manufacturer. This has provided further opportunities for 3PLs to offer this return-and-refurbishment service.
- **Information management:** the availability of Big Data sets and other advances in information technology have enabled a vast amount of detailed logistics and demand data and information to be available and to be manipulated very easily

and quickly. Some 3PLs have identified this as an opportunity to devise suitable processes to support these developments. Detailed information can be made available for individual customers, concerning not just product preferences but also customer service requirements that are distribution-specific (delivery time preference, order size preference, invoicing requirements, etc). In addition, systems have been developed for order fulfilment software to support selection via customer fulfilment centres or store picking, packing and delivery.

Outsourcing: decision criteria

35

Introduction

In this chapter, the key decision criteria concerning whether or not to outsource all or part of a logistics operation are discussed. Initially, the difference between a dedicated and a multi-user operation is explained. This is particularly important because some of the key advantages and disadvantages for outsourcing are influenced dependent on which of these alternative approaches is to be adopted. The main content of the chapter concerns the drivers and drawbacks of outsourcing logistics operations.

Different types of operation: dedicated or multi-user?

There is a multitude of different factors that need to be considered when a company assesses the question of whether to outsource its logistics operation or to keep it in-house. In order to make this assessment it is essential to be aware of the two key types of outsourcing that can be undertaken: a multi-user solution or a dedicated solution. It is important to understand this difference because some of the key drivers and drawbacks for outsourcing may apply to a dedicated operation and not a multi-user operation – and vice versa.

What is the difference?

Dedicated operations are normally used by large companies, but the basis for any decision can be a trade-off between cost and service. Generally, small to medium-size companies, due to their lack of scale, cannot afford the high costs associated with an operation that is exclusively dedicated to their logistics operations, so they opt for a multi-user solution. However, there may be occasions when the service they need for their customers requires that an exclusive operation is used. The two alternatives are as follows.

Dedicated (or exclusive) operation

This is where an exclusive logistics or distribution operation is provided by a third-party logistics (3PL) services provider for a single client company. The 3PL undertakes to provide the client with the necessary distribution facilities and operations, exclusively, on an international, national or regional basis as required. The resources used may include – all or a combination of – warehouses, distribution centres, transport fleets, managers, etc. Thus, the service provider sets up a specific operation to run all of these different elements for the client that is exclusive to the client company's products – an operation dedicated to that client alone.

Very large companies may use several 3PL service providers to run various parts of their supply chain operation. The opportunities for dedicated operations are usually confined to very large companies because of the scale and cost involved. Most large retailing companies have at least some dedicated third-party logistics operations.

Multi-user (or shared-user) distribution operation

Multi-user distribution operations are different to dedicated operations because a group of client companies is catered for, within the service provider's operation, rather than just a single client. Ideally, there will be some similar characteristics among the different companies that are within the same operation so that there are clear advantages gained in linking them together. For example, the clients may all be manufacturers or suppliers of similar goods and their products may all be delivered to the same or similar customers – electrical goods to retailers, food to catering establishments, etc.

A shared-user operation is very similar to a multi-user one. It occurs when a single client company has a dedicated operation that is operating at less than full capacity. Here, additional smaller clients may be taken on for storage and picking within the depot or for delivery via the transport operation. Thus, there is one major client together with a few much smaller clients. Although they are often known as shared-user operations, they are, in essence, multi-user operations that have initially developed from dedicated operations. Such an operation may be owned and operated by the third-party logistics company, or may be a joint venture between the third-party operator and the main client company.

The major advantage of both of these multi-/shared-user approaches is that expensive logistics operations and costs are shared between the clients so all parties enjoy the benefits.

Which operation to choose?

As with many decisions within logistics, the most appropriate solution is based on achieving a suitable balance between service requirements and operational costs. This is true for the dedicated or multi-user option. As a general rule:

- 1 A dedicated operation may provide superior opportunities for service but at a high cost.
- 2 A multi-user operation may provide opportunities for low-cost logistics but could mean a compromise for service requirements.

Figure 35.1 summarizes this, showing the key factors in the dedicated or multi-user decision process, and emphasizing the differences in terms of service and cost advantages and disadvantages. The key elements are described below.

Figure 35.1 The key trade-offs between dedicated and multi-user distribution emphasizing the different cost and service advantages and disadvantages

	Dedicated	Multi-user
Advantages	• Organization and resources focused exclusively on the customer • Specialism and loyalty of staff • Specialism of depot, handling equipment and delivery vehicles • Confidentiality of customer’s product specifications/promotional activity Service	• Scale economies gained by sharing resources between a number of clients • Consolidation of loads enable higher delivery frequency • Opportunity to find clients with different business seasonality to maximize utilization of assets Cost
Disadvantages	Cost • Total costs of the operation borne by the sole customer • Off-peak seasonal under-utilization of resources	Service • Conflicting demands of each customer can compromise service • Staff do not gain specialist customer knowledge • Equipment is not specialized and may not exactly meet individual customers’ requirements

Cost perspective

From a cost perspective, major savings can result from the economies of scale that are achieved with joint operations when the key resources are shared among a number of clients. Most small and medium-sized companies that try to run single dedicated operations are unable to maximize the use of a variety of resources such as:

- storage space
- warehouse equipment

- specialist warehouse labour
- delivery vehicles
- delivery drivers

Such operational scale economies are gained through the use of a multi-user option, as well as the scale economies arising from spreading the cost of overheads across a much wider range of activities. The consolidation of loads enables higher delivery frequency to be achieved and also leads to better load utilization in vehicles. Also, there is often the opportunity to find and link together clients with different business seasonality, thus creating an opportunity to maximize the utilization of assets throughout the year.

Service perspective

From a service perspective, the dedicated operation provides the major advantages. All of the organization and resources within the operation are focused on the single client. In a multi-user operation there may be conflicting demands from different clients, which might compromise the service that is provided. An example concerning delivery transport might be that one company requires early morning delivery of its products, but another has restricted delivery windows at lunchtimes that need to be met. It may not be possible to meet both of these requirements effectively within the same multi-user delivery operation because of the implications for cost and vehicle utilization.

Dedicated operations also allow for staff to become more specialized in terms of product familiarization and operational requirements. This can, for example, help to maximize the accuracy and speed of picking performance because order pickers are more often than not dealing with the same products and the same product locations. Staff in a multi-user operation do not get so much opportunity to gain specialist customer knowledge, due to the number of different products and clients with whom they will be dealing, as well as the continual change in clients using the operation.

Service is also often enhanced in dedicated operations through the specialization of buildings, depot storage and handling equipment, packaging requirements, unit loads and delivery vehicles. Once again, the existence of a single client means that all of these different distribution elements can be designed specifically for that client in terms of what is most suitable for the demand characteristics of the product and the customer service that is required.

For multi-user operations, it is often not possible to deal appropriately with some special requirements because, in general, only standard equipment, procedures and processes are used by the 3PL. Some exceptions may be possible, but, where they are feasible, they will be at a cost, which must be met solely by the client that requires

them. Thus, some service demands may be adversely affected because not all individual customer requirements can be met.

In summary, large companies and organizations can afford the cost of dedicated services, while most small companies are better suited to multi-user operations. It is the medium-sized companies that have to consider their options carefully, in order to make the right choice and balance between service and cost.

Drivers and drawbacks of outsourcing logistics

There is a multitude of different elements that need to be considered when a company assesses the question of whether or not to outsource its logistics operation. A number of advantages and disadvantages can be claimed both for and against third-party and in-house distribution. Some of these can be objectively assessed, while others are subjective, relating, perhaps, more to conventional viewpoints and personal preference than to anything else. The major criteria for consideration have been split into different categories as follows:

- organizational
- financial
- service
- physical

Some of the issues that are covered may apply more specifically to multi-user operations rather than to dedicated operations or vice versa. As already indicated, generally a client requiring a dedicated operation is able to define and buy a specially designed service from the supplier, so many of the issues will not apply. Thus, it must be remembered that as well as the main decision whether or not to outsource, there is also a crucial decision for a company to make as to whether to use a dedicated or a multi-user operation. The decision, as so often in distribution and logistics, is a question of a trade-off between cost and service. However, there are also other aspects that need to be considered.

Organizational factors: advantages and disadvantages

One of the prime reasons quoted for outsourcing is the opportunity for users to focus on their *core business* or *core competence*, be this manufacturing or retailing. There are both organizational and cost benefits to be gained from this. Various benefits related to the saving of capital costs are discussed in the section on costs later in this chapter. The organizational advantages are more difficult to measure,

but concern the opportunity for companies to streamline their organizations and particularly to concentrate their own management expertise in their core business areas.

The use of a third-party company can provide the user company with *access to wider knowledge*. This may be through the opportunity to use leading-edge technology such as advanced warehouse management systems (WMS), track and trace, geographic information systems (GIS), or by providing a broader management experience and knowledge beyond that of their own industry. This will enhance the opportunities to improve the operation.

It is thought that 3PLs may *lack the appropriate experience* of client companies' products and markets, but the growth in specialist distribution companies has helped to challenge this point of view.

There may be an issue with *cultural incompatibility* between contractor and client. It is now recognized that company cultures can vary quite dramatically from one to another. It is important that there is no clash of culture in a contractor/client relationship because this may lead to problems in the way that the operation is run.

It is claimed that the use of third-party distribution can mean a *loss of control over the delivery operation*. This may be important if logistics is seen as a major element of competitive advantage. Any lack of control can be reduced, however, by buying the right service at the outset, and by carefully monitoring the performance of the distribution company in terms of the service that it is actually providing.

There may also be a *loss of control over the company's logistical variables* if a third party is used. This means that the company is no longer in a position to define the number, type or size of distribution centres, or vehicle types and sizes. Once again, if this is important, the company must choose the third-party structure that suits it the best or it may, of course, choose a dedicated operation where these elements are provided exclusively for the company. Perhaps of greater concern, however, is the fact that, as the contractor owns the systems and logistics resources, the balance of power has shifted away from the user to the contractor.

When moving from an own-account to a third-party operation, there is thought to be a *loss of distribution and logistics expertise* in the user company. This will make it more difficult for the user company to revert to an own-account operation should it so wish. Clearly, the maintenance of some distribution and logistics expertise within the client organization would help this, as well as enabling a better-informed monitoring and assessment of the actual performance of the contractor.

It is said that *brand integrity* cannot be guaranteed if an operation is outsourced. For example, using a third party means that the company does not have its own livery and brand name on a vehicle, so the value of advertising on a vehicle is lost. This is not an issue for most companies, but one that is quoted by some. For dedicated contract distribution this does not apply because the livery of the client company is often used on the vehicles.

There might be problems maintaining the *confidentiality of information* when using a third-party distribution service. This may arise if products are mixed with those of competitors. This is an issue that has hampered the take-up of 3PL services in some newer emerging logistics markets.

Financial factors: advantages and disadvantages

There are several financial and cost advantages claimed because of the elimination of asset ownership. In particular, there are *capital cost* advantages through using third-party distribution, because the client company does not have to invest in facilities and resources such as distribution centres and vehicles as it would for its own operation. Thus, the capital can be invested in more profitable areas of the business, such as new production machinery, retail stores, etc.

A *one-off cash injection* can occur when the service provider pays for existing assets that are owned by the client company but are transferred to the service provider at the start of the contract. The client can then use this cash input to help in other parts of the business. Such a transfer of assets from client to service provider can be a very important aspect of logistics outsourcing because most in-house operations have a great deal of cash tied up in DCs: warehouses, vehicles and other equipment. Clearly, any transferable assets must be suitable for the operation that the service provider has planned.

Associated with the elimination of asset ownership is that the reduction of ownership and responsibility for plant, property and equipment means that these items can be taken off the balance sheet. This may make the company more attractive from an accounting perspective, as *fixed costs are converted to variable costs*.

A particular advantage for multi-user operations is the opportunity to benefit from cost savings through *economies of scale*. Many own-account operations are too small to be run economically in their own right. If a number of operations are run together by a third-party company, the larger system that results will be more economic because a single large distribution centre may replace the three or four sites used by the different smaller companies. This will provide cost savings through reduced overheads, better utilization of equipment and labour, etc. Note, for example, that EU legislation (Acquired Rights Directive) and UK legislation known as TUPE (Transfer of Undertakings (Protection of Employment) Regulations) prevents the reduction of the terms and conditions of the existing workforce in the short term and is therefore no longer a driver for outsourcing, although it may be elsewhere (Acas, 2021).

Linked closely to the previous point, and an advantage for multi-user distribution, is that third-party operations may provide day-to-day *operating cost* savings. This is because the various labour and equipment resources may be run more efficiently at the operational level.

Third-party distribution allows for a *clearer picture of actual operating costs*. Payments need to be made on a regular basis, usually every month, and this makes the actual distribution costs very visible. Reporting systems are generally more transparent than for own-account operations.

It may be the case that the *changeover costs* of moving from own-account to third-party distribution are such that it negates the overall financial benefits, because some costs cannot be retrieved. The most likely areas are the sunk costs of existing owned sites, any fixed low rents or, perhaps, any long-term leases on property that have to be paid. Also, some vehicles and equipment may be relatively new and of high value, but not usable in the operation that the service provider has planned so cannot be transferred to the 3PL.

Service factors: advantages and disadvantages

It is a question of some debate as to whether or not *service levels* are better or worse when third-party distributors are compared to own-account operators, but as a general rule service levels should improve following a move from in-house to outsourced operations:

- For dedicated operations, there should be no significant difference in service level provision between an outsourced and an in-house operation because the outsourced operation is an exclusive one and will be undertaking exactly the same business as the in-house operation. However, service level improvement is often achievable through outsourcing because an existing in-house operation may suffer from inertia to change, making it difficult to identify and also to put into practice any potential service improvements. As part of the process of change, it is, nevertheless, important that sufficiently detailed service level agreements (SLAs) are produced at the inception of the contract to promote service level improvement.
- For multi-user operations, delivery service should be better. This is because many third-party distributors make more frequent and regular deliveries to their delivery points due to the higher demand resulting from distributing for several companies together. This is known as the density problem within delivery operations, whereby small own-account operators have insufficient delivery or order density in their network to make separate delivery operations viable. Basically, vehicles would have to travel uneconomically long distances between deliveries. Thus, outsourcing to a multi-user third-party transport operation should lead to improved service levels. This applies particularly in remote rural areas. It is claimed, however, that the mix of different company products within multi-user warehouse operations can lead to service (picking) problems due to the unfamiliarity of new and different products from the various companies that use the operation.

The use of a third-party distribution operation should offer *greater flexibility* to the user company. This is particularly true when a company seeks to develop new products and services, and new markets. A company that intends to launch its products into a new geographic area will find it far more economical to use a third-party service provider rather than developing an expensive new logistics infrastructure in an area where initial sales are likely to be low and subsequent success for its products is not guaranteed. This has been seen, for example, by companies moving into the evolving markets of Eastern Europe. Also, as a company introduces new products and services it may find that they do not fit easily into their existing logistics structure. Third-party operations may fill these gaps more effectively. For example, many companies that now offer internet sales and home delivery outsource the physical elements of the operation to specialist home delivery service providers.

As indicated in the previous chapter, third-party companies are able to offer a number of *value-added services*. These may provide a significant added attraction to user companies. For example, the use of a track and trace facility may be a competitive advantage that has a very positive impact for key customers.

It is often thought to be easier to initiate logistics service improvements via a third party rather than through an own-account operation. This is because incentives for service improvement can be written into service contracts for third-party companies. These are likely to be *performance-related incentives*.

Service level improvement may be achieved through a multi-user third-party operation via *more frequent delivery*. As already indicated, the use of a third party can greatly improve service levels because deliveries are likely to be more frequent than can be undertaken by a small own-account operation.

Physical factors: advantages and disadvantages

As businesses evolve, particularly in the context of both global sources and global markets, logistics and supply chain structures have become very complex. This *complexity* may best be planned and managed by a third-party company that has a broad international experience of the many different logistics elements. This may involve longer travel distances, many different modes of transport, customs procedures, varied types of distribution centre, cultural diversity, etc.

The *need to relocate* logistics facilities can also be an important reason or opportunity for outsourcing. Relocation in a logistics context normally means that a strategic study has indicated that demand and perhaps supply points have shifted such that existing distribution centres are inappropriately located and that some need to be closed and other new ones opened. This is potentially an enormous cost to any company as well as being potentially very disruptive to operations and service levels as the process of change takes place. Thus, it may become both financially and operationally attractive to outsource.

For some companies, the move to a third-party operator provides a major opportunity to solve any *industrial relations problems* that might otherwise be difficult or costly to eradicate. Legislation, such as the Transfer of Undertakings (Protection of Employment) Regulations in the UK, has, however, diminished the potential impact of this aspect.

Special *vehicle characteristics* may be required for some products and product ranges and these may not be available in some multi-user operations. Vehicle size, body quality, equipment and unit load specifications may all be affected dependent on weight/volume ratios and any 'special' product features. Once again, the use of a specialist third-party company could be appropriate.

The *delivery characteristics* or requirements of some products may be incompatible with those offered by some third-party operations. This may, for example, relate to the frequency of deliveries that are required (i.e. a frequent number of small drops for high-value items compared to occasional deliveries for low-value items) or the nature of the product itself (heavy products may require special unloading equipment or double-manning). It is possible that some form of specialist distribution system can provide an appropriate alternative.

Basic delivery systems may be incompatible. An obvious example is the use of preselected orders compared to van sales. Another is when the delivery process includes installation and the basic tuition of the customer in the use of the product (electrical goods such as televisions and washing machines), which does not fit well in a standard delivery process. It is important to ensure that products are not being distributed via incompatible delivery systems, as this can be both costly and inefficient.

Some *products* may be *incompatible*, a particular problem being the danger of contamination caused by one product to another. If some food products are carried next to a product with a very strong smell then they may easily absorb the smell and be spoiled. Many third-party companies solve the problem by the use of special sections in vehicles.

Critical factors of choice

Before leaving the topic of the key drivers of logistics outsourcing it is probably relevant to note that there is no one single answer to the question: what are the most important drivers? Clearly, this depends very much on the industry, company, market, product and any other feature that might impact on the design of an appropriate logistics structure. Dependent on the situation faced by each individual company, some factors will be vital and others of no consequence whatsoever. Nevertheless, the main critical factors usually quoted to explain why companies do and do not outsource their operations were outlined at the end of Chapter 4.

Understanding the likely and expected benefits of outsourcing for a company is one of the most important steps at the start of the outsourcing selection process. This is emphasized in the next chapter when the outsourcing selection process is described.

Outsourcing: the selection process

36

Introduction

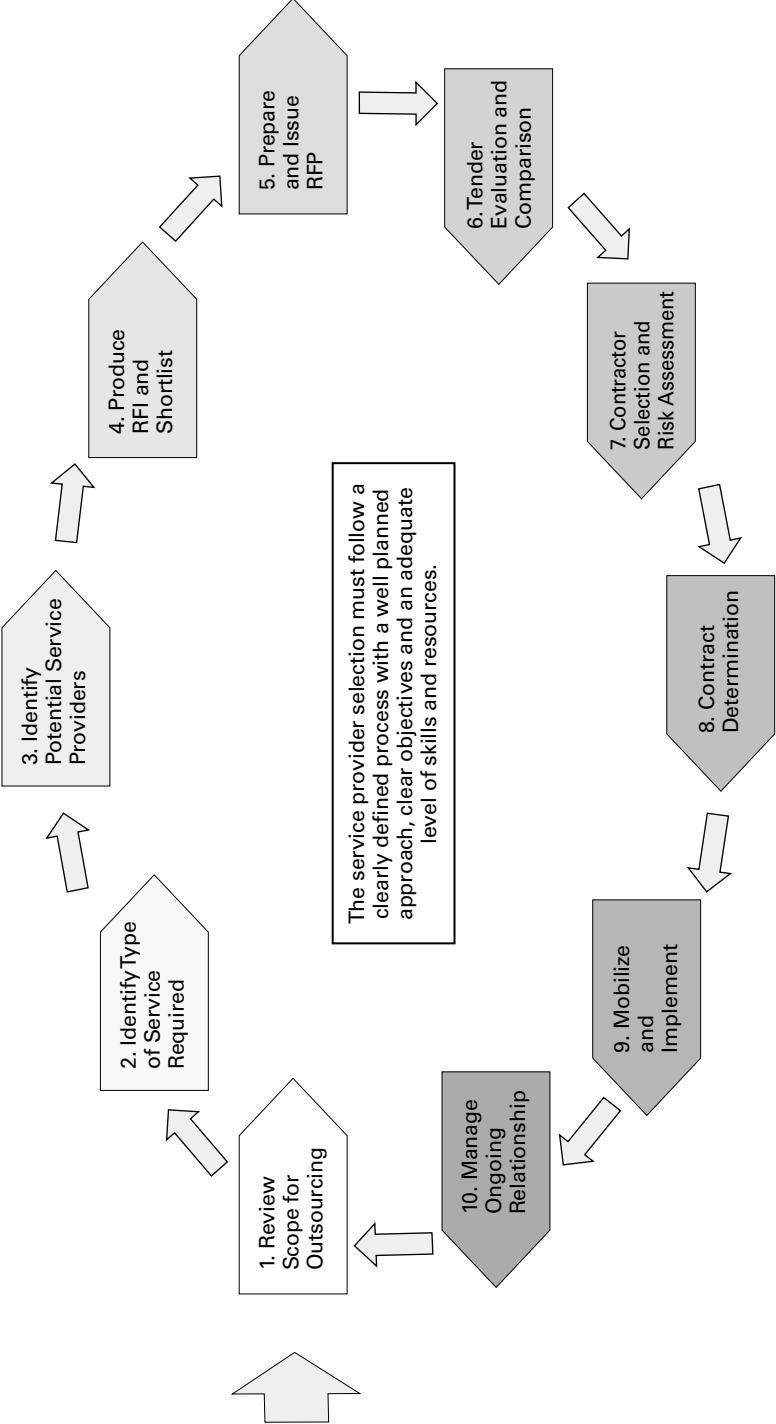
It was noted in the previous chapter that probably the most important channel decision for those operating in distribution and logistics is whether to use an own-account (in-house) operation or whether to outsource to a third-party logistics (3PL) service provider. Having made the decision to outsource, this is by no means the end of the story, as it becomes equally important to take great care in both the selection and the management of the service provider. This chapter describes an approach for the selection of service providers and explains the detailed steps that are required from the initial scoping of outsourcing requirements through to the final negotiation and contract agreement. In addition, the main content of a typical contract is outlined. The important element of contractor management is then described in Chapter 37.

Approach

In order to ensure that all of the many different aspects of contractor selection are adequately addressed, it is advisable to adopt a general, step-by-step approach. Such an approach is outlined in Figure 36.1, and is discussed in detail in the rest of this chapter. This approach describes the different stages that must be followed to ensure that all of the important elements are considered. It is typical of the approach that is used by major companies who are contemplating the use of a third-party service provider to undertake all or part of their logistics operations. The emphasis is on a clearly defined process that is well planned, has clear objectives and is adequately resourced, so that the many key stages can be completed successfully.

Figure 36.1 shows that the first two stages of the selection process should involve an internal assessment of the need for and requirements of outsourcing (Step 1, review scope for outsourcing and Step 2, identify services required). The aim is to

Figure 36.1 Key steps of the contractor selection process



ascertain from the outset that outsourcing is an appropriate option and to identify which of the many different parts of the company's operations should be considered as suitable for outsourcing.

The next stages are concerned with an initial review of the services available and the identification of potential providers of these services in order to produce a short-list of interested parties that are able to offer the particular services that are required (Step 3). Then, the most familiar features of the selection process occur, as follows:

- the preparation and issue of an invitation (RFI) for contractors to tender for the work in question (Step 4)
- the production of the request for a proposal (RFP) for the shortlisted contractors (Step 5)
- the evaluation and comparison of the responses to this request (Step 6)

These steps are usually perceived to be the major part of the selection process, and frequently the evaluation and comparison is treated as the final stage. There are, however, still some key steps that need to be considered:

- a risk assessment exercise should be undertaken to identify any potential problems and issues – and to determine how to address them (Step 7)
- the final contract has to be formulated and agreed (Step 8)
- the implementation and management of the outsourced operation should be carefully planned and monitored (Steps 9 and 10).

Detailed steps

Step 1: Review the scope for outsourcing

There are a number of key questions that need to be considered as a first stage in the selection process. Although outsourcing a logistics operation is very common practice, it is not necessarily the best solution for all companies. Essentially, a scoping review should take place to address the five key 'W' questions, as follows:

- 1 Why outsource?
- 2 Whether outsourcing is the right step to be taking?
- 3 What are the key requirements?
- 4 Where are the boundaries?
- 5 Which outsourcing approach to adopt?

Why outsource?

The main drivers for outsourcing were discussed in the previous chapter. Identifying which of these drivers are relevant to a company should be the starting point of any review of the scope for outsourcing because this will help the company to ascertain exactly what, if any, services are required from a 3PL.

Whether outsourcing is the right step to be taking?

A company needs to be sure that outsourcing is the right step for it to be taking. Some key questions are outlined in Figure 36.2. These endorse the need for a company to have a true understanding of its own operation and the associated costs. A company should be wary of taking the decision to outsource just because it has some apparent logistics cost or service issues. One clear option for such a company is to find out why there is a problem and to try to solve it internally, if this is feasible.

Figure 36.2 Outsourcing is not for everyone

Is outsourcing the right step to be taking?	
Some key questions are:	
Internal	• Do we understand the true cost that can be compared to outsourcing options? • What risks are there with outsourcing? • What competitive advantage is expected from outsourcing? • Do internal processes need to be fixed before outsourcing? • Does capability exist to manage the 3PL?
External Provider	• Does the third party provide competencies lacking internally? • Does the third-party provider have a portfolio of clients that can be leveraged to gain efficiencies for our business? • What 'best practices' can the provider quickly apply to our business?

What are the key requirements?

As indicated previously, a company needs to understand the reasons why a decision has been made to outsource any of its operations. The reasons should help to provide some clear objectives that can be used to establish the basic requirements for outsourcing, and which can subsequently be used to assess the various alternative proposals that are put forward by prospective contractors. Such objectives should become clearly identifiable requirements that are used as decision criteria in the selection process.

Where are the boundaries?

A further scoping decision concerns the extent of the operation that is to be outsourced. The basic question is – what should be outsourced and what should be

kept in-house? The broad range of possibilities was described in Chapter 34 and illustrated in Figure 34.1.

Which outsourcing approach to adopt?

At a very early stage in the selection process a company should undertake a broad strategic review of the likely distribution structure that it will be looking for. A general approach to logistics strategy planning is described in Figure 10.1. Many companies might complete this as a matter of course when taking their initial decision about whether or not they should continue as own-account or go the third-party route. It is also very useful to help clarify the type of service that might be required, particularly whether a dedicated or a multi-user approach is the most suitable. Such a review can be used for several different purposes:

- To help identify the type of outsourcing approach to adopt. At its most obvious, is a dedicated or multi-user operation preferable?
- To provide a clearer idea of what the main requirements are. It is far easier to assess the different quotations made by the third-party companies if the user already has a good understanding of what the operation should look like.
- To help in the eventual preparation of the invitation to tender. In requesting the third party to quote, it will be necessary to provide a great deal of data and information on which it can make its analysis. It is useful to use this data to undertake a strategic review to identify likely feasible solutions.
- To clarify key activities. Certain activities will be outsourced, while others will be kept in-house. A strategic review will help to identify those elements of the business that should be considered by the third party. It will also help to clarify exactly where the line is to be drawn between outsourcing and own-account. Clarification of these areas of interface is crucial at an early stage.
- To enable a 'long list' of potential contractors to be drawn up. The information from a strategic review will help to identify which contract companies are the most appropriate for consideration in the selection process. This will help to ensure that time is not wasted holding preliminary discussions with companies that are unlikely to be able to offer appropriate services.

Step 2: Identify the type of service required

Having made the decision that all or part of the business is to be outsourced, the next step is to determine which of the many services offered by third-party providers are likely to be required. The main types of service were described in detail in Chapter 34. As already discussed, another major question is whether the user company should choose a dedicated operation or join a multi-user operation where resources will be shared with other companies (see Chapter 35). For some companies this may not be

a clear-cut decision, and they may decide to ask the shortlisted service providers to quote on the basis of both of these different types of operation. The most important factor is that the providers are clear on what basis they should be quoting for the work, so that they don't base all of their effort and analysis on determining a solution that is inappropriate to the user.

Step 3: Identify potential service providers

The next step in the selection process is to draw up a 'long list' of potential contractors that might be suitable as potential service providers. The aim behind this is to identify a large number of service providers that are capable of undertaking the business, and then to draw up a suitable shortlist. This should consist of those that show both an 'expression of interest' and also are able to meet any important qualifying criteria and so provide a cost-effective and service-proficient solution. Taking an extreme (if rather obvious) case as an example, there is no point in contacting companies that specialize in small parcels delivery if it is a full-trailer-load service that is required.

It is neither feasible nor sensible to have a large number of potential contractors provide a full tender, because the entire process is a very time-consuming one for both the contractor and the user company. Information on contractors can be obtained very readily from the trade press, where there are many articles to be found that review the service providers and comment on the latest contracts. In addition, there are websites available that provide information and contact details for major contractors (Armstrong & Associates, 2021b). A typical long list might have 10 to 15 contract companies, dependent on the size of the operation that is to be outsourced.

Step 4: Prepare the request for information (RFI) and then the shortlist

Each potential contractor that appears on the long list should be contacted and provided with a brief description of the likely requirements for the operation to be outsourced and an indication of the technical requirements that are considered as essential from the third-party company.

There are two aims to this part of the selection process. The first is to ascertain whether the contractor would be interested in tendering for the business. There are several reasons why a company might not want to quote for the business:

- it may not have the resources to undertake the operation
- the work may be insufficient for a large-scale operator
- it may not be a sector in which the company wants to operate

It is useful to be able to identify and eliminate these companies before entering into the next stage of the selection process.

The second aim is to identify that the company is an appropriate one to include on the eventual shortlist of contractors. Thus, the user company decides which of those companies that are interested should be taken to the next stage of tendering for the business. Some may be eliminated because they appear to be too small, do not adequately cover the distribution area, or cannot provide suitable reference sites (similar operations that indicate their capabilities), etc. A key aspect here is, therefore, the perceived technical competence of the company, which needs to be ascertained prior to moving forward to a commercial bid. In essence, the commercial bid should not be pursued if the technical assessment is seen to be inadequate. Of course, care must be taken to ensure that a potentially suitable contractor is not rejected at this early stage of the process.

The description of requirements is often known as the ‘request for information’ (RFI) and it forms the basis of this part of the selection process. The RFI should be a concise document consisting of key information, as follows:

- 1** Introduction and confidentiality clause: the confidentiality clause is used to protect the confidentiality of the information that is supplied and also the confidentiality of the fact that the operation is being considered for outsourcing.
- 2** Description of the company: this is an overview of the company operations, products, demand characteristics, general logistics constraints, etc.
- 3** Description of opportunity:
 - a** Company business strategy and an indication of likely requirements: the provision of a clear description of exactly what the user company wishes to outsource, including top-level data to enable the contractors to get a feel for the size of the operation.
 - b** Contractual relationship: here, for example, the user company might indicate any preference for the style of operation preferred – dedicated or multi-user.
- 4** The selection process: the process to be used by the client for its selection of a contractor should be described. This will cover:
 - a** The procurement process: of particular relevance is the timescale of the procurement process and any deadlines that have to be met.
 - b** Key selection criteria: these will consist of the important elements on which the suitability of the potential contractors will be assessed for inclusion in the next phase of the selection process. It should include any technical requirements related to the potential contractor.
- 5** Content of response: this is the information that the service provider must supply in its response to the RFI.

- 6 Format of response. A clear and precise format for the response should be given. This is important to ensure that all of the responses can be easily compared with each other so as to simplify the process of drawing up a shortlist of companies to take forward to the next phase.

Responses to the RFI and any other factors should be evaluated against key selection criteria to enable a shortlist of between four and six contractors to be drawn up. Selection of the key potential providers might be based around:

- the written response to the RFI
- technical competence
- an assessment of supporting documents
- the current client list
- contact with current clients, which might include a visit
- an assessment of broad capability
- the financial probity of the company

Step 5: Preparation of request for proposal (RFP), invitation to tender (ITT) or request for quotation (RFQ)

Objectives of the RFP

The major part of the contractor selection process revolves around the provision of detailed data and information to the shortlisted companies, which they then use to develop a plan and cost the proposed operation. These responses are then compared by the user company to enable them to identify one or two companies with which to complete the final negotiations. This process is based on a very important document, which may be known as the request for proposal (RFP), the invitation to tender (ITT) or the request for quotation (RFQ).

There are four main objectives for the RFP from the user company viewpoint:

- 1 To provide a specification of business requirements in a standard format to selected vendors to assist them in the preparation of their proposals. Thus, the business and operational requirements must be clearly described, using appropriate descriptions and data.
- 2 To facilitate the objective comparison of proposals. This is best pursued by the use of a standard format response or standard pro forma. Thus, all contractors must respond in the same way to enable ease of comparison and to eliminate (or at least minimize) errors of comprehension and understanding due to the different presentation of the proposals.

- 3** To maintain an equitable flow of information across all tendering companies. The aim is that all contractors should receive exactly the same information so that all their quotes are based on identical information. This applies to any supplementary information that is supplied after the initial RFP. It also applies to the answers to clarification questions raised by the bidders. Both the clarification questions raised and the company's answers must be distributed to all bidders. This not only maintains the integrity of the process but strengthens the quality of the subsequent bids submitted. It is good practice to issue a deadline for raising clarification questions.
- 4** To establish total confidentiality rules. This is a two-way street because the confidentiality rules should cover both the data that is given to the contractor in the RFP and also the response data and ideas that will be provided by the contractor in the response.

Although it is extremely important to have contractors respond in a fixed format against the operational requirements outlined in the RFP, it is also important to identify and consider any innovative suggestions that are appropriate. The bidders must respond to the fixed format but should be allowed to submit a further proposal in which they may outline alternative ways of achieving the same outcome.

There are also some specific uses for the RFP from the point of view of the contractor. They are to enable the contractor to:

- design a logistics system to perform the task and meet the service requirements
- determine all of the many resources that are required to run the operation (personnel, property, vehicles, plant and equipment)
- estimate the costs and hence decide on the structure and level of the rates to be charged
- be clear which distribution components are to be provided by the contractor and which by the user company
- be clear which information systems need to be provided and specify them in detail

Data requirements

It is evident from these requirements that a great deal of detailed data and information must be included in the RFP. A typical RFP structure might be as listed below, but the precise content will vary according to the company, operation and contract requirements:

- 1** introduction, including confidentiality clause
- 2** background to operating company
- 3** business description

- 4 data provided with the invitation to tender
- 5 physical distribution specifications
- 6 information systems requirements
- 7 distribution service levels and performance monitoring
- 8 assets currently employed in distribution operations
- 9 risk assessment and transfer
- 10 industrial relations
- 11 business relationship – contract type and contract management relationship
- 12 charging structure
- 13 terms and conditions; an example of the complete contract format, which will include liabilities and insurance issues
- 14 environmental issues
- 15 the selection process including key selection criteria
- 16 response format
- 17 criteria for award of contract
- 18 timescale and method of submitting clarification questions regarding the RFP
- 19 deadline for submission of a response to the RFP
- 20 the proposed start date for the contract after award

The data to be provided with the RFP should be at a sufficient level of detail to allow the contractor to undertake adequate analysis to calculate the resources required to run the operation and to identify all the associated costs. As might be imagined, this is a lot of data! It is usually supplied using an electronic format, typically spreadsheet-based. Actual data requirements will vary depending on the services required, but typical distribution data is likely to include those elements outlined in Figure 36.3.

Pricing and charging structures

There are several different types of pricing or charging structure that might be adopted and the RFP should indicate very clearly which of these should be used by the contractor. These are categorized below. For dedicated operations the choice of these is the prerogative of the client. For multi-user operations involving low volumes of business, it will probably be necessary to use the pricing structure offered by the 3PL:

- Unit price or fixed price agreements. An agreed unit price is paid for the services provided. This is generally a sum of all operating costs (including overheads, facilities and profits) divided by the number of units handled or transported. This

Figure 36.3 Typical distribution data requirements

Storage and order picking	Delivery
Receipt • Number of suppliers • Extent of palletization • Notice given for time of delivery • Extent of inspection or check • Dealing with returns Stock profile • Number of lines • Stock volumes • Activity levels • Normal storage levels • Peak levels and duration of peak Throughput • Seasonal/daily variations in volumes Order picking • Order transmission procedure • Order volumes including seasonal and daily variations • Service time cycles from receipt to delivery • Lines per order and total quantity per order including peak variations	Despatch • Outlets including location defined by post code, etc • Delivery quantity by location • Peak variations Delivery • Constraints on delivery times • Problems at specific locations • Delivery methods Service • Service level requirements Others • Returns • Repacking, stock checking • Telesales, ordering • Promotions, etc

might be cost per case, cost per mile, cost per delivery, etc, or a combination of these costs, depending on the services being offered. The advantages of this approach are that it is easy to understand, flexible and visible (the price charged varies in accordance with the volume throughput). This is the traditional method of third-party payment and is common for low-volume business.

- Hybrid unit price agreements. These are based on a unit price but also include guarantees for specified volume throughput, resource usage, etc. This ensures that seasonal effects or unexpected demand fluctuations do not penalize the contractor, which might otherwise result in the contractor having resources that are underutilized. This approach allows for the unit price to be reduced by degrees as throughput increases.
- Cost-plus arrangements. These provide for the payment of an agreed fee for the facilities used and the services provided. Thus, the client meets the actual costs of the operation. A pre-set profit margin for the contractor is added to this, which may be a flat fee or may be a percentage of the costs incurred. A major advantage to this approach is that the costs are visible to the client company, making it easier to budget internally. One major criticism of cost-plus is that it offers no incentive

for the contractor to enhance the operation through productivity improvements. Indeed, any trimming of costs would lead to a reduction in payments to the contractor if the profit arrangement were based on a percentage of costs. To overcome the possible disadvantages of a cost-plus arrangement, additional measures may be incorporated such as gainshare.

- **Gainshare.** The aim of this approach is to align shipper and contractor objectives and to incentivize the contractor in the process. The idea is to create a constructive partnership to motivate the contractor to provide improvements in the business. This approach is seen to be far more positive and effective than identifying KPIs and penalizing the contractor if these are not achieved. An example of gainshare is an electrical company that has a cost-plus arrangement with a third-party contractor which also includes:
 - shared incentives on transport and warehouse productivity improvements (in this case a 50/50 split for any successful economies)
 - a minimum and maximum level of profit (minimum as a guarantee for the contractor, maximum to protect the user company in an environment of a growing business)
 - clearly defined contractor management – the aim is to reduce costs incurred and to monitor spending levels
 - contractual agreement to undertake joint cost reduction initiatives
- **Open-book contract/management fee.** As it suggests, an open-book contract is where the client company pays for the entire operation plus a management fee to the contractor. This type of arrangement is typically used for completely dedicated operations. Performance is monitored against a budget that is agreed between the contractor and the client. The danger with this type of arrangement is that it may compound any inefficiencies that are built into the original agreement. It is now common to include cost reduction or performance-related incentive clauses to provide a shared benefit where the contractor identifies improvements (see gainshare above).
- **Evergreen contracts.** These contracts are for no defined length of time. A fixed price structure and specific performance requirements are agreed for a 12-month period. Performance is then monitored against the agreed KPIs. Notice to terminate the contract of, say, six months can be given by either side. The idea of these contracts is to eliminate the very stressful and time-consuming renegotiation that often occurs with traditional contract arrangements at the end of each contract period.

It is also possible to use a mixture of these arrangements. One European company adopted a three-phase approach, as follows:

- First year: a cost-plus, fixed management fee to enable the operation to ‘bed in’ or settle down. It is a useful approach because it is optimistic to expect a newly created operation to run smoothly, as planned, straight from day one.
- Second and subsequent years: open-book, cost-plus, incentivized management fee. After the operation has bedded in, this arrangement is aimed at producing operational savings that the user company can see and will benefit from.
- Third and subsequent years: in addition, an agreed continuous improvement programme, which provides a positive (and written down) agreement to improve service and reduce costs.

Linked to these structures described above, there are a number of associated charging and non-charging mechanisms that can be incorporated. Their use will vary according to the type of service that is purchased. They include:

- charging:
 - annual rate negotiation
 - failure penalties
 - shared savings incentives
 - payment for shrinkage (loss of product)
 - agreement over extraordinary costs (fuel surcharges)
- non-charging:
 - specified service targets (minimum, normal)
 - continuous service-monitoring using KPIs
 - regular meetings
 - regular management information

Preferred response to the RFP

A response pro forma should be included in the RFP to ensure that all contractors respond in the same way so that comparisons can easily be made. It is extremely difficult to make meaningful comparisons between tenders if all the responses are constructed to a different format. As well as a clearly defined format for the numerical response, many companies ask the service provider to identify specific elements on which they expect detailed information to be provided. Responses can then be evaluated against set goals, business metrics, costs and any other particular selection criteria. Specific elements might include:

- the resources and facilities to be used
- contract management and supervision

- information systems – data processing and communications
- security, insurance, stocktaking procedure, etc
- structure and level of charges and procedure for price increases
- penalties (if any) for premature termination of contract
- invoicing and payment
- draft outline contract, conditions of carriage or conditions of storage
- project management/transfer/implementation
- health and safety performance record and policy
- environmental policy

Note that answers to any queries from individual contractors that arise from the RFP should be circulated to other bidders prior to their final submission. This is to ensure that all contractors have exactly the same information on which to base their tenders.

Step 6: Tender evaluation and comparison

Tender evaluation is undertaken with a view to identifying key data and information from the tenders submitted and then drawing comparisons between the different submissions. Hence the importance of using a response format that is straightforward for the contractor to use. Comparisons should be both quantitative (mainly assessing the relative costs of the different solutions) and qualitative (a consideration of all the non-quantifiable aspects that may be relevant). The qualitative assessment acts as a useful supplement to the very analytical quantitative assessment.

Quantitative assessment

This is a cost-based assessment that is normally used as the key measure of comparison between quotations. For a typical warehouse and delivery transport proposal, the main cost elements are the same as the standard logistics ones, and they have been discussed in previous chapters. They would include the costs of storage, delivery transport, information systems, administration, overheads and management fee – depending on the extent of the logistics operation to be outsourced. Costs may be expressed as totals for the operation as a whole or as unit cost per pallet stored, case delivered, etc. It is useful, for comparative purposes, to ask for a breakdown of the costs for each of the key logistics components. Some key points are:

- Compare quotations on a standard basis. It is essential that a ‘like-for-like’ comparison is made between the different proposals.
- Be clear what has and what has not been included in the prices (e.g. ‘other’ work, collections, etc).

- It is likely that the quotation includes some qualifications (perhaps because of the interpretation of the specification). These need to be clarified or eliminated before comparisons are made.
- Beware of imponderables such as ‘likely future rate/rent reviews’.
- Check that service levels can be met within the costs outlined in the proposal.
- The lowest price may not be the best! Some qualitative issues may override a low-cost proposal.

Qualitative assessment

Non-quantifiable factors that might be considered could consist of many different aspects. The ones to use are those that are seen to be important to the user company. For one company these might be environmental or people-related. For another they might be more concerned with ease of management and control. Key aspects include:

- the quality of the proposal
- the extent to which the proposal meets the RFP requirements
- views on the extent to which it is felt that the proposed physical system can perform the required tasks
- views on the extent to which it is felt that the proposed resources are appropriate to the task and the system
- whether levels of utilization, productivity and cost are realistic
- how appropriate the cost is to the recommended design
- the overall design of the information systems
- strategies for future enhancement of the operation
- environmental policy, and health and safety policy
- the culture of the company – whether it fits with that of the user company
- the quality of the contract management team
- staff training

It is appropriate to adopt a structured assessment of the qualitative elements of the contractors’ tender submissions and the experience/expertise of the contractor. This is often achieved through the use of an evaluation matrix, which is a structured assessment of the main factors involved. The factors to be included should be determined at the outset and should be identified in the original RFP. Such a matrix can be summarized into major factor groups, typically:

- operational factors
- financial factors

- service factors
- contractor-related factors

All of the key elements within each factor group are listed and given an appropriate weighting that reflects their importance to the company. The various criteria and weightings should be discussed and agreed with the selection team to produce a balanced scheme. Each element will be scored between 1 and 5 to reflect how well the overall submission meets the criteria concerned (1 is poor, up to 5 which is excellent). The final weighting is multiplied by the score to give the total for that particular element. An example of how a part of a structured qualitative matrix might look (in this example, for contractor-related elements) is shown in Table 36.1. It can be seen that, in this instance, the total of the contractor-related elements represents 10 per cent of the overall qualitative assessment factors.

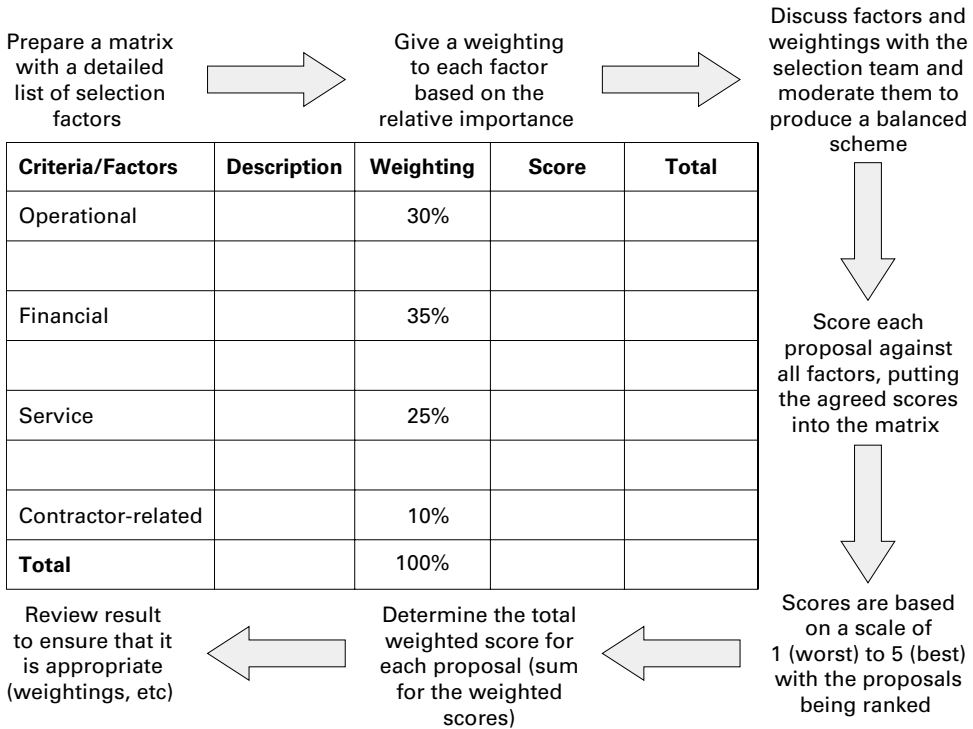
Table 36.1 Example of a structured qualitative assessment matrix (for contractor-related elements)

Contractor-related Factors Description	Weighting within Factor-group	Final Weighting (%)	Score (1 to 5)	Total (%)
1. Financial standing	20	2.0%		
2. Current client base	5	0.5%		
3. Management structure and resources	10	1.0%		
4. Understanding of requirements	20	2.0%		
5. Information systems and expertise	15	1.5%		
6. Initial presentation	5	0.5%		
7. Management (structure, culture)	5	0.5%		
8. Innovation & flexibility	5	0.5%		
9. References (existing clients)	10	1.0%		
10. Reputation	5	0.5%		
Contractor-related TOTAL	100%	10%		

Once all of the relevant factors have been assessed, an overall evaluation matrix can then be produced to show the results for all of the main factor categories. Each submission is then scored against all of the different elements, the scores are recorded and the overall evaluation matrix is produced for each submission. An overall total for each submission will then provide a comparative measure to help differentiate between the various tender submissions. It should be emphasized that this type of qualitative assessment is normally used in conjunction with, and as a balance to, the cost-based quantitative assessment.

A summary of the tender evaluation process together with an example of an overall evaluation matrix is provided in Figure 36.4.

Figure 36.4 Summary of the tender evaluation process together with an example of an overall evaluation matrix



Another method that can be adopted is what is sometimes known as the ‘traffic light’ approach. This can be used on its own or as a precursor to the evaluation matrix. For this method, the key factors are categorized according to their importance to the user company. The categories are red: ‘must haves’ (sometimes known as ‘showstoppers’), which are essential requirements for the user company; amber: ‘should haves’, which are important but not crucial requirements and green: ‘nice to haves’, which are interesting additional ideas raised by the contractor in the proposal.

The idea of the traffic light is that any absolutely essential requirement that is not adequately addressed by the contractor in the proposal is given a ‘red light’ and the proposal is immediately deemed to be unworkable and so is eliminated. Other factors may then be treated in a similar fashion to the approach adopted for the evaluation matrix.

Step 7: Contractor selection and risk assessment

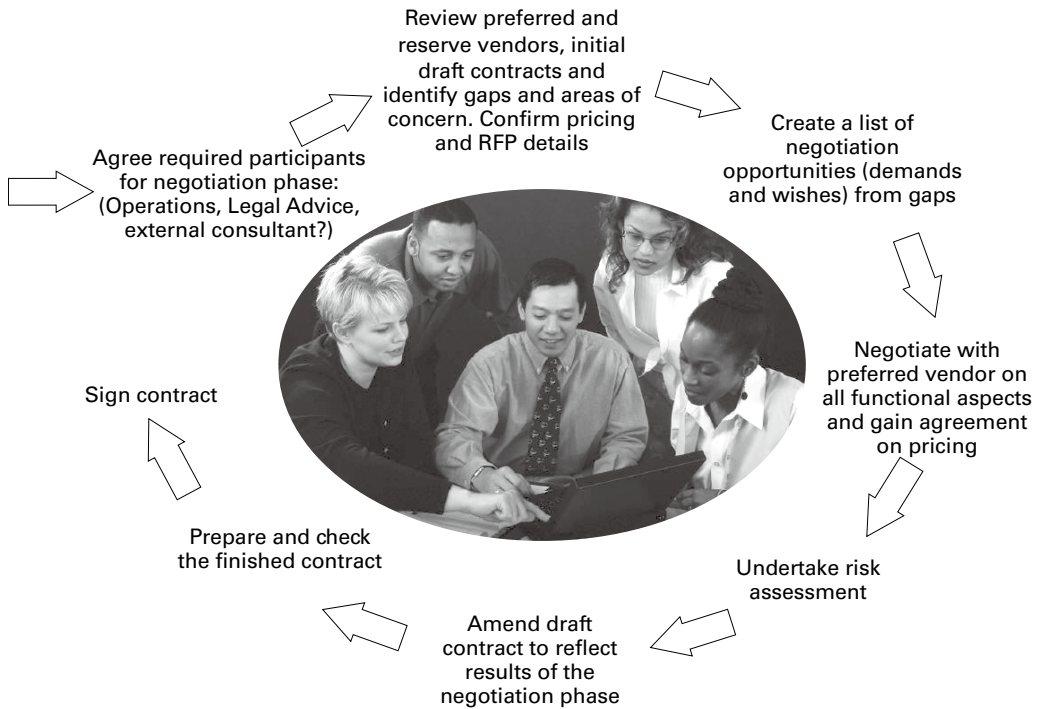
The use of a structured approach for the assessment of the different submissions makes the final selection process a distinctly simpler task because the main points for comparison are much clearer. When this assessment process is completed and ready to use, it is possible to make the final contractor selection. It is quite usual to identify a preferred vendor together with one or two reserve vendors who may be chosen should a key and insurmountable problem arise with the preferred vendor. The final stages concerning vendor selection, which end with the signing of an agreed contract, are summarized in Figure 36.5.

Contractor selection

The most favoured contenders can be investigated further through visits to reference sites if that was not undertaken in the tender evaluation phase, and through preliminary negotiations. For large, dedicated contracts it is likely that two or three preferred service providers will be identified, one of which is likely to be the first choice at this stage. These can then be taken forward for much more rigorous negotiation to ensure that the detailed elements of the proposal are satisfactory and to identify further opportunities for enhancing the contract arrangements. These stages are concerned with the development and agreement of the final contract, so it is important to ensure that suitable representation is included in the team. The final selection process needs to be undertaken by an experienced team that has all the relevant negotiating skills and authority. Thus, it should include representatives with legal, procurement, human resource and logistics operational skills.

As Figure 36.5 indicates, after a suitable negotiating team has been agreed, the next step is to identify any gaps or areas of concern with the preferred vendor that need to be addressed. Some of these might have arisen out of the tender evaluation stage and some are likely to arise from the chosen contractor's initial draft contract. In particular, the key pricing and service elements should be reconfirmed. The result of these preliminary discussions and evaluations should be a list of key negotiating opportunities. These need to be pursued until all the operational, service and pricing issues have been satisfactorily addressed.

One key element that should also be considered at this stage is the calibre of key operational personnel. Almost all of the contacts made with the contractor during the selection phase are likely to be with head office and sales project teams. These people will not be responsible for the day-to-day running of the contract. Logistics is very much a 'people' business and the client company needs to be more than happy with the managers who will be in charge. Thus, it is vital to meet the key operational personnel who will be managing the outsourced operation and to be satisfied with their competence and abilities. In practice, bids may require the CVs of key

Figure 36.5 The final stages of contractor selection

personnel to be presented as part of the proposal, together with the right to refuse to accept certain key individuals.

Risk assessment

The next key stage concerns risk assessment, and it is one that many companies often neglect due to the time pressures that build up because of the need to finalize arrangements as quickly as possible. The lack of time is a common problem that produces the greatest pressure at the end of the selection process. Risk assessment is undertaken in order to identify any factors that might be a major issue either at the time of the changeover to outsourced distribution (such as the loss or transfer of personnel, facilities, etc) or during the operation of the contract (such as delivery failure, etc).

There are three main categories of risk in outsourcing that are often considered. These are:

- 1 *Operational/service risks*: relating to the provision of services; these are generally internal factors related to the client company (a change in demand levels, new

product introduction, etc) or the operation (information system failure, vehicle breakdown).

- 2 *Business risks*: relating to the contractor's business: insolvency, industrial relations issues, etc.
- 3 *External risks*: relating to external factors that might affect the operation: fire, acts of God, etc.

The overall aim of the risk assessment process is to confirm that all of the contract arrangements are acceptable and to identify any issues that require either immediate attention or future consideration. Issues tend to concern key service requirements and operational performance rather than costs. The output from the process is to rewrite the contract where necessary and to agree any contingency arrangements that need to be put in place to cover potential future problem areas. The process is usually undertaken in the format of a brainstorming session, which should include personnel from both the client and the preferred vendor.

In this context, risk can be measured by assessing the *likelihood* of an event occurring together with the *impact* that the event may have. Each event is marked from, say, 1 to 10, and the risk is the product of these two numbers. Figure 36.6 summarizes this approach.

The method is fairly straightforward, consisting of the following steps:

- 1 Compose assessment teams from preferred vendor and client company.
- 2 Identify events (strategic, tactical and operational). *All* events with a potential risk, however small or large, should be listed separately.
- 3 Brainstorm events, assess likelihood and impact and agree risk potential for *all* events.
- 4 Take appropriate action:
 - a identify changes required for operational issues and include these in the contract
 - b set up contingency plan for any important high-impact events
 - c reject contract if any potential problem cannot be resolved

The development cycle

During the final negotiation it is important to be aware of the different phases that a dedicated contract relationship might take. These are often termed the 'development cycle'. The development cycle reflects the evolutionary process of many dedicated contract arrangements and should be recognized in the planning process and reflected in the contract. There are three different stages:

Figure 36.6 Operational risk assessment: measurement of risk

Measure			
$\text{risk} = \text{likelihood} \times \text{impact}$			
0 : not relevant		0 : no effect	
2 : very unlikely		2 : insignificant effect	
5 : average chance		5 : average effect	
8 : very likely		8 : very disruptive	
10 : absolutely certain		10 : complete disruption	

Example			
event	likelihood	impact	product
depot fire	1	10	10
labour dispute	3	8	24
vehicle failure	8	1	8

- A** Initial set-up. The contractor takes over an existing operation with all its inherent problems and physical assets. The major aim is to keep the operation running efficiently during the changeover period.
- B** Medium term. Here, the two parties enter into a more clearly defined agreement over three to five years, looking for opportunities for performance improvement and cost reduction.
- C** Longer term. In the longer term, the contractor may wish to take on additional third-party work in association with the existing operation. This will occur as market opportunities arise and as scope for cost reduction by better asset utilization becomes apparent. It is essential that any benefits that arise are mutual to the contractor and the original user, and that the user is protected in terms of service and cost, as well as market competition. This stage of the cycle has become known as the development of shared-user opportunities. It is unlikely to arise with very large, dedicated operations.

The complete development cycle may not occur for all dedicated contract arrangements, but it has occurred for some. It is important that the opportunities for potential future developments of this nature are borne in mind and are taken into account during the preparation of any initial contract.

Step 8: The contract

The contract contains a large amount of detailed information and requirements. It will include a comprehensive specification of the services that are to be provided, the

associated tariffs and the obligations of the parties concerned. The format of the contract is usually based around the format of the tender document that was originally submitted, but of course will include any changes that have resulted from negotiation and risk assessment. It is usually recommended that companies draft their own contract document, and this is certainly advisable for complex operations. There are a variety of independent standard documents that can be used directly or that can provide a basis for drawing up a new document. It is strongly advised for the user company not to adopt a contract that has been specifically devised by the contractor.

TUPE

An important element in the change to a new contractor is the question of responsibility for existing staff for which legislation exists: in the UK, the Transfer of Undertakings (Protection of Employment) Regulations 2006 (SI 2006/246) known colloquially as TUPE; in the EU, the Acquired Rights/Business Transfers Directive. Such legislation protects employees where a business is being transferred to another business. The precise implications of this legislation may be a little unclear at times, because, periodically, it is reinterpreted and this process of reinterpretation continues. The main requirement is that, if employees are transferred to a new contractor, the new contractor must honour the existing terms and conditions of employees.

Thus, the key issues are that all staff should transfer on existing contracts and that all the associated liabilities should transfer with the staff. Any dismissals at the time of the transfer of business will be treated as unfair unless an ETO (economic/technical/organizational) reason can be shown to have occurred. This means that an acceptable reason must demonstrate that a change in the workforce requirements has taken place.

So, TUPE applies if it is a relevant transfer. The key question is – what is a relevant transfer? A relevant transfer is broadly one that is ‘the same business in different hands’ or ‘the transfer of an economic identity retaining its identity’. The consequence is that whenever a new contractor takes on an operation, it must be clear where the responsibility lies for any labour-related issues such as the payment of any redundancy payments and ongoing pension liabilities.

There are useful articles published periodically in the logistics press and some valuable websites that provide up-to-date information on the existing position of TUPE with respect to logistics outsourcing (Acas, 2021; CIPD, 2018; UK Government, 2006).

Content of the contract

Some of the detailed points that are likely to be included in the contract are listed below under the four headings of initial contract, cost-related/tariff structure, service-related and administrative/other.

Initial contract:

- takeover of warehouse sites: which are acceptable/unacceptable, procedures for takeover
- takeover of vehicles and capital equipment: which vehicles and equipment are included, how they are valued, etc
- takeover of personnel: which, if any, are transferred, the financial basis, terms of employment, pension rights, etc
- redundancy agreement: that agreement will be negotiated as necessary by the client, the basis of this agreement, etc

Cost-related/tariff structure

A cost and tariff structure should be included. This may take a variety of forms and will, of course, depend on the precise payment method that has been agreed. Those elements that need to be covered are indicated below. Important considerations will be the costs of any additional activities that are to be included as exceptional payments (e.g. product returns), costs that are beyond the control of the contractor (e.g. fuel price increases and inflation) and any productivity targets or opportunities. Key elements are:

- capital/investment costs (vehicles, warehouse equipment, hardware, etc), depreciation timescale and return on investment
- operational costs (rent, building services, staff, transport running costs, administration, insurance, etc) and cover for operational costs
- management costs and expenses (proportion of contractor head office cost – diminishing short to medium term, and including project work and time related to contract)
- cover risk/make profit – should be taken into account by return on investment and operational cost cover and length of formal contract

Service-related

A service level agreement (SLA) will be an important part of the contract. It will identify all the key performance indicators related to the provision of customer service and will indicate the levels of service that have been agreed. Key elements are:

- service requirements: definition of service to be provided, indication of main areas, including delivery zones and service levels (e.g. once a week), delivery/collection times, cut-off points for receipt of information at depots, special orders and how to deal with them, emergency orders and how to deal with them, etc
- service-related aspects: preferred vehicle specification, vehicle livery, driver uniforms

- service/performance measurement: key performance indicators (KPIs), report format and timings, etc, damages, late delivery, refusals, etc

Administrative and other:

- information systems: formal means of communication, operating requirements (order processing systems procedures, stock control, etc)
- administration/liaison: head office (planning), regional (liaison), specific feedback (proof of delivery (PODs), stock control, etc)
- 'prospective' agreement: regular sight of client's business plans (with respect to the distribution operation), one- to three-year horizons, delivery point openings and closures, product mix, etc
- 'retrospective'/inflation clause: to allow for regular (annual) readjustments where estimates are sufficiently different from actual to warrant financial adjustment (demand levels, product mix, etc)
- fuel surcharge mechanisms
- personnel to be employed on the contract: the right to reject certain staff prior to recruitment, the sight of CVs of senior staff and a right of veto
- start date and duration of contract, together with any break clauses
- penalty/termination clause: in the event of premature termination by either party, to cover, for example, the risk of 'unusable' assets specially taken on for the operation

The contract specification will necessarily be very detailed. Typical components that need to be considered are as listed above, although within a contract they would be to a greater level of detail. These will vary considerably from one contract to another, depending on the breadth of the operational coverage and the type of contractual arrangement. It is common practice to include the tender response from the contractor, as this contains a description of the operational elements. The measures by which operational performance is to be assessed may also be included. Usually, operational and technical schedules are included as appendices as they can be amended more quickly and easily during the life of the contract.

The length of a contract can vary from six months to five years. Three- to five-year contracts have become the norm for dedicated operations because of the amount of capital required for investment in DC and transport facilities and equipment.

As a final part of the preliminary adoption process, the chosen contractor should be subject to detailed scrutiny and contractual due diligence. It is important that a client company takes great care with this investigatory phase. Elements to cover should include: a review of industry sources, talking to existing clients, a thorough

investigation of financial health, internal management capability, strategic direction, IT capabilities, security and labour relations.

Step 9: Implementation plan

For almost all new outsourcing arrangements, the initial issue after the contract has been successfully negotiated is the successful implementation of the operation. As with any large business project, it is essential to identify and agree a project plan to ensure that responsibilities are clear and that there is a feasible timetable for implementation. A typical implementation plan will need to identify the tasks for both the user and the contractor organization, including contingency planning. The aim is to effect a smooth transition from the old operation to the new contract (see Chapter 37).

From the user perspective it is vital to ensure that there is clear visibility of the implementation process. A team that includes both user and contractor staff needs to be established and this team needs to meet on a regular basis to monitor and discuss progress. Detailed project plan activity charts should be used. Part of the implementation process is likely to include the preparation of new administrative, safety and service procedures, which will be incorporated in an operations manual.

It has been said that the real work begins once the contract has been signed. Undoubtedly, the work required for the creation of a practical operation from a conceptual document is not to be underestimated.

Step 10: Contractor management

The final part of the outsourcing process is to ensure that the contractor is adequately managed. This is covered in Chapter 37.

Outsourcing: management

37

Introduction

The effective management of outsourcing arrangements is fundamental to the success of the relationship between the third-party logistics (3PL) provider and the customer. All too often contracts fail because both the service provider and/or their client do not fully appreciate the need for sound management. Their roles in ensuring a successful relationship are essential.

This chapter discusses the need for managing an outsourced contract looking at the responsibilities of each party. The key factors required in managing a successful relationship are then examined, including partnership and collaboration, active engagement between the 3PL and the client, continuous improvement and communications. For almost all new outsourcing arrangements, the initial issue after the contract has been successfully negotiated is the successful implementation of the operation. This process is discussed.

Whether running a logistics operation as an in-house manager or as a third-party contract manager the basic reasons for monitoring the operation are very similar: to measure whether the operation is meeting set service levels at an acceptable cost. A discussion and examples of these metrics are included in Chapter 38. There are some other monitoring activities that are specific to outsourced operations and these are described in this chapter.

A formal approach to outsourcing management is outlined. There are several techniques that can be used and these are discussed.

This final part of the outsourcing process is, therefore, to ensure that the contractor is adequately managed. This is a key consideration that is sadly neglected by some users. The signing of the contract should not be seen as the end of the outsourcing process. It is vital to continue to monitor and control the contract operation to ensure that the overall business and operational objectives are achieved. As will be stressed during this chapter, both the client and the 3PL have a very active role to play in this process.

Managing the relationship

Partnership and collaboration

A good 3PL/client relationship is generally one where ‘partnership’ provides the basis for the business relationship. Good partnerships will encourage the sharing and joint development of a strategic vision. Not only does a client get the benefit of the 3PL’s thoughts and experiences; it also achieves its buy-in for the realization of the vision.

To develop a true partnership requires a high degree of trust and collaboration. It is thought that the degree of trust in a relationship determines the level of flexibility that a client will allow the 3PL in operating to the best of its capability. Flexibility makes it easier for the 3PL to deliver best-in-class processes and solutions and, in turn, achieve the required performance and cost objectives.

Clearly, moving to an outsourced service cannot happen overnight, although some companies may think that it does! It is more of a journey that starts with the implementation itself and then goes through a series of maturity phases. Although working in a collaborative manner during the definition of the initial road map from the existing to the desired vision is important, this approach is equally important as the relationship matures. A good collaborative approach will support business change and challenges, allowing both parties to review continually the current state against the vision and to agree actions to be taken to stay on course.

There can be a temptation, when outsourcing, to think that all problems with logistics or supply chain activities become the responsibility of the 3PL. Although this is true of many problems, others still remain firmly the responsibility of the client and indeed there will be new issues related to how the relationship is managed. Certainly, it is important that clients stay involved but they should focus on managing the 3PL and not controlling them. The client should not need to be involved in every decision taken by the 3PL – that is what the 3PL is paid to do. However, a good client will want to collaborate around those activities that directly impact on service and where there is a direct interaction with their business – for example, in the transfer of customer orders from the client’s ERP system into the logistics provider’s warehouse management system, clients will want to ensure that there is a full audit trail and exception reporting. They will expect to be notified immediately of any issues. They will also require regular meetings and reports against which they can monitor the 3PL’s performance.

Engagement between the 3PL and the client

Account management

Account management is important for two reasons. First, executed correctly, it can help with the retention of clients. Second, it can lead to more business with the client, potentially leading to improved profits for the 3PL.

However, good account management also focuses on identifying benefits for the client. By helping the client to improve performance in operations, cost control or sales, the 3PL is adding value. Part of account management is ensuring that staff are aligned across the various levels of the organization. In addition to the tactical staff to run the operation, the relationship also needs strategic thinkers who can demonstrate what is often called ‘thought leadership’. To do this, the senior 3PL management need an understanding of the account’s long-term business needs.

Implants

For some time now, 3PLs have adopted the practice of embedding implants into their clients’ operations. These are 3PL staff who work directly with the client on the client’s premises. There is no better way to understand the main drivers for a client’s business than to provide an implant working side by side in a planning or related supply chain role. The implant is also in a good position to identify issues and concerns before they become problems between the 3PL and the client. They are ideally placed to identify further business opportunities for the 3PL. One drawback of implants is that they can ‘go native’ and associate themselves too closely with the client. Also, the efficacy of implants is much enhanced when they act as the only day-to-day face of the 3PL rather than when there is a whole crew working on site. Implants need to be well managed and motivated (see also Chapter 33).

Integrated information systems

A measure of the level of engagement between a 3PL and its client is expressed in how well data is circulated between them; integrated information systems should be used wherever possible. It is essential in operations of any scale to integrate tightly the 3PL systems (usually warehouse or transport management systems) with the client’s ERP system. Many 3PLs have invested in integration software that allows them quickly and reliably to connect the various systems. High levels of integration allow not just high volumes of data to be passed between companies, but also at a very high speed. The process should be extremely reliable, with leading integration platforms having audit techniques that can alert if messages leave one system but are not received or processed in the other.

Continuous improvement

Clients want to see continuous improvement in the way that 3PLs run their operations over time. These may benefit both cost and service. Clients also seek innovative solutions from 3PLs to enhance their operations.

Sector expertise

3PLs who already specialize or operate in their client's industry sector may be able to bring particular expertise to the client. This provides the opportunity to help clients understand industry best practices and to provide benchmarking data. Also, it is often expected that every 3PL should continuously assess what they learn from any sector in which they operate in order to provide ideas for their clients. The issue of client confidentiality can sometimes hinder 3PLs from sharing such information.

Process improvement

Clients look to see continuous improvement in processes because process improvement is one way to enhance a relationship and to identify more efficiencies in a client's supply chain. The more familiar a 3PL becomes with a supply chain, the easier it should be for it to identify opportunities to drive down cost or improve service levels. In some instances, the expectation of such improvements may be written into contract agreements.

Innovation

As already indicated, clients seek innovative solutions from 3PLs to enhance their operations. Innovations such as voice picking systems provide an example of this.

Communication

Almost certainly the key ingredient for ensuring a good relationship between provider and client is good communication. Of course, communication is the responsibility of both parties in the relationship and to ensure good levels of communication they both need to provide channels for this to happen.

Regular meetings provide a forum for discussing key operational issues, but also give both parties the opportunity to discuss areas for additional work outside the explicit services included in the contract. These opportunities should emerge as the relationship matures. It is especially important for 3PLs to communicate regularly with their clients in order to understand how the clients' businesses might be changing and how that might impact on the operations and services that are being provided.

Implementation planning

Importance of implementation

For almost all new outsourcing arrangements, the initial issue after the contract has been successfully negotiated is the successful implementation of the operation. As with any large business project it is essential to identify and agree a project plan to ensure that responsibilities are clear and that there is a feasible timetable for implementation. A typical implementation plan will need to identify the tasks for both the user and the contractor organization, including contingency planning. The aim is to effect a smooth transition from the old operation to the new contract. From the user perspective it is vital to ensure that there is clear visibility of the implementation process. A team that includes both user and contractor staff should be established and this team should meet on a regular basis to monitor and discuss progress. Detailed project plan activity charts should be used. It is often said that the real work begins once the contract has been signed, and the work required for the creation of a practical operation from a conceptual document is not to be underestimated.

An appropriate provider representative or representatives should be included in all client planning meetings, especially where strategy and performance is reviewed as this may impact on the new operation. By the same token, the provider should be responsive to any changes that are requested by the client, and should communicate and discuss any implementation issues as they arise. There are a number of potential pitfalls that might occur during the implementation process, and some common faults are shown in Table 37.1 and discussed in the following sections. Note that these pitfalls can originate from the client as well as the provider!

Client perspective

One key issue that can arise, from the client perspective, is the adoption of unrealistic goals for the start-up of the operation. There are always going to be teething problems as the operation beds down, so the provider cannot be expected to hit all the key targets and achieve all the key metrics from day one. Suitable goals need to be determined with a gradual, but agreed, timetable to meet full operational requirements. Poor decision-making can also have an adverse effect on successful implementation. This might include delays to the contract finalization, last-minute changes, the moving of the start date or inappropriate mechanisms for making decisions. Clients can also be prone to sitting back and letting implementation take place without providing sufficient input or taking appropriate responsibility. This is a classic problem, and one that re-emphasizes the need for a client to work together

with the 3PL to make sure that the contract is implemented successfully. Finally, the metrics that are used to measure the operation can be a problem if the client misinterprets them or uses them as a whip to punish the contractor rather than as an aid to help manage and improve the operation.

Contractor perspective

There are also a range of potential contractor-initiated problems, as Table 37.1 illustrates. A classic communication issue is the failure to manage the client's expectations. If problems, errors and delays occur, then it is essential that the client is made aware and kept up to date with any changes and developments. Failure to do this is exacerbated if there is an insufficiently high level of executive support from the provider to help explain and alleviate problems. Similar to some of the client issues are poor decision-making, which might include delays to the contract finalization or last-minute changes to the physical or operational processes. The lack of appropriate metrics can, of course, be an issue, as can the failure to measure performance accurately for feedback to the client.

Key considerations for implementation

The implementation process is likely to include the preparation of new administrative, safety and service procedures, which will be incorporated in an operations manual. It is also strongly recommended that prior to, or during, the implementation phase the 3PL and the client go through the contract in detail to ensure that each operational requirement is being suitably addressed. The transition plan should reflect these requirements, and any issues that cannot be agreed at operational level should be taken up during regular discussions between the senior management of the client and the provider.

Another important aspect, as already indicated, is to develop and agree suitable metrics that enable accurate measurement of the operation. These should include measures that are relevant to the transition from the existing operation to the new one. Ideally, metrics for implementation and for the finalized operation should be developed and agreed during the contract negotiation period, although this is not always undertaken in time! These metrics are, in any case, likely to need some adjustment during the implementation phase because it is virtually impossible to derive a completely suitable set of metrics for an operation when it is only in its planning stage.

Table 37.1 Potential pitfalls that might adversely impact the successful implementation of an outsourcing operation

Client initiated problems	Contractor initiated problems
Unrealistic goals at start-up	Failure to manage expectations
Delaying or failing to finalize the contract	Not having executive support
Making last-minute requests, setting up new expectations, moving up the start date	Making last-minute decisions and changes
Poor decision-making mechanisms	Delaying or failing to finalize the contract
Maintaining a hands-off attitude	Not dedicating the implementation team to a sole project
Poor internal employee communications	Not developing agreed start-up and steady state metrics
Not accepting any responsibility in the implementation process	Not measuring performance accurately (or at all) during start-up
Misinterpretation of the service agreements and the associated metrics	Not communicating metrics to employees
Using metrics as a whip rather than a tool for managing the relationship	Not being proactive with communication, thus forcing the client to initiate meetings, etc
Reacting too severely to the first quality breakdown	Failing to adjust processes and retrain staff as operational changes and quality issues arise
Expecting total adherence to the contract agreements on the first day of implementation	Lack of awareness of regional HR issues, such as employee quality, availability and cost
Internal team not capable or not totally committed to the implementation	Moving to steady state operation before implementation phase is fully completed

SOURCE Based on Tompkins, 2006

Monitoring an outsourced logistics operation

Whether running a logistics operation as an in-house manager or as a third-party contract manager, the basic reasons for monitoring the operation are very similar: to measure whether the operation is meeting set service levels at an acceptable cost. The major difference is that for an outsourced operation there will be certain selected metrics that will need to be provided to the client company. These metrics will also be used to confirm to them that the operation is being well run and that service levels are being met. These metrics will relate particularly to the service level agreement

(SLA) and the main outsourcing contract (see Chapter 3 for additional comment on an SLA).

Key elements

Different methods of monitoring the cost and performance of a logistics operation are described in Chapter 38. These are usually linked to the twin goals of cost and service performance achievement or improvement. There will also be a number of other monitoring metrics that are more specific to outsourced operations. Linking these together, the main methods for monitoring and controlling a 3PL are, therefore, likely to include:

- Monitoring against the contract.
- Monitoring against the SLA: the service level agreement should identify key performance measures and link the supplier's payment to performance against them.
- Budgetary control: this is described extensively in Chapter 38.
- Management information and metrics of the operations (KPIs): see Chapter 38 for detailed examples.
- Review meetings: there should be a series of meetings to enable performance review and to investigate variance analysis. Dependent on the issues involved, meetings will vary with regard to regularity, personnel, etc. There are likely to be quarterly strategic meetings between senior management, and weekly operational meetings between supervisors.
- Activity forecasts/redefinition of targets: this approach recognizes the dynamic nature of most businesses, and the need to reassess accordingly.
- Audits through open book: as required according to the contract agreement.
- Incentivization of the management fee: incentive (or penalty) programmes to be activated based on service performance.
- A constructive review process to include continuous improvement: this should involve the interpretation of KPIs to identify and enable continuous improvement and an integrated approach to performance improvement, including both supplier and customer processes.

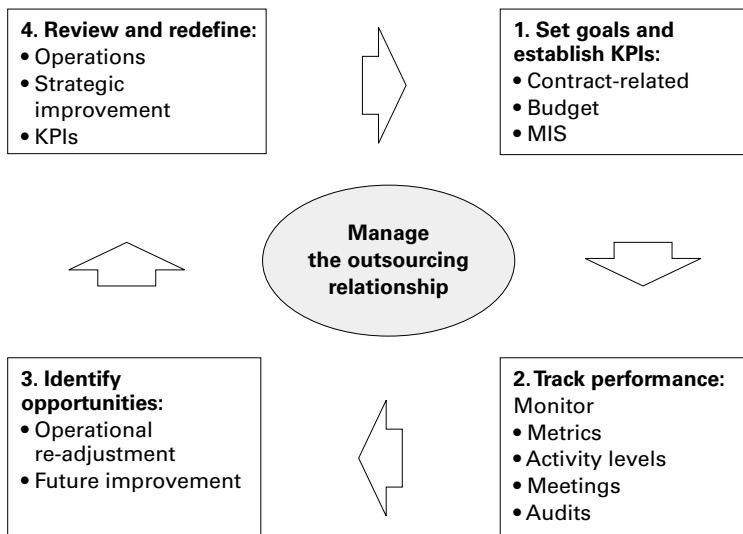
An overall approach to outsourcing management

An overall approach to outsourcing management is summarized in Figure 37.1. This shows the four key stages in setting up and running a system to manage the outsourcing relationship, encompassing the main methods discussed throughout this

chapter. There are four stages indicated in this approach, but it should be treated as a continuous process that reflects the fact that all businesses develop and change over time. The four stages are:

- 1 Set goals/establish KPIs:** this concerns the determination of goals, as required, with respect to the contract, the SLA, the budget and any incentivization. These are then converted into appropriate metrics within the management information system (MIS).
- 2 Track performance:** this involves the monitoring of the MIS and appropriate key metrics, which will include activity levels. It should involve regular review meetings (at different hierarchical levels and frequencies) and open-book audits (if appropriate).
- 3 Identify opportunities:** including both operational readjustments (personnel, facilities, etc) and future strategic and tactical improvements.
- 4 Review and refine:** implementing strategic, tactical and operational improvements, adjusting and resetting KPIs as necessary.

Figure 37.1 An overall approach to outsourcing management



Typically, a manager is nominated from within the user organization to be responsible for the management of the contract. The manager's objectives are likely to be to ensure that cost and service targets are met and to develop opportunities and initiatives for continuous improvement. This will be achieved through the use of suitable metrics. The use of a nominated manager brings both focus and accountability to the outsourcing arrangement, as well as providing the contractor with a main point of communication. This manager is likely to meet with the contractor for

regular reviews. As well as reviewing cost and service performance, these meetings should consider any operational difficulties that are at issue and look forward to future forecasts of changes in activity that might impact on the operation. As already indicated, the relationship that is developed should not just consider how well the contractor is complying with the contract arrangement, but should also look to identify opportunities for the continuous improvement of the operation through better service performance at lower costs. This is often associated with the use of incentives linked to the management fee.

For any new contract it is important to introduce all of the relevant processes for outsourcing management, so that the 3PL can be monitored and managed effectively. Many successful relationships reflect this and they also support the need to treat outsourcing more as a partnership than as a strict contract-driven arrangement.

Longer-term contract management

Some longer-term contract management techniques are also used, because even where original contractual criteria are being met, support can become ineffective because the original contract has become steadily irrelevant as the business changes. As a consequence of these problems, and as a means of resolving them, a number of collaborative outsourcing management techniques have been developed. These include:

- **Competitive benchmarking.** Here, performance is compared with competitors in functions controlled or heavily influenced by the 3PL (e.g. call centre response times, transaction processing costs). The 3PL can be rewarded for identifying areas for improvement and be encouraged financially to invest in associated efficient technologies that help improve performance. Where both in-house and 3PL operations operate within the same company network then one may be benchmarked against the other. This should create an ongoing beneficial internal competitive tension (see Chapter 39 for more details).
- **Profit sharing ('gain sharing').** Bottom-line targets are agreed (e.g. profitability levels on certain functions) and the 3PL takes a share of the profits or gains over the target. This technique can be quite complex in practice and time-consuming to set up and operate.
- **Special purpose financial vehicle.** Essentially, this is a subsidiary or joint venture specially created to deliver the services to the client. This can help to ring-fence the budget and is used to separate out the contract from the rest of the client's business activity.
- **Self-funding project or 'pay as you save'.** In this example, clients ask providers to break down projects into pieces that produce measurable cost savings. The idea is that these savings will allow them to fund the projects.

Cost and performance metrics

For most logistics operations it is possible to identify certain key measures called key performance indicators (KPIs). These measurements (or metrics) are likely to differ from one company to another, depending on the nature of the business. As indicated earlier, similar metrics will be used for both in-house and outsourced operations and these are described in Chapter 38. The likely differences are the introduction and use of metrics that are specific to the contract or to any incentive payments or clauses.

Examples of a number of general logistics metrics are provided in Chapter 38. A specific example that illustrates the development of metrics for a 3PL provider planning to operate a warehouse and storage operation for an online retailer is given in Table 37.2.

Table 37.2 An example of the development of metrics for a 3PL provider planning to operate a warehouse and storage operation for an online retailer

Client Commercial Objectives	Supporting Logistics Goals	Metrics
To offer an exceptional level of product quality compared to competitors.	To maintain product integrity throughout storage, handling, packing and delivery.	Breakages. Storage temperature and humidity conditions.
To offer exceptional levels of service in order to establish a strong reputation in a new market.	To exceed average order-processing times for the recommended product range. Continuous improvement in picking accuracy and order fulfilment. To process standard range products to allow all incoming product to be picked and dispatched on the same day. To maintain stock levels and avoid stockouts of recommended products via proactive inventory management.	Order fulfilment rate. Order fill rate. Line fill rate. Receipt processing rate. Stockouts.
To return a reasonable profit, even during start-up when customer demand is yet to grow.	To manage costs within the agreed framework and assumptions, and provide opportunities for year-on-year cost savings.	Total cost per case delivered.
To grow the business quickly into additional European markets.	To provide consistently high performance across all markets by sharing best practice between operations.	Internal benchmarking.

PART SEVEN
**Operational
management**

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Cost and performance monitoring

38

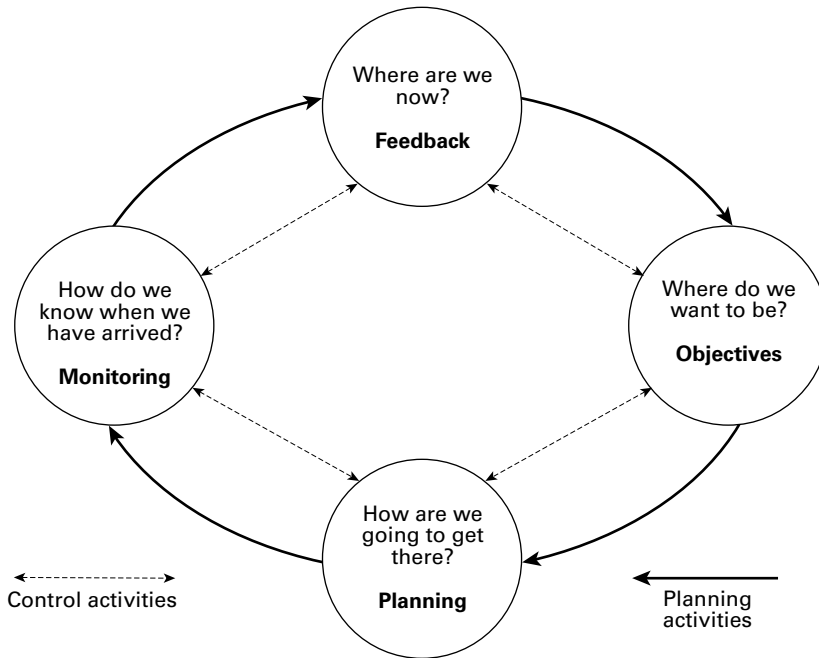
Introduction

Information can be seen as the ‘lifeblood’ of a logistics and distribution system. Without the smooth flow and transfer of information, it is impossible for a logistics system to function adequately and effectively. To this end, it is important that an enterprise develops an appropriate approach for its information requirements in line with its logistics strategy and operations. This approach will need to take account of a number of different objectives, from strategic planning through to operational control.

A typical framework illustrating the planning and control cycle is shown in Figure 38.1 (introduced in Chapter 2). This framework emphasizes the cyclical nature of the planning and control process, starting with the question ‘Where are we now?’, where the aim is to provide a picture of the current status of an operation. This might be through an information feedback procedure and/or through the use of a distribution audit.

The second stage is to identify the objectives of the logistics or distribution process. These should be related to such elements as customer service requirements and marketing decisions. The third stage in the cycle is the process that includes the development of appropriate strategic and operational plans to achieve these objectives. Finally, there is a need for monitoring and control procedures to measure the effectiveness of the logistics operation compared to the plan. This chapter on cost and performance monitoring is focused on this key aspect.

In this chapter the key questions of why and how to monitor and control the costs and performance of logistics operations are addressed. The importance of identifying clear business objectives as the basis for setting up appropriate operational measures is emphasized. A formal approach for monitoring and control is recommended, and several different approaches are described. These include the balanced scorecard, the Supply Chain Operations Reference (SCOR®) model, an integrated supply chain approach as well as a basic operational approach.

Figure 38.1 The planning and control cycle

One important factor is to determine against what to measure or compare the operation. There are a number of alternatives, and these are described. They range from traditional cost and performance measurement against historical data and/or a budget plan, developing physical or engineered standards, methods such as direct product profitability, activity-based costing and cost-to-serve, to benchmarking against 'best practice'.

A simple and straightforward logistics operational planning and control system is outlined, using the budget as the basis for providing quantitative objectives for the key elements to be monitored, but linking this directly to appropriate internal and external standards.

Some key areas of good practice are considered. Although based on sound common sense, these factors are essential to the development of an effective monitoring system. In addition, several influencing factors are highlighted. These are used to help explain the differences that occur when systems are monitored for comparative purposes. Finally, and most importantly, a number of detailed and key cost and performance monitoring metrics are described, together with an example of how these metrics can be presented.

Why monitor?

To establish an effective system for cost and performance monitoring and control it is crucial to identify the overall guidelines or aims that the system is designed to fulfil. These are likely to reflect major business objectives as well as more detailed operational requirements. Thus, it is important to be aware of the role of logistics and distribution within the context of the company's own corporate objectives. It is also essential that the control system reflects the integrated nature of logistics within an organization.

Typical aims might be:

- To enable the achievement of current and future business objectives – where these are directly linked to associated logistics and distribution objectives.
- To facilitate the effective provision of logistics services, thus enabling checks to be made that the distribution operation is appropriate for the overall objectives ('doing the right thing').
- To enable the efficient operation of logistics resources, to ensure that the distribution operation is run as well as it can be ('doing the thing right').
- To support the planning and control of an operation, so that any information can be fed back into the process of planning and management.
- To provide measures that focus on the real outputs of the business – this enables action to be taken when the operations are not performing satisfactorily or when potential improvement to the operation can be identified. This may be linked to some form of productivity improvement or better use of resources.

In addition, some fairly specific objectives should be identified that relate to the logistics operation itself. A major feature is likely to be to measure actual progress against a plan. Typically this will be to monitor the budget in a way that identifies if some change from plan has taken place, but also to provide a usable indication of why actual performance or achievement does not reflect what was originally planned. Another feature may well be to highlight specific aspects or components of the system that need particular attention.

Care needs to be taken in identifying these broader objectives. They need to be meaningful. Examples that fail the test include:

- 'The aim for distribution is to minimize costs.' Is this to be at the expense of customer service? There needs to be a clearly identified relationship between cost and service requirements.
- 'The level of service is "as soon as possible".' What does this really mean? Are all orders treated as urgent?

- ‘Everything is to be delivered on our own vehicles.’ Does this mean resourcing the fleet to cover peak demand all year round? This is almost certainly not a cost-effective approach for determining transport requirements.

An example of carefully prepared objectives comes from a manufacturer and distributor of soft drinks. The overall aim is to provide accurate, timely and useful information on logistics cost and operational performance:

- to enable the business to monitor progress towards set objectives at the total logistics level
- to enable the operational departments within logistics to measure their performance against their objectives and targets, and to make operational adjustments as necessary
- to provide regular information to other internal operations and functions to help assess wider trade-off opportunities
- to develop a dynamic set of data and information for use in strategic and operational planning

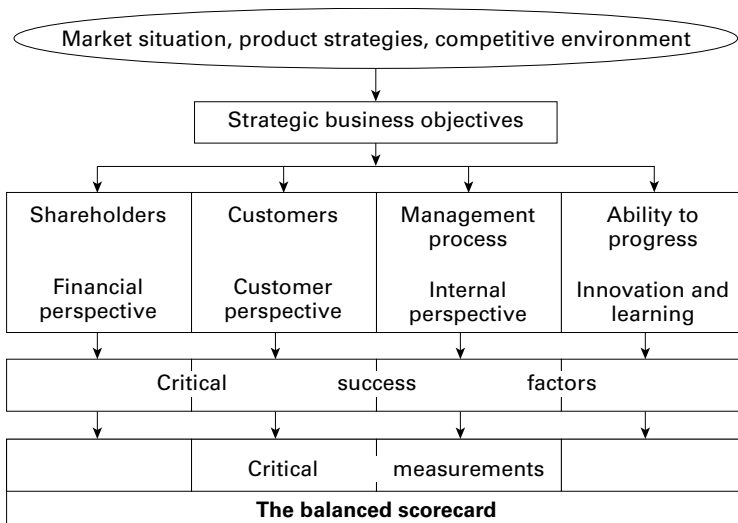
Overall, the information must be quantitative and comparative wherever possible, relating to set objectives.

Different approaches to cost and performance monitoring

The monitoring and control of logistics and distribution operations can be relatively unsophisticated and unplanned. Control measures may be adopted as problems arise, almost as a form of crisis management. It is important to adopt a more formal approach, although this should not necessitate a complicated format. There are several systematic approaches that have been developed and these have a varying degree of sophistication and detail.

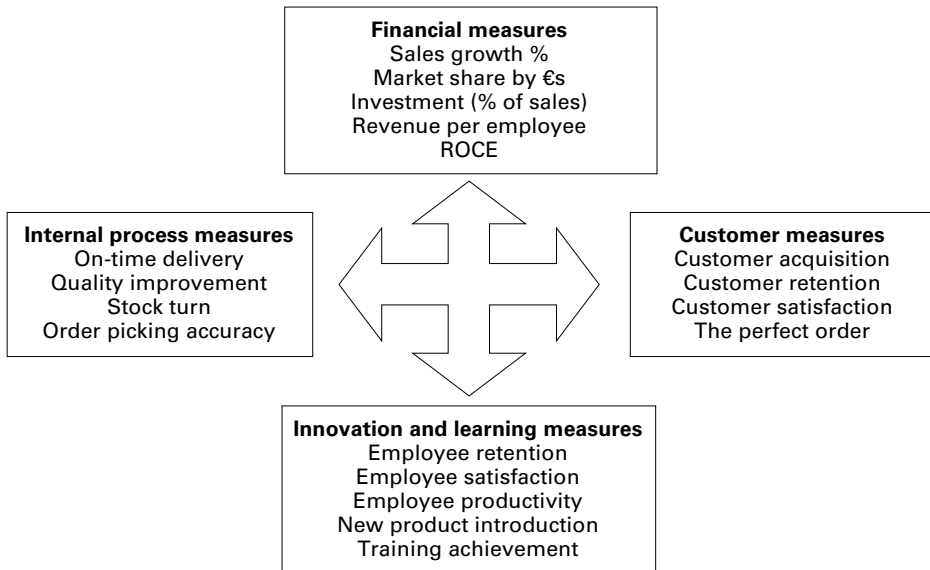
Balanced scorecard

The balanced scorecard was initially developed by Kaplan and Norton in 1992. This is a broad business approach that translates the strategic mission of a business operation into tangible objectives and measures. These can be cascaded up and down the enterprise so that realistic and useful key performance indicators (KPIs) can be developed to support the business. These should represent a balance between external measures for shareholders and customers, and also internal measures of critical business processes, innovation and learning. This structure is shown in Figure 38.2.

Figure 38.2 The balanced scorecard

SOURCE Based on Kaplan and Norton, 1992

The financial perspective concerns the relationship with shareholders and is aimed at improving profits and meeting financial targets. The customer perspective is designed to enhance customer relationships using better processes to keep existing customers and attract new ones. The internal element is to develop new ideas to improve and enhance operational competitiveness. Innovation and learning should help to generate new ideas and to respond to customer needs and developments. A series of critical success factors is identified that relate directly to the main business perspectives. These are then used as the basis for creating the critical cost and performance measurements that should be used regularly to monitor and control the business operation in all the key areas identified. Some typical measures are shown in Figure 38.3 under the appropriate scorecard categories. More detailed metrics are listed later in this chapter.

Figure 38.3 Balanced scorecard: typical measurements

SCOR[®] model

The SCOR[®] model is an important approach that has been developed as an aid to cost and performance monitoring. It is a hierarchical model, consisting of four different levels: competitive advantage, strategy implementation and process definition, detailed process elements and implementation. It is very much a process-oriented approach, where the initial aim is to benchmark, refine and improve key operational processes, and then to identify and introduce key measures that monitor set cost and performance targets. Eventually, the major company performance attributes are identified and the appropriate metrics are developed. A typical example of this performance metric development is shown in Table 38.1.

SCOR[®] metrics are generally arranged under a number of categorizations. There are many different individual measures that come under the different categories. The main categories are:

- assets (such as capacity utilization, equipment availability)
- cost (inventory holding, invoicing)
- data (forecast accuracy, visibility)
- flexibility (order, returns)
- inventory (availability, obsolescence)
- orders (fulfilment accuracy, invoice errors)

Table 38.1 SCOR®: typical performance metric development

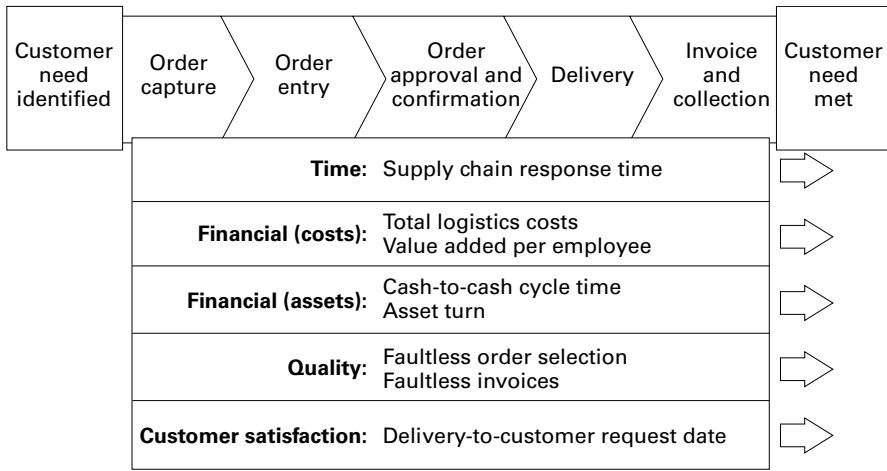
Performance attributes	Attribute definition	Metrics
Supply chain delivery reliability	The performance of the supply chain in delivering against the perfect delivery criteria	Perfect order fulfilment Picking accuracy Delivery performance
Supply chain responsiveness	The speed at which the supply chain provides products to the customer	Ease of order placement Order fulfilment lead time
Supply chain flexibility	The agility of the supply chain in responding to marketplace changes to gain or maintain competitive edge	Production flexibility Supply chain response time
Supply chain costs	The costs associated with operating the supply chain	Value added productivity Supply chain management costs Cost of goods sold
Supply chain asset management	The ability to manage assets to support customer satisfaction	Equipment utilization Capacity utilization

- productivity (direct versus indirect labour, vehicle subcontracting)
- time (order cycle time, on-time delivery)

Integrated supply chain approach

An integrated supply chain approach recognizes that a total systems approach can be adopted for the whole business or supply chain and that any performance metrics should be developed on this basis. This, again, is a process-oriented approach that attempts to enable cost and performance monitoring to be based on a horizontal view of a business rather than the traditional, vertical, silo-based functional structure that is often used (see Chapter 11 for a related discussion on organizational structures). This approach to the development of supply chain metrics is outlined in Figure 38.4.

This type of framework can be used initially to help to identify required outcomes that need to be measured, and then subsequently for establishing any relevant diagnostic measures. Suitable and accurate diagnostic measures are essential to enable the reasons for any problems to be identified and then rectified. This is a vital element of good cost and performance monitoring that is often neglected. Some examples are indicated in Table 38.2.

Figure 38.4 Integrated supply chain metrics framework**Table 38.2** Integrated supply chain metrics

Metric Type	Outcomes	Diagnostics
Customer Satisfaction/Quality	Perfect Order Fulfilment Customer Satisfaction Product Quality	Delivery-to-Commit Date Warranty Costs, Returns & Allowances Customer Inquiry Response Time
Time	Order Fulfillment Lead Time	Source/Make Cycle Time Supply-Chain Response Time Production Plan Achievement
Costs	Total Supply Chain Costs	Value-Added Productivity
Assets	Cash-to-Cash Cycle Time Inventory Days of Supply Asset Performance	Forecast Accuracy Inventory Obsolescence Capacity Utilization

Operational approach

The approaches discussed so far can be fairly complicated, so a more simple and straightforward operational approach is sometimes the most appropriate for small to medium-size companies. This stepped approach is as follows:

- 1 *Determine the scope of logistics activities:* the scope of distribution and logistics activities will, of course, vary from one company to another, as will the extent of integration. Because of this, it is impossible to identify a standard system that can

be adopted generally. A company must first determine the scope of activities that need to be considered, taking into account the overall logistics requirements and objectives as well as the traditional components of the functional subsystems (primary transport (line-haul), distribution centre operations, local delivery, etc).

- 2** *Identify the organization and departmental objectives:* more detailed departmental objectives should be defined. These will include such areas as stockholding policies by individual line or product group; customer service levels by product, by customer type or by geographical area; delivery transport costs, utilization and performance.
- 3** *Determine operating principles and methods:* operating principles and methods need to be clarified with respect to the different logistics components, such as primary transport (line-haul) and delivery transport, warehousing resources and usage, together with implications for seasonality, etc. These factors will provide the basis for establishing realistic and relevant measures.
- 4** *Set productivity and performance goals:* productivity and performance goals should then be set in relation to the detailed operational tasks that are performed and with respect to the overall output requirements for the integrated logistics system as a whole. These should cover all the essential aspects of the physical distribution system. It is often easier to categorize these under the major subsystems of warehousing (order picking performance, labour utilization, cost per case, etc), transport (vehicle utilization, cost per mile/kilometre, fuel consumption, etc) and administration/stockholding (customer orders received, stockouts, percentage of orders fulfilled, etc). Goals should be set based on some acceptable standards or comparative information. There are several different approaches used by organizations, and these are discussed in the next section of this chapter.
- 5** *Measure and monitor performance (develop management information system) (MIS):* key indices and ratios need to be developed to allow for appropriate monitoring and control to be undertaken (e.g. actual work against planned work, cost per case, cases per hour, tonnes per journey, etc). These need to be representative of the logistics operation, and they should be capable of clearly identifying why a deviation has occurred as well as if a deviation has occurred. Some key measures and metrics are given at the end of the chapter.
- 6** *Action:* take corrective action where necessary.

What to measure against?

As already indicated, there are a number of different approaches that can be adopted to determine appropriate goals. These range in sophistication from very simplistic internal year-on-year comparisons to quite detailed externally related engineered

standards. Most well-developed systems are internally cost-oriented, but are also linked to external performance measures.

Historical data

Systems that merely compare overall activity costs on a period-by-period basis may not be providing any useful information that can be used to monitor operational performance. As an example, a measure may indicate that the cost of distribution for a company has reduced as a percentage of total revenue for this year compared to last year. Without any background to this measure, it is impossible to be sure whether or not this is an improvement in terms of distribution performance.

Budget

Almost all companies will have a budget plan, and this should include a breakdown of the logistics costs in appropriate detail – an activity budget. A traditional means of monitoring an operation is, therefore, to evaluate the cost of the logistics operation in relation to the expectations of the budget plan.

The budget approach has been developed in a variety of ways to enable more sophisticated and more meaningful measures to be created. The ‘*activity*’ concept can be used so that the budget – and the respective measurement process – can identify and differentiate between functional activities (warehouse, transport, etc) and, more importantly, across core business-oriented activities. This might, for example, be by product group or by major customer, thus allowing for very detailed measurements reflecting the integrated nature of the logistics activities under scrutiny. (See later in this chapter for discussion on the more formal method of activity-based costing).

An additional development is the concept of *flexible budgeting*, which recognizes one of the key issues of monitoring – the need to be able to identify and take account of any changes in business volumes. This is particularly important in the logistics environment, where any reductions in volume throughput can lead to the under-performance of resources. The concept is based on the premise that budgets are put together with respect to a planned level of activity. The fixed, semi-variable and variable costs appropriate to that level of activity are identified and form the basis of the budget. If activity levels fluctuate, then in flexible budgeting the planned budget is flexed to correspond with the new conditions. Thus, semi-variable and variable budgetary targets (actuals) are adjusted for the change. In this way the change in cost relationships that results from a change in the level of activity is taken into account automatically, and any other variances between planned and actual cost performance can be identified as either performance, level of activity or price changes.

This approach is particularly applicable to logistics activities, as there is very often a high fixed-cost element, and any reduction in levels of activity can increase unit costs quite significantly. With a fixed (i.e. non-flexible) budget system it can be difficult to identify the essential reasons for a large variance. To what extent is there inefficiency in the system that may be controlled, and to what extent is there under-utilization of resources due to falling activity? A typical example is the effect that a reduction in demand (throughput) can have on order picking performance and thus unit cost. A flexible budget will take account of the volume change and adjust the original budget accordingly.

An effective budget measurement system will incorporate the idea of *variance analysis*. In the context of logistics activities, variance analysis allows for the easier identification of problem areas as well as providing an indication of the extent of that variance, helping the decision process of whether or not management time should be assigned to solving that particular problem. As indicated earlier, an effective system will indicate if a variance has occurred, the extent of that variance and also why it has occurred. This should be indicated in terms of a change in levels of activity, performance or efficiency, or a change in price or cost (or a mixture of some or all of these). Variance analysis is best used within the context of a flexible budget, because flexing the budget takes account of changes in activity.

It is worth noting that a good way to prepare for the monitoring of an agreed budget is to identify the largest cost areas and to concentrate on the regular review of these. Pareto analysis can be used as the basis for this, as described under the 'Tools and techniques' section in Chapter 7. Typically, in logistics, the largest cost element is labour, so this would be one key area to have effective measurement. Suitable logistics metrics are discussed later in this chapter.

Direct product profitability

An alternative approach to logistics cost analysis, direct product profitability (DPP) aims to identify all of the costs that are involved with an order or a product as it moves through its distribution channel. Very often the only easily identifiable cost of a product is the actual purchase price but there are also other costs incurred with respect to many distribution- and logistics-related elements such as ordering cost, storage costs, transport cost, etc. This real cost is often known as the 'total cost of ownership'. These hidden costs can in many instances be quite substantial and might influence the product attractiveness if the company knows these true costs. Often, due to lack of information and due to reliance on classic accounting systems, these logistics costs are 'averaged' inappropriately across a broad range of products, thus producing inaccurate 'real' costs of many individual products.

Activity-based costing

Concerns expressed over the unsuitability of conventional accounting systems for monitoring logistics operational costs has led to the development of more appropriate methods, the most common approach being that of activity-based costing (ABC). Key problems with traditional accounting systems include:

- conventional accounting systems are not output-oriented but are functionally based
- costs are collected at too general a level
- costs are collected as aggregates rather than directly related to specific activities
- it is impossible to identify appropriate cost implications for different markets, product groups, channels or customers

ABC methods allow for greater visibility of the true costs that are involved in the overall logistics process by identifying cost implications at a much greater level of detail. The key to this approach is to allocate costs on the basis of the activities that are using the resources rather than on the traditional allocation based only on a broad unit product or the number of orders. To achieve this, the real cost drivers need to be identified and used. Thus, for order picking, for example, it is likely to be the number of lines on an order that should be used for the purposes of picking cost allocation rather than the traditional approach of an average cost per order made. Orders can differ quite dramatically in terms of the workload that is required to complete them.

Thus, activity-based costing allows for the particular characteristics of a customer's ordering, storage and delivery requirements to be identified and accounted for. This is useful for the supplier as a means of identifying more accurate cost allocation and also for the customer to help them better understand the true costs of product supply.

This approach to distribution and logistics cost analysis can provide much more reliable and more accurate information to enable a company to run a more effective operation and to understand the true costs of distributing a multitude of different products to a range of different customers.

For a more detailed description of this type of approach, see the section on 'Benchmarking distribution operations' (in Chapter 39). An approach to a distribution cost audit is described where the individual elements of distribution are broken down to identify the key costs for each activity. Appropriate product categories or groups are used as the basis for data collection and analysis. The results of this can then be used as the foundation for developing an appropriate ABC system.

Cost-to-serve[®]

Cost-to-serve[®] is a similar approach to activity-based costing. The major difference is that cost-to-serve[®] is not as resource-intensive because it is based on aggregate analyses using a mixture of appropriate cost drivers. It is broadly a process-driven accountancy tool and it is used to calculate customer profitability using the actual business activities and overhead costs that are involved.

For distribution and logistics it can be used to assess how costs are consumed throughout the supply chain. It takes into account that each product and each customer have a different cost profile and use different activities. Pareto analysis can be used to show that certain products and certain customers (usually the top 20 per cent) are the most profitable for the company and that the others (usually the bottom 80 per cent) are the least profitable or indeed run at a loss. Unlike activity-based costing, cost-to-serve provides an integrated view of costs at each stage of the supply chain. It helps a company to identify opportunities for appropriate short-term improvements and also provides useful input into long-term decision-making.

Engineered standards

A number of companies use internally derived measures for certain logistics activities through the development of engineered standards. This involves the identification of detailed measures for set tasks and operations and is particularly appropriate for many key warehousing tasks, especially picking operations. The means of determining these measures is a lengthy and often costly process involving the use of time and work study techniques but the accuracy of the measures provides the basis for a very powerful measurement tool.

When suitable and acceptable standards have been agreed for specific tasks, then a performance monitoring system can be adjusted to allow for direct measurement of actual performance against expected or planned performance. The advantage of using engineered standards is that each task is measured against an acceptable base. A monitoring system that measures against past experience alone may be able to identify improved (or reduced) performance, but it is always possible that the initial measure was not a particularly efficient performance on which to base subsequent comparisons.

As well as cost, a potential drawback with engineered standards is that the initial time or work study data collection can be difficult to verify. There is no certainty that an operative who is under scrutiny will perform naturally or realistically (whether consciously or subconsciously).

Many logistics tasks do, however, lend themselves to the application of engineered standards. Most warehousing activities fall into this category (goods receiving, pallet put-away, order picking, etc), as well as driver-related activities (vehicle loading time,

miles/kilometres travelled, fixed and variable vehicle unloading times). An outline example is given in the box.

EXAMPLE Developing standards for delivery transport

Standard costs can be related to measured or standard times. These should cover the three main operations:

- 1 vehicle preparation and loading at the distribution centre
- 2 running/driving time (speeds related to road types)
- 3 load selection and delivery time (fixed and variable) at the delivery (drop) points

Standard time journeys can then be built. These can be incorporated with standard costs to give a standard cost per minute. Thus, the planned performance and actual performance are linked, and variance analysis can be undertaken. This provides for a stronger system of control.

External standards

Another approach to cost and performance measurement is to make comparisons against industry norms. The intention here is that a company's performance can be compared to similar external operations and standards, making comparison more realistic and therefore more valuable. For some industries, such as grocery retailing, these measures are fairly readily accessible through industry journals and associations. Examples of typical measures include order picking performance (cases per hour) and delivery cases per journey.

Some of the largest manufacturers and retailers that outsource to several different contractors use this concept to allow them to make detailed performance comparisons between their various depot operations. Thus, they draw up 'league tables' of their distribution centres (DCs) based on their performance against an industry standard and compare each of their own DCs and any third-party logistics (3PL) provider DCs against the others. This can create a useful incentive for the different operations as they strive to maintain or improve their respective positions in the 'league'. Some of the potential difficulties of this approach (for example, comparing operations that have inherent differences such as different depot size, different materials handling equipment) are discussed later in this chapter in the section 'Influencing factors'.

A further development to this is the idea of 'benchmarking'. Here, the aim is to identify appropriate 'world-class' or 'best-in-class' standards across a whole range of

different organizations and operations. This enables a company's performance to be compared with the very best in any industry. It is a broader concept than merely identifying variations in performance, the intention being to identify the reasons why a certain operation is the best and to establish ways and means of emulating the operation. A number of 'benchmarking' clubs have been formed to this end (see Chapter 39 for a detailed discussion on benchmarking and auditing logistics operations).

A logistics operational planning and control system

In this section, a simple logistics operational planning and control system is outlined. For this, the budget is used as the basis for providing quantitative objectives for the relevant elements to be monitored within the logistics operation. Linked to this would be appropriate internal (engineered) and external standards that are important measures of the business.

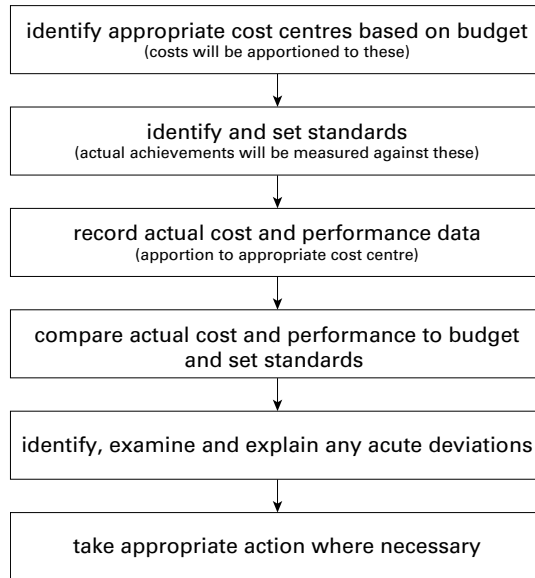
The *operating plan* is drawn up based around the operational parameters or cost centres that are used. This shows how costs are split by period (week or month), by functional element (e.g. fuel or wages), by logistics component (storage, local delivery, etc) and by activity (major customer, product group, etc). The plan shows which logistics KPIs are used (e.g. tonne/miles or tonne/kilometres travelled, etc) and demonstrates how these indicators are linked to set standards.

The *operating control system* is concerned with the process of identifying whether the operating plan has been adhered to – what deviations have occurred and why – so that remedial action can be speedily taken. Figure 38.5 outlines this process by summarizing the key steps that are involved in the preparation and use of an operating control system.

It should be noted that in measuring the deviations referred to in Figure 38.7, it is important to be aware of three major causes of deviation. These are:

- changes in the levels of activity (i.e. less work is available for a fixed capacity – labour or equipment)
- changes in efficiency or performance (i.e. the resource, labour or equipment has not performed as expected)
- changes in price (i.e. the price of an item, say fuel, has increased – so costs will increase)

Activity level changes can, of course, be taken into account by the use of flexible budgets.

Figure 38.5 The steps required to prepare and use an operating control system

The key indices and ratios that are developed need to allow for appropriate monitoring and control to be undertaken (actual work against planned work, cost per case, cases per hour, tonnes per journey). They need to be representative of the logistics operation, and they should be capable of clearly identifying *why* a deviation has occurred as well as *whether* a deviation has occurred.

Good practice

There are a number of key areas of 'good practice' that should be followed when developing the detail of an effective cost and performance monitoring and control system. These are all fairly obvious but bear discussion because they can have a significant impact on the success of a monitoring and control system. They can be broadly categorized as principles, content and output; they are outlined in the remainder of this section together with an example of what one company sees as being the key characteristics of a good monitoring system.

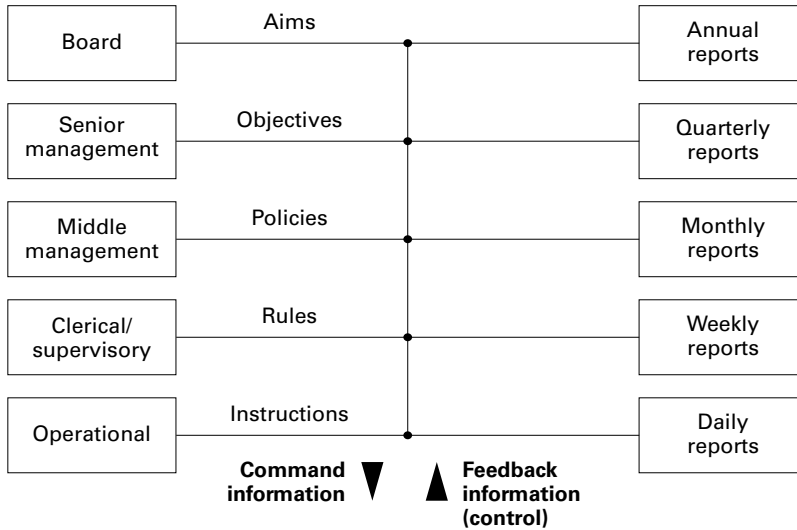
Principles

Most of the main principles associated with an effective system are based on sound common sense. They can, of course, be used to provide distinct guidelines for the

development of an appropriate new control system but they can also help to identify reasons why an existing system is not functioning satisfactorily. They include:

- **Accuracy:** the basic input data to the system must be correct. Inaccurate data will obviously produce incorrect measures, but will also undermine confidence in the system as a whole.
- **Validity/completeness:** the measures used must reflect a particular activity in an appropriate way, and must cover all the aspects concerned. For example, a broad carton-per-hour measure for order picking is clearly inappropriate if there is a substantial element of full pallet picking or broken case picking undertaken as part of the operation.
- **Hierarchy of needs:** individuals within an organization require only certain pieces of information. To swamp them with unnecessary information is expensive and may diminish the usefulness of an information system. Typically, the higher the level of personnel within an organization, the more general or more aggregate is the information required. Figure 38.8 indicates this hierarchy, illustrating the relationship between what might be termed as command information and feedback/control information.
- **Targeting of the correct audience:** linked very much to the previous point is the need to ensure that the correct audience is identified and that all the key information is then directed to this audience.
- **User ownership:** the fault of many an information system is to impose information on individuals without first including them in the process of identifying and determining information requirements. This can be very demotivating. It is a very valid step to include potential users at the systems design stage, thus conferring user ownership of the information when the system is in place. The information should be useful, and those who use the information should understand the detail.
- **Reactivity to changes in business activity:** not a simple requirement to put into practice, but an effective control system will need to be dynamic and so take account of any changes in business activity. To a certain extent this is achieved through flexible budgeting.
- **Timeliness:** reports must be available at the agreed time, and the frequency of reports should be such that suitable control action can be taken.
- **Ease of maintenance:** a fairly obvious comment is that an effective system must not be overly complicated to maintain and progress. Simplicity is certainly a virtue.
- **Cost-effectiveness:** again, a fairly obvious but very relevant point is that a monitoring system should not cost more to set up and run than can possibly be saved through using the system.

Figure 38.6 Hierarchy of needs showing the different information requirements at the different levels of an organization



Content

The elements of good practice that come under the category of content have almost all been covered in previous sections of the chapter, and they are as follows:

- the need for clear cost categories, with careful identification of fixed and variable costs
- the use of flexible budgeting
- the use of variance analysis
- the clarification of controllable and non-controllable elements
- the use of reference points against which the monitored elements can be measured, which might include:
 - budget
 - forecast
 - trends
 - targets
 - comparative league tables

The final two factors (targets and league tables) are useful for monitoring contractor operations and for setting up inter-site comparisons.

Output

This aspect of good practice concerns the type of output that the system produces. This is the information on which any form of action is based. It has already been emphasized that this information must be relevant and useful. The major output characteristics are:

- Reports can vary. They may be:
 - summary (providing key statistics only)
 - exception (identifying the major deviations from plan)
 - detailed (including all information)
- Reports should be made to a standard format – especially important where any inter-site comparisons are to be made.
- Data should be presented in whatever means is most appropriate to the eventual use of the data.

Different types of data output are as follows:

- trend data – based upon moving annual totals to identify long-term changes
- comparative data:
 - over a short period (e.g. this month against last month)
 - against a target (e.g. this month compared with budget)
 - against a measured standard (e.g. this month compared with standard)
 - note that comparative data analysis also identifies variances that indicate the degree of performance success
- indices – data in statistical form compared with a base position over time
- ratios – a combination of two or more pieces of meaningful data to form a useful figure for comparison
- graphs – comparative trends in pictorial form

Key characteristics

What do companies see as being the most valuable characteristics of a good monitoring system? The example outlined below provides an indication:

EXAMPLE Valuable characteristics of a good monitoring system

An international manufacturer and supplier of computer equipment identified the need for a more adequate information system for monitoring and controlling performance in its three warehouses. Five key areas for measurement were identified:

- 1 Volume – what is moving through the warehouse?
- 2 Efficiency – how well is the operation being run?
- 3 Cost-effectiveness – is the cost reflecting the work being undertaken?
- 4 Quality – how well are the service levels being met?
- 5 Stability – what does the staff turnover picture look like?

Outline requirements were:

- overall business control
- activity measures within the business area
- trend indicators and productivity measures

Factors for consideration were:

- action: the system should lead to a change in the current position, and should be used
- confusion: the system should filter out the irrelevant information that confuses and diverts attention
- comprehensibility: everyone who receives information must understand it
- defensiveness: a defensive reaction to figures, especially adverse ones, needs to be overcome
- timeliness: the information has to be available in sufficient time for action to be taken
- validity: actual changes in performance must be reflected by the system
- dynamism: the system must be sensitive to the changing internal and external conditions, as tomorrow's problems cannot be solved with yesterday's measurement system

Influencing factors

Many monitoring systems are developed with a view to using them to enable comparisons to be made between different distribution centres. Some companies will do this across their own operations. It is also common practice for some of the major users of dedicated contract operations to compare how well one contractor is performing against the others.

If this is the major use of a monitoring system, then it is essential that there is a broad understanding of any different operational factors that might influence the apparent effectiveness or efficiency of one operation compared to another. Thus, a number of operational influencing variables can be identified, and may need to be measured at each site in the comparison, to enable suitable conclusions to be drawn and explanations given for any comparative dissimilarities.

Any number of these may be relevant, but typical examples are:

- throughput variability (by day) – this is likely to affect labour and equipment utilization
- product profile – some products are more difficult to select or handle than others
- order profile – orders with many line items take longer to pick than single line orders
- store profile – sites serving mainly small stores may expect to have less efficient picking operations than those serving large stores
- store returns – this will influence workloads
- special projects (promotions, alternative unitization) – these will create additional work
- equipment specification – specialized equipment may be essential but also underutilized
- regional distribution centre (RDC) design (building shape, mezzanines) – will affect most performance statistics
- employee bonus schemes – these may influence picking rates
- methods – different operational methods (such as secondary sortation) will influence productivity
- local labour market – staff quality, need for training, etc
- regional cost variations – labour, rent, rates
- staff agreements – some, such as guaranteed hours, can affect productivity and utilization figures
- unit definitions – ‘case’ sizes and types may be very different at different sites

Logistics metrics and KPIs

For most logistics operations it is possible to identify certain key measures or metrics that provide an appropriate summary measurement of the operation as a whole and of the major elements of the operation. These are very often called key performance indicators (KPIs). Detailed measurements are likely to differ from one company to another, depending on the nature of the business.

Measures are generally aimed at providing an indication of the performance of individual elements within an operation as well as their cost-effectiveness. In addition, the overall performance or output is often measured, particularly with respect to the service provided, the total system cost and the return on capital investment.

KPIs can be categorized in a number of different ways. They can be measures of:

- input (time, labour, cost)
- output (throughput, production, profit)
- ratio (efficiency, productivity)

In practice, an effective measurement system will cover all of the major operational areas within a business. A typical categorization might be:

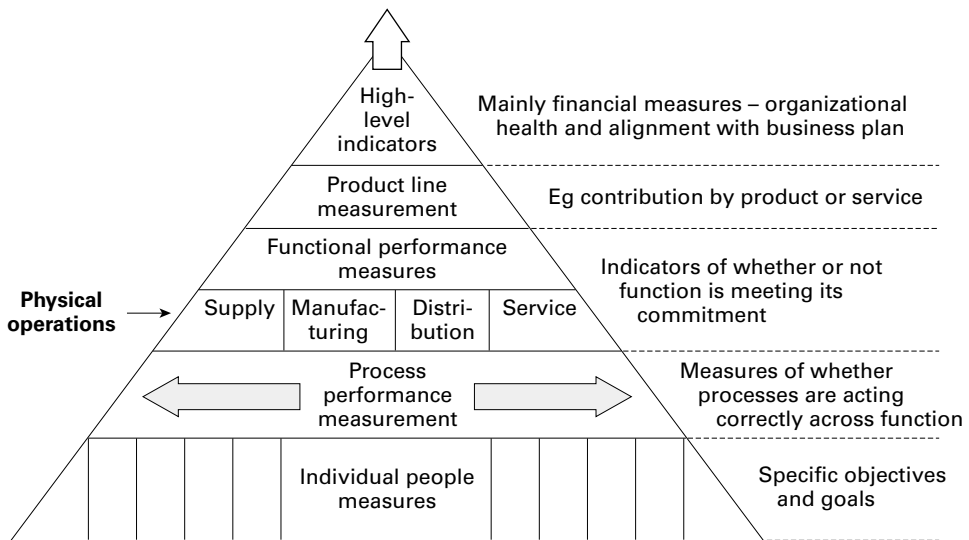
- financial KPIs: return on investment (ROI), return on capital employed (ROCE), stock turn
- customer KPIs: new customers, lost customers, on-time-in-full (OTIF)
- sales KPIs: total volume, total value, sales per customer
- process KPIs: productivity, efficiency
- people KPIs: labour turnover, training, average length of service
- supplier KPIs: OTIF, cost per piece

It is also worth re-emphasizing the importance of hierarchy in a performance measurement system. Figure 38.7 shows how a manufacturer of household products uses a hierarchical model to drill down to the much more detailed measures that are used to assess the more detailed operational aspects of its business.

Typical detailed and key logistics operational metrics are summarized in three different case examples. These cover customer service requirements, a multi-site delivery transport operation and a warehouse operation. Both the transport and the warehouse examples indicate adherence to the principle of the hierarchical nature of information requirements. For additional discussion, see Chapter 3 for customer service measurements and Chapter 24 for warehouse performance monitoring.

A supplier of consumables uses these major customer service measurements:

Figure 38.7 Hierarchical structure of a measurement system used by a household goods manufacturer



- percentage of orders satisfied in full
- percentage of items supplied at first demand
- percentage of overdue orders
- number of stockouts
- orders delivered within set lead times
- percentage of deliveries outside fixed delivery windows/times

A *grocery multiple retailer* has the following metrics that are designed to assess the performance of the delivery transport system. They are aimed at measuring the cost-effectiveness of the operation and also the quality of service. Note the hierarchical approach and also that there are no cost-related measures at the lowest level. The levels and associated measures are:

- director/head office (strategic planning and control):
 - ROCE
 - cost per case (divisional)
 - cost per vehicle (divisional)
 - cost per value of goods delivered
 - cost as a percentage of company sales

- managers (management control):
 - cost per mile or kilometre
 - cost per vehicle
 - cost per roll pallet
 - average earnings per driver
 - maximum earnings per driver
 - maintenance costs per vehicle
- transport manager (operational control):
 - cost per mile or kilometre
 - cost per case
 - cost per vehicle
 - cost per roll pallet
 - cost per journey
 - roll pallets per journey
 - journeys per vehicle
 - damage repairs per vehicle
 - miles (kilometres) per gallon (litre) per vehicle
 - damages in transit and cases delivered
 - percentage cases out of temperature
 - percentage journeys out of schedule
- supervisors (operations):
 - overtime hours as percentage of hours worked
 - contract vehicles as percentage of vehicles
 - percentage of vehicles off the road
 - percentage of drivers absent
 - percentage vehicle fill
 - percentage of vehicles over weight
 - percentage of breakdowns
 - average hours worked per driver

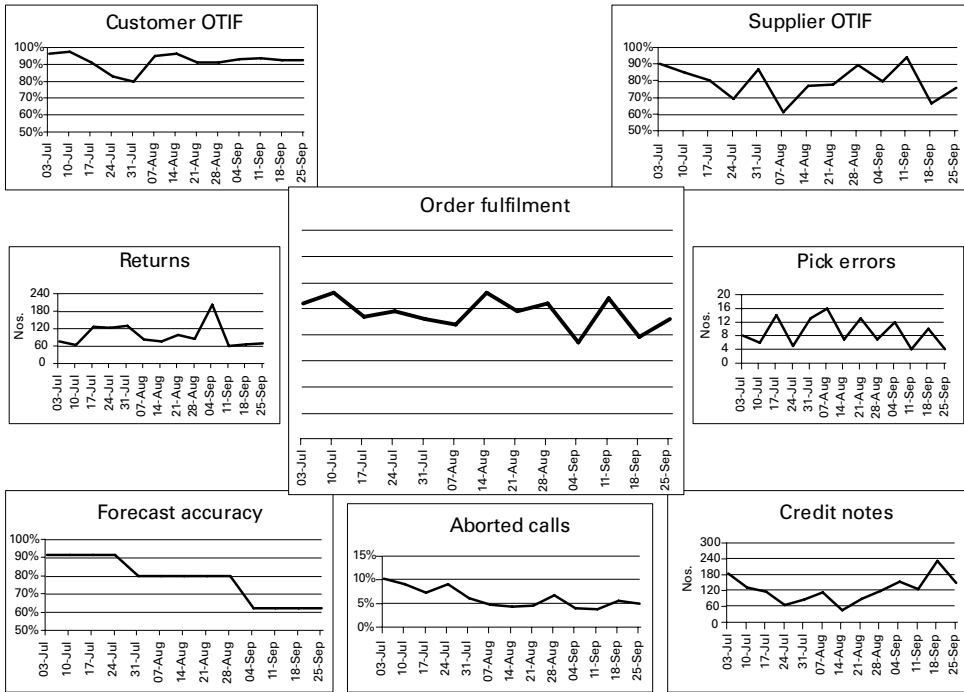
The information requirements for a *fast-moving consumer goods (FMCG) manufacturer and supplier* are set at three management levels. The detailed performance measurements and operating ratios for the company's warehouse operations are shown:

- CEO:
 - profit
 - ROI
 - growth
 - stock turnover
 - distribution cost
 - sales value
- distribution director:
 - service achievement
 - cost-effectiveness
 - capital employed
 - stock turnover by site
 - storage cost per unit
 - warehouse handling cost per unit
 - overall labour efficiency
- warehouse manager:
 - inventory level
 - stock availability
 - operating cost
 - operating productivity
 - actual hours
 - standard hours (stock receiving and location, order picking, packing, dispatch)
 - warehouse cost per unit (order)
 - stock turnover

The presentation of metrics

A good cost and performance monitoring system will cover all of the major elements of a business operation, but, aside from the importance of the accuracy of the data, it will only be effective if it is presented in a timely, usable and clear format. A number of companies have developed very visual output to try to achieve this. Figure 38.8 shows a measurement dashboard that represents the output data very visually. The main KPI is that of order fulfilment. This order fulfilment measure is calculated from a number of supporting measures that are also visually represented.

Figure 38.8 A measurement dashboard



Thus, any underachievement in the overall order fulfilment measure can easily be compared to the supporting measures to identify where the problems have occurred so that remedial action can be taken.

The means by which the detailed measures are used to produce the overall order fulfilment KPI are shown in Figures 38.9 and 38.10. The actual measurement for each element is scored according to how successfully it achieved its goal for the given period. These scores are then aggregated to produce the overall KPI.

Figure 38.9 Example of actual measurements for the dashboard

ACTUAL MEASUREMENT		03-Jul	10-Jul	17-Jul	24-Jul
	Supplier OTIF	90.37%	85.04%	79.95%	68.96%
	Supplier presentation	85.44%	85.55%	81.93%	86.30%
	Aborted calls	10.21%	9.12%	7.28%	9.15%
	Forecast accuracy	91.19%	91.19%	91.19%	91.19%
	Pick error	8	6	14	5
	Customer OTIF	96.20%	97.66%	90.93%	82.80%
	Credit notes	183	130	117	66
	Returns	77	64	125	122
SCORE	Supplier OTIF	8	7	5	2
	Supplier presentation	7	7	6	7
	Aborted calls	4	4	6	4
	Forecast accuracy	8	8	8	8
	Pick error	6	7	3	8
	Customer OTIF	9	10	8	6
	Credit notes	3	5	6	8
	Returns	7	8	5	6
	ORDER FULFILMENT	52	56	47	49

Figure 38.10 Basis for the scoring system for some of the processes for the dashboard

RATING					
Supplier OTIF %		Supplier presentation %		Aborted calls	
0	<60	0	<60	0	>15
1	60–64	1	60–64	1	13.5–15
2	65–68	2	65–68	2	12–13.5
3	69–72	3	69–72	3	10.5–12
4	73–76	4	73–76	4	9–10.5
5	77–80	5	77–80	5	7.5–9
6	81–84	6	81–84	6	6–7.5
7	85–88	7	85–88	7	4.5–6
8	89–92	8	89–92	8	3–4.5
9	93–96	9	93–96	9	1.5–3
10	97–100	10	97–100	10	0–1.5

Benchmarking logistics operations

39

Benchmarking is the process of continuously measuring and comparing one's business performance against comparable processes in leading organizations to obtain information that will help the organization identify and implement improvements.

BENSON, 1998

Introduction

Benchmarking can be very useful for a company because it enables relevant performance measures to be developed based on good practice that has been achieved by best-in-class external companies. Although the process is quite straightforward to explain, in practice, it can be difficult to conduct.

In this chapter the reasons for benchmarking are summarized and the key steps for conducting a benchmarking project are described. Finally, a specific approach to distribution benchmarking is outlined. This includes a detailed discussion of some of the key practical issues that may arise when conducting such a project.

The aim of benchmarking is to aspire to match the best external business operations. It is certain that organizations can learn from one another, and benchmarking is one way of facilitating this learning process. By definition, benchmarking forces an organization to change its focus from the internal to the external environment and it can and should lead to substantial performance improvements.

Why should an organization engage in benchmarking?

The simple answer is that organizations need to remain competitive. The process of institutionalizing benchmarking leads to an organization having a better understanding of its competitive environment and its customers’ needs. Table 39.1 neatly sums up the main reasons for benchmarking.

Table 39.1 Reasons for benchmarking

Objectives	Without Benchmarking	With Benchmarking
Becoming competitive	Internally focused Evolutionary change	Understanding of competition Ideas from proven practices
Industry best practices	Few solutions Frantic catch-up activity	Many options Superior performance
Defining customer requirements	Based on history or gut feeling Perception	Market reality Objective evaluation
Establishing effective goals and objectives	Lacking external focus Reactive	Credible, unarguable Proactive
Developing true measures of productivity	Pursuing pet projects Strengths and weaknesses not understood Route of least resistance	Solving real problems Understanding outputs Based on industry best practices

SOURCE Camp, 1989

Key steps to benchmarking

The following is a step-by-step guide to conducting a benchmarking exercise. Naturally, each organization will have its own special needs and circumstances that will dictate how it will conduct its own projects; therefore, this is a general approach that can be adapted as necessary to particular circumstances.

Step 1: Senior management commitment

As with any major project, senior management commitment to the exercise must be secured at the outset. This is necessary not only to ensure that resources are made available for the project but also because any potential improvements identified by

the benchmarking team will need senior management support to progress them satisfactorily.

Step 2: Set objectives

Clear objectives need to be set for the project. It is a mistake to attempt to do too much too soon. It is much easier to identify a specific process or activity and concentrate on this one area before moving to the next one. Therefore, a list should be prepared of specific processes and performance criteria that the company wishes to benchmark in order of their importance and value.

Step 3: Choose benchmarking partners

The next stage involves deciding whom to benchmark against. There are several options.

- *Internal departments or divisions*: this is the easiest form of benchmarking to conduct, as the information should be readily available and accurate. Different divisions in the same organization may be compared easily. The problem with this approach is that if performance is generally poor in the company then any benchmarking project is unlikely to improve competitive performance.
- *Industry benchmarking*: it may seem unlikely that a competitor would wish to engage in an exercise that might lead to a loss of competitive advantage, but some organizations are very open with their information so it is possible. The desire of many companies is to be the best-in-class or world-class for their industry and they often join benchmarking clubs to pursue this end. Companies who already engage in benchmarking activities should make good benchmarking partners.
- *Non-competitive benchmarking*: this type of benchmarking involves benchmarking against other companies in different industries. This has the advantage of excluding market competition from the process of comparison, but it may make it more difficult to identify specific areas of comparison between different industries. However, what they may have in common is processes such as purchasing or supplier appraisal. In addition, many logistics activities such as warehousing, inventory management and transport will also be in common despite the difference in goods handled.

Step 4: Choose a mixed-discipline team

Having decided on objectives and benchmarking partners, it is necessary to identify what disciplines are required in the team. Clearly, one member of the team should be

intimately acquainted with the process to be benchmarked. Other useful disciplines might include an accountant for financial information and an information systems expert, if that is appropriate.

Step 5: Getting acquainted with your partner

It is highly likely that a number of visits and meetings will be required as requests for information from both sides are processed after each round of meetings. Early meetings are likely to include tours of facilities. In some cases, confidentiality agreements are exchanged between the participating companies.

Step 6: Exchange of information

Information is unlikely to be forthcoming from the benchmarking partner in a format that matches the company format. Time will have to be spent configuring and sifting the information from both sides to allow meaningful comparisons to take place. Mapping out the steps in a process by producing a process flow diagram is also very useful.

Step 7: Analysis, interpretation and implementation

Later in this chapter, in the section entitled 'Benchmarking distribution operations', is a more detailed guide to analysing and interpreting benchmarking data. This is logistics specific.

Step 8: Continuing the process

Really effective benchmarking becomes a continuous activity and not just a one-off exercise. There are several ways of continuing the process:

- Allocate staff on a permanent basis to engage in continuous benchmarking activities.
- Identify long-term benchmarking partners. Perhaps, join a benchmarking club (see 'Formal benchmarking systems' section). There is also a benchmarking exchange website on the internet.
- Use benchmarking as part of a continuous improvement culture.
- Use industry-specific trade association figures; for example, the UK Freight Transport Association produces *The Manager's Guide to Distribution Costs* every year.

Formal benchmarking systems

Some formal benchmarking systems have been developed over the years:

- **Quality function deployment (QFD):** this benchmarking approach was developed in Japan. It takes the customer's requirements as the starting point and aims to improve performance by converting customers' perceptions of suppliers' performance into an improvement agenda.
- **ISO 9004-2009:** as part of the ISO 9000 series of quality management frameworks, ISO 9004-2009 provides a framework of constant comparison for any type of business.
- **The Malcolm Baldrige National Quality Award benchmarking framework:** this is an award for quality awareness started in 1985 in the United States by the American Productivity and Quality Center (APQC). It is enshrined in law and constitutes the only official recognition of outstanding performance by companies in the United States.
- **The CILT (UK) Logmark Supply Chain Benchmarking Group:** members complete an online survey that covers a broad spectrum of areas from inventory to the environment and transport to customer service. Each member receives a tailored report and holds meetings on a quarterly basis.

Benchmarking distribution operations

This section outlines the major features of a benchmarking or auditing exercise for a group of companies involved in grocery distribution. The aim is to describe an approach to distribution benchmarking. In addition, some of the potential problems and pitfalls are identified, and some key issues are highlighted. The major emphasis is on distribution centre operations, but a similar approach can also be used for benchmarking transport operations.

For this type of benchmarking, there is a recognized benchmarking hierarchy that can be summarized at four different levels:

- 1 Single task benchmarking:** covering single distribution activities such as goods inwards, order assembly, etc.
- 2 Function-wide benchmarking:** where all the tasks in a distribution function are reviewed with an aim to improving overall performance. For example, this might include all the processes from goods receipt to vehicle loading in a given distribution centre.
- 3 Management process benchmarking:** covering broader cross-functional issues such as quality, information systems, payment systems, etc.

- 4 Total operation (logistics) benchmarking: where the complete logistics chain is reassessed, from procurement and supply through to end-user delivery.

The approach described here is for the quite specific function-wide benchmarking that applies to a distribution centre (DC). The example used is based on an inter-firm comparison in the grocery industry. The major factor is that it is a single industry study. This helps to ensure that any comparisons between the different operations are drawn on a reasonably similar base.

The study broadly consists of a series of snapshot evaluations of the actual cost and performance derived for the different DCs. This is undertaken through detailed data collection and analysis of the key functions within the sites. Data is broken down according to various activities (goods receipt, reserve storage, etc) and various product groups (chilled, ambient, wines and spirits, etc). Other categorizations may be relevant in different circumstances – for manufacturers, customer classification may be important (national account, wholesale, independent, etc). Comparisons are made across different distribution centres and/or companies according to a series of ‘league tables’ drawn up for all the key statistics. The cost and performance of an individual site can then be assessed according to the position in the league table.

Format and approach

There are two main areas for data collection and analysis. The first includes all the major functional DC activities, costs and performance factors. These are likely to be fairly standard (cases picked per hour etc). The second includes those other elements that may be essential to help *explain* the cost and performance indices derived. These are often classified as a part of the logistics ‘environment’ in which the distribution function operates. Typical examples of the essential elements within the logistics environment include product characteristics, sales characteristics, customer profile and inventory profile.

Distribution centre performance is very dependent on the impact of service levels. Important measures may include:

- service levels required (and achieved!)
- lead time
- stock availability
- minimum delivery/order size policy
- order and delivery frequency

The general approach to the distribution audit is outlined in Figure 39.1. It follows a logical sequence of data collection, collation, analysis and interpretation.

Figure 39.1 Distribution audit: general approach

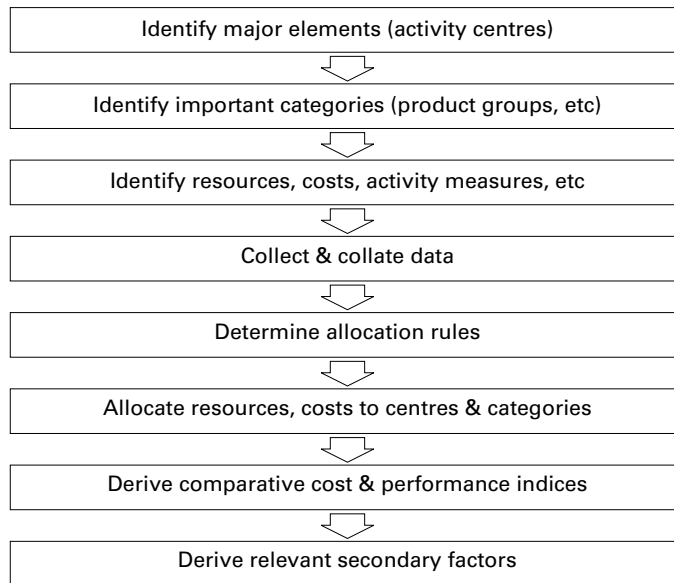
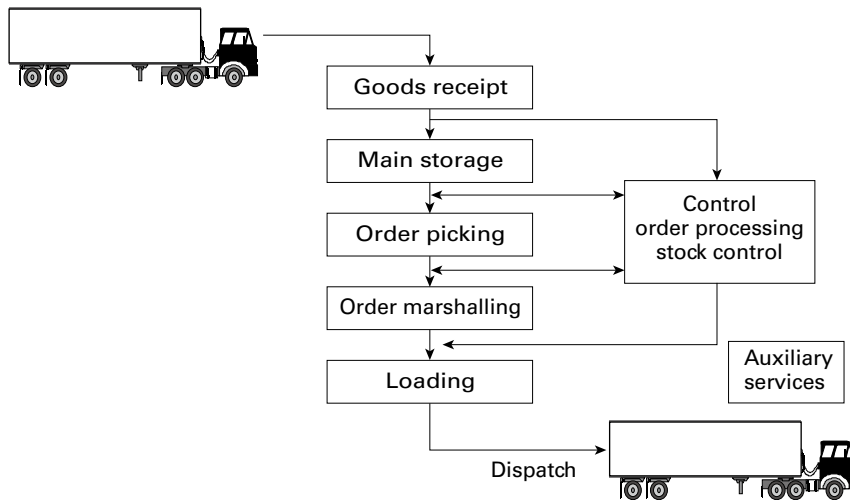


Figure 39.2 Typical activity centres



The steps are:

- 1** Identify major elements. These are the major activity centres that best represent the flow of product through a distribution centre (see Figure 39.2).
- 2** Identify important categorizations. These should consist of any major categories that are fundamental to the operations under review. For grocery distribution, this typically means different product categorizations – chilled, ambient, fresh, etc.

- 3 Identify resources, costs and activity measures. All resources and their associated costs need to be included. A classic breakdown covers buildings, building services, equipment and labour. In addition, some key activity measures need to be made. These are likely to include throughput in an appropriate unit of measurement. Examples may include:
 - a receipts in outers
 - b storage in pallets
 - c picking in line items
 - d the number of orders
 - e the number of picking list
 - f the number of lines per picking list, etc
- 4 Collect and collate data. This is ideally undertaken using a spreadsheet format. This shows the main activities across the top of the spreadsheet and the main cost elements along the side of the spreadsheet.
- 5 Determine allocation rules. This is an important aspect of the process. A typical example might be how to allocate main storage costs across a number of different product groups where products are randomly located. Most rules will follow a logical, common-sense approach – in this example, allocate main storage on the basis of the number of pallets stored per different product group.
- 6 Allocate resources and their costs to centres and categories. Use the allocation rules.
- 7 Derive comparative cost and performance indices. Many of these will be common to most DC operations (cases picked per hour, etc); others may be particular to one type of operation (units returned and reprocessed in a mail order depot, etc).
- 8 Derive relevant secondary factors. These are the elements of the logistics ‘environment’ that might help to explain the main results. For example, some products may be of non-standard size and require special handling.

Data collection and analysis

The collection of accurate and useful data is by far the most problematic aspect of such a study. Some of the major problems and potential pitfalls are:

- Data availability. It will always be necessary to compromise. The data required will never be available in their entirety. This is especially so where several companies are involved.
- Sampling. It is likely that some sampling will be required. Care must be taken to ensure that sample sizes are sufficient and that samples are adequately representative.

- Data consistency. Again, especially where cross-company analysis is to be undertaken, care must be taken that allocation rules and procedures are common. Most companies have different accounting practices, so there is ample opportunity for error due to inconsistent classification. It is likely that a uniform or generalized allocation procedure will need to be designed and used.
- Appropriate categories and groups. Any categorization needs to be relevant for all participating companies. An example might be where different companies have different product groups or unit load devices.
- Time periods. Clearly, these need to be common for all distribution centres. Any sales cycles, seasonality and so on need to be taken into account.
- Units of measure. These may differ from one company to another, and will be especially important when drawing comparisons across industry sectors.

Interpreting results

This study produced a series of results that could be interpreted in a general context, as well as some that were specific to a particular distribution operation as it was compared to the others. In general terms, there were two key drivers identified as being crucial to the understanding of each site's efficiency in the context of grocery distribution.

First, the results indicated that building costs could vary considerably from one location to another. The extent of this variation, and the impact of these costs, meant that some distribution centres that appeared to be operationally expensive were not in fact so, because the major cost element was a very high building cost. Second, the highest-cost operational area in all the sites was that of order picking. Clearly, good picking performance was one of the keys to a cost-effective operation.

It is possible to produce a myriad of detailed results from a study of this nature. Some useful results from this study included the overall warehouse unit cost analysis broken down by main costs, the relative weekly throughputs for the different sites involved – these can help to explain some of the differences in cost and performance results, the breakdown of direct labour costs for the different sites, and the range of picking performance for the different sites in cases picked per person/hour.

It is useful to differentiate between controllable and non-controllable elements and costs. An expensive building may lead to a relatively high-cost operation overall. The actual operation itself (that is without consideration of the cost of the building) may be very cost-effective. There is little that a manager can do to affect the cost of a building. Regional differences may impact on results, especially considering relative labour costs. Scale effects may be relevant – that is, economies that result from large-scale operations.

Information and communication technology in the supply chain

40

Introduction

There have been enormous developments and advances in information and communication technology (ICT) in all aspects of life from everyday functions to scientific and business applications. This is also a key area of development and change for logistics and the supply chain. The ability to pass information between supply chain partners via mobile devices, satellite systems and electronic data interchange is being practised by all types and sizes of companies. Information and communication systems, along with the associated hardware, fulfil many roles in supply chain management. They enhance the decision-making process, help to monitor and control operations, create simulated systems, store and process data, and aid communication between individuals, companies and machines.

This chapter highlights the key ICT elements with respect to supply chain and logistics management. The basic communications systems are discussed. The major applications in logistics and the supply chain are described. The particular changes and developments associated with e-commerce are outlined and explained. Finally, the concept of the digital supply chain is considered.

Basic communication systems

Satellite communication

The development of a network of geostationary satellites located in space enables communication with people, remote installations and equipment virtually anywhere

on the Earth's surface. Where there are no mobile or fixed-line telephone facilities it is possible to use satellite telephones. Mobile assets such as road vehicles, ships and containers are tracked through the use of satellites. Operating instructions are sent via satellite to remote equipment. Access to the internet is also available using these networks. This capability to send and receive data via a satellite system has dramatically improved the ability of supply chain managers to manage their networks and assets wherever they may be located.

Mobile data

Mobile phone technology enables people to connect via voice communication and short messaging systems and this has revolutionized the whole process of communication. Sophisticated mobile devices allow photos to be taken, stored and sent. They can provide access to the internet and email facilities. They can enable the use of many specialized software applications or 'apps'. This helps mobile staff to stay in contact with their base offices wherever there is network coverage. Many delivery drivers carry ruggedized mobile devices that allow customers to sign electronically for the receipt of their goods. These devices then update the company system in real time with the information that the delivery has been made. Many courier companies allow customers access to their consignment tracking systems via the internet so that they may check the progress of urgent consignments.

Electronic data interchange (EDI)

EDI is the computer-to-computer exchange of structured data for automatic processing. EDI is used by supply chain partners to exchange essential information necessary for the effective running of their businesses. These structural links are usually set up between organizations that have a long-term trading relationship. For example, some multiple retailers supply electronic point-of-sale (EPOS) data directly to suppliers, which in turn triggers replenishment of the item sold. A consequence of this type of link is that suppliers are able to build historical sales patterns that aid their own demand forecasting activities. In this context, EDI has many benefits. It is providing timely information about its customers' sales; it is highly accurate; and is very efficient because it does not require staff to collate the information manually. EDI is used to send invoices, bills of lading, confirmation of dispatch, shipping details and any information that the linked organizations choose to exchange.

UN/EDIFACT is the standard that ensures that information may be sent and retrieved in an appropriate format by trading partners. The initials stand for United Nations/Electronic Data Interchange for Administration, Commerce and Transport.

The main advantages of using EDI are that information only needs to be entered onto the computer system once; transactions speeds are much faster and cost and error rates are reduced. Also, there continue to be fruitful developments in this field, such as the use of extensible mark-up language (XML) that enables users to connect different companies' systems via the internet without the need for expensive hardware.

Barcodes

A barcode is the representation of a number or code in a form suitable for reading by machines. Barcodes are widely used throughout the supply chain to identify and track goods at all stages in the process. Barcodes are a series of different-width lines that may be presented in a horizontal order, called ladder orientation, or a vertical order, called picket fence orientation.

For example, goods received in a warehouse may be identified by the warehouse management system and added to stock held in the warehouse. When put away, the barcode is used to associate the storage location with the barcoded stock, and on dispatch the stock record is amended. The use of barcodes can speed up operations significantly. Problems can occur if barcodes are defaced or the labels fall off in transit.

Radio frequency identification (RFID)

RFID is a technology whereby objects can be tagged with a device that contains a memory chip. The chip has a read-and-write facility that is enabled using a variety of radio frequencies. This means that a pallet of goods can have an RFID tag attached that contains a large amount of information regarding the pallet content. This might include product details, the number of cartons, stock-keeping unit number, the origin and the destination of the goods, the location in a warehouse and so on.

One of the advantages of RFID compared to barcodes is that the information contained in the tag can be updated or changed. Also, the tags are less vulnerable to damage, as unlike the barcode label they are not easily defaced. Another advantage is that the tags may be read from a distance and in some cases do not require 'line of sight' visibility. It is also possible to read RFID tags through packing materials, but with greater difficulty through metal and liquids. A mixed pallet of different products may be read simultaneously by one scanner, thus significantly reducing the time required for this process. RFID tags may be used to track many different types of assets (people and animals included). As the cost of this technology reduces, so the take-up of its use is likely to become even more widespread. The use of RFID and other associated developing technologies is described further in Chapter 24 under 'Data capture and transmission'.

Key applications in the supply chain

Systems architecture

Supply chain systems architecture will differ when comparing companies and organizations for a variety of reasons, dependent on size, structure, global reach, product type and customer type, among other possible differences. Thus, it is no easy task to compose a systems architecture diagram that is appropriate to all. However, there are many elements that may be identifiable and these can be found in Figure 40.1 which shows a ‘typical’ supply chain systems architecture. The key element that acts as an overarching link is the main transaction system, typically an enterprise-wide information system. Various planning and operational systems, such as the transport management system (TMS), are to be found within the structure. These are, generally, internal and are functionally based in that they are associated with a particular logistics component such as storage or delivery. However, they may be external and are supplying or receiving vital information that allows the overall supply chain system to work effectively, such as linking with suppliers or customers.

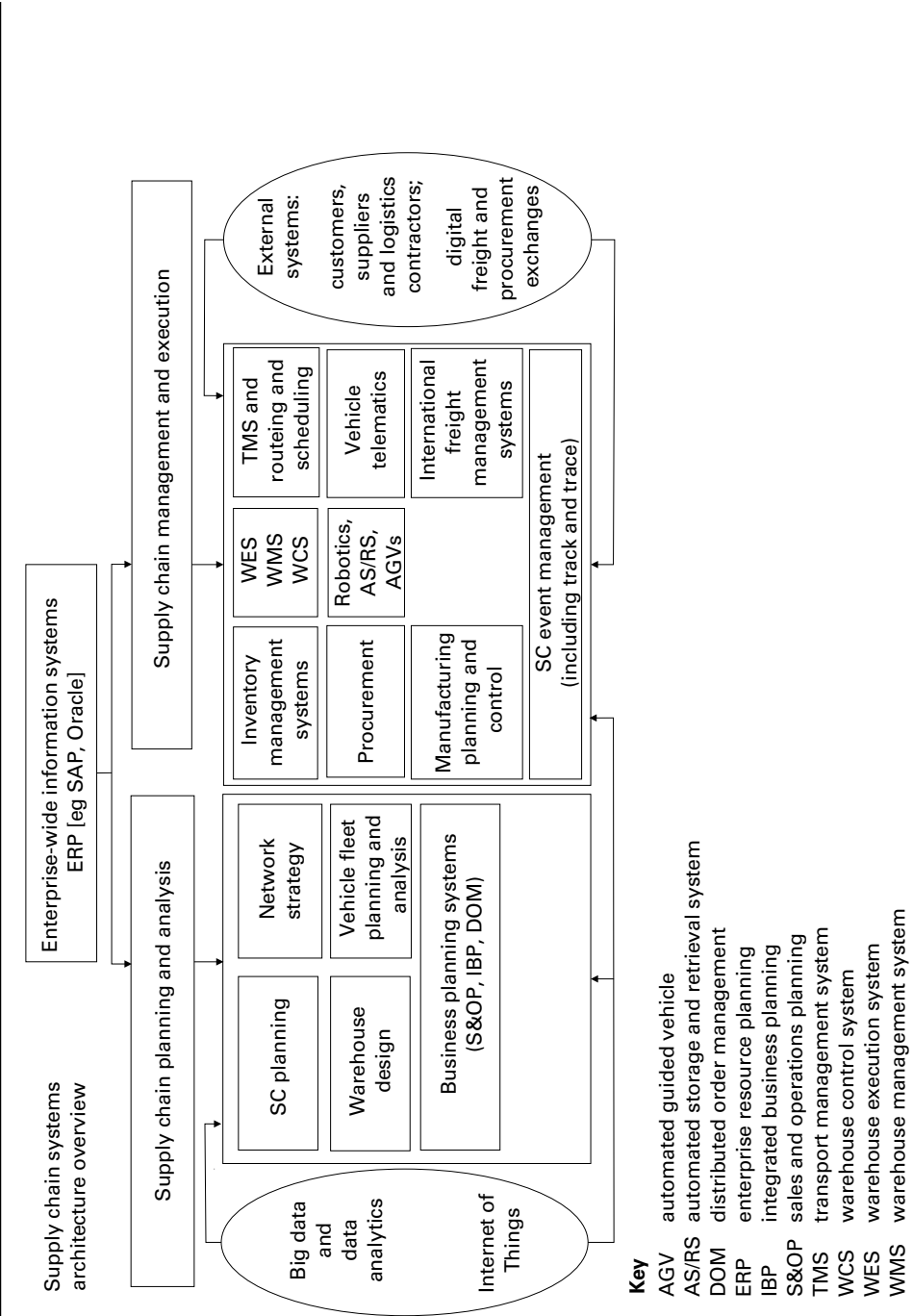
The remainder of this section reflects the content of the supply chain systems architecture shown in Figure 40.1 and provides a summary of each of the key components that are included.

Enterprise-wide information systems

A key systems element for many major companies is the use of enterprise-wide information systems, often known as enterprise resource planning or ERP systems. These are transaction-based information systems that are integrated across the whole business. Basically, they enable data capture for the whole business using a single computer package, which then gives a single source for all the key business information activities, such as customer orders, inventory and financials. Proprietary names such as SAP, Oracle and Microsoft feature strongly whenever these systems are discussed.

Many companies benefit from using these systems, although some do experience significant problems with their initial application. Generally, they are very expensive to purchase, require a lot of tailoring for each user company, and take a lot of expensive consultancy time to implement. A high degree of training for use at the operative level is also required. It is a logical extension of the principles of supply chain management to have one overarching computerized system that allows for the organization and support of the planning of the whole enterprise. Some, more basic, ERP systems do not do this but several specialist planning modules are used successfully with these. Also, many ERP systems are linked to appropriate supply chain management and network strategy software so that the relevant overarching planning can be undertaken.

Figure 40.1 Supply chain systems architecture overview



Enterprise-wide information systems are used by many companies. Information technology continues to develop at pace, however, so it is sensible to select and use systems that can be readily amended and revised to incorporate such developments. Ideally, these should be ‘open’ systems that are linked to suppliers and customers alike to ease the flow of information up and down the supply chain. Significant provision should also be made for disaster recovery in the event of system failure, because effectively all of a company’s ‘eggs are placed in the one basket’. The remainder of this section describes other key associated logistic and supply chain modules that can be linked or incorporated with an organization’s main transactional and financial system such as ERP. Note that some of these modules may already be included as a part of one of these broader systems.

Supply chain planning

Supply chain management/advanced planning and scheduling (APS) systems

Supply chain management systems are, very broadly, decision support and operational planning tools. They enable a company to plan and manage its logistics operations through the use of an integrated system-wide package. Such tools use information such as real-time demand and/or forecasting, linked to production capacities and run rates, inventory-holding levels and locations, supplier lead times, associated costs, etc to help determine operational production and inventory requirements.

To be effective, these systems rely on the accuracy and real-time nature of the data that are fed into the system. Planners can then undertake ‘what-if’ analyses on the basis of the latest (or potential) customer orders, manufacturing capability, inventory disposition, etc. They rely on the appropriate algorithms embedded in the software in order to arrive at useful solutions. Such supply chain management software may be modules within an ERP system or specialist planning software linked closely to the enterprise-wide system.

Network strategy

Network strategy systems consist of a variety of different strategic rather than operational decision-making tools. Typical of this type of package is the distribution centre (DC) location package, which attempts to optimize the number and location of DCs within a company’s distribution network.

These systems allow for the analysis of data using various algorithms to arrive at an optimum solution for a given situation. For example, the problem may be to establish the optimum location to make a product within a network of production sites that themselves are spread across a wide geographical area. The system will

enable the analysis of the costs of sourcing raw materials, the costs and availability of production capacity and transport costs in order to arrive at the optimum location.

A more detailed discussion of the use of network strategy modelling is given in Chapter 10. In addition, warehouse design and vehicle fleet planning tools are described in Chapters 23 and 31 respectively.

Business planning systems

Logistics systems and operational software need to interface with various business planning systems such as sales and operations planning and integrated business planning, as well as certain optimization packages. These include the following.

Sales and operations planning (S&OP)

Sales and operations planning (S&OP) is a business management process designed to ensure each business function is aligned to balance supply and demand. Cross-organizational collaboration is used to create detailed forecasts for predicted sales. The aims are to increase transparency, balance supply and demand, and to achieve profitability. S&OP can be used as a planning tool and/or for more short-term operational purposes.

Integrated business planning (IBP)

Integrated business planning (IBP) is an expanded form of S&OP that concentrates on the end-to-end value chain of a business. It can be used to link strategic objectives with short- and mid-term operational planning decisions. This is undertaken via cross-functional analysis, based on decisions concerning supplier collaboration, demand shaping, marketing and product growth/development.

Distributed order management (DOM)

Distributed order management (DOM) can be used to optimize fulfilment so orders arrive to customers on time while incurring the lowest possible cost. DOM systems are software that facilitate this process and improve overall supply chain by automating several functions, including order routing, order splitting, shipping, forecasting and inventory management. Consumers may want to buy products from different channels, move between platforms or order online directly from store. The order should also be delivered according to the customers' requirements. Physical store locations and e-commerce platforms must work together.

Warehouse management systems

A warehouse management system (WMS) is the key information system used for warehousing. These are sometimes embraced within an overall warehouse execution system (WES) and supported by a warehouse control system (WCS). These are described in detail in Chapter 24. They are used to run and control all the activities of a warehouse and often include radio frequency (RF) communications with operators and fork-lift trucks. They may interface with equipment control systems, which control complex equipment such as robotics, automated storage and retrieval systems (AS/RS), automated guided vehicles (AGVs), conveyor and sorters.

Sophisticated 3D simulation models are available that provide a graphic, moving illustration on the computer screen of the layout of the warehouse. They enable different design configurations to be simulated, depending on varying demand requirements. They can also be developed for operational purposes and are then known as ‘digital twins’.

Inventory management and demand forecasting

Inventory management systems provide the ability to run the day-to-day detailed management and control of stock within a company. They are absolutely essential for the location of stock and their ability, if used effectively, to control the levels of stock within a system. This type of capability allows organizations to reduce their inventory-carrying requirements, which improves stock turn and return on capital invested. Customer service is also maintained through the use of these systems by reducing the incidence of stockouts. The aim of inventory optimization is to identify the most effective inventory locations and stock levels for the supply chain as a whole. This type of approach has become feasible because of the extent of data that is now available and the ability of computer systems to analyse such large quantities of data. This multi-echelon software can optimize inventory levels across the whole supply chain, taking into account the multiple stages in the supply chain, different types of inventory and time-phased demand.

The area of forecasting future customer demand and associated inventory-carrying requirements has been revolutionized by the use of advanced computer software, based on features such as real-time information, data analytics and artificial intelligence. These packages contain many different algorithms that allow the forecaster to use various techniques, such as regression analysis, exponential smoothing and moving averages. These systems may be fed with information directly from sales order processing and inventory management systems to allow them to assess very quickly how customer demand is developing by individual stock-keeping unit.

More information on inventory planning systems and demand forecasting is provided in Chapter 17, covering MRP, DRP, VMI, CRP, ECR and CPFR.

Freight transport

There are a number of different ICT applications that are used in freight transport for both planning and operational purposes. These are described in detail in Chapters 31 and 32. The key areas are outlined below.

Vehicle fleet or transport management systems

These systems assist transport managers in the task of monitoring the effectiveness of their vehicle fleet to enable improvements to be implemented. Vehicle data is used to produce key performance indicators (KPIs) for the vehicle fleet. Computerized fuel monitoring equipment which controls and records fuel dispensed to each vehicle can be transferred automatically into the fleet management system. In a similar way, tachograph records can be analysed and the information downloaded into the main system. Many modern vehicles are equipped with engines that are controlled by computerized engine management. This information can provide a great deal of detailed information about the vehicles' activities.

Vehicle telematics

Telematics is the combination of telecommunication systems and information systems in various practical applications. Some applications such as global positioning systems (GPS) may be used to aid the navigation of commercial vehicles as well as to provide a security element by tracking assets throughout a journey (see Chapter 41). Remote assets may be sent instructions such as adjusting temperatures on refrigerated containers at sea. In-vehicle technology can advise drivers about traffic congestion ahead, and reroute vehicles if required, helping to reduce vehicle emissions as well as improving efficiency (see Chapter 31).

Computerized vehicle routing and scheduling

Computerized vehicle routing and scheduling is essential for many key planning and operational aspects of road transport. These include resource planning, 'what-if' planning, fixed route planning and variable route planning. These are all reviewed and discussed in detail in Chapter 32.

International trade and freight management systems

With the growth in global trade, there are now specialist software packages available to control the international movement of goods. These include features to assist with the complex documentation requirements, trade finance, dispute management and export/import compliance, as well as monitoring the progress of orders around the world.

Digital freight exchanges or digital platforms

These are online transaction systems for shippers and carriers that enable online freight purchasing, hosted by third-party organizations. Basically, they are internet-based trading mechanisms that facilitate the matching of shipper demand with carrier availability. They range in complexity from simple electronic bulletin boards to sophisticated algorithmic-based systems. These are described in more detail in Chapter 5.

Supply chain event management systems

Supply chain event management systems monitor the progress of orders and highlight any 'events' that are outside the norm. These events normally relate to the late dispatch or arrival of orders at pre-specified milestone points (e.g. a container being shipped from a port). These events are notified to the relevant parties so that corrective action can be taken, and the event is continually monitored until the delay is rectified or the goods eventually arrive. For road freight deliveries this would be highlighted via track and trace systems.

Procurement

Procurement software provides an organization with a set of tools to support the acquisition of goods and services. Contemporary procurement software enables employees to request a purchase from virtually anywhere in the world. A procurement system is a digital application that is used to enable and regulate the purchasing of goods and services. A typical procurement system provides buyers with extensive requisition, quotation, vendor, purchase order and contract capabilities (see Chapter 14 for the functional areas of procurement and details of e-procurement).

Manufacturing planning and control systems

Manufacturing systems for planning and control have been covered in Chapter 13. These include, for example, materials requirements planning (MRP), manufacturing resource planning (MRPII) and demand-driven material requirements planning (DDMRP) systems.

E-commerce

E-commerce (electronic commerce or EC) is the buying and selling of goods and services, or the transmitting of funds or data, over an electronic network, primarily

the internet. This is a particularly important development for the retail sector, but is also used for business transactions.

As well as a large year-on-year increase in e-commerce transactions, there is also a major challenge to most logistics operations due to the extreme seasonality of much of the demand created via or moving to e-commerce. In Western countries this is seen in the run-up to Christmas or Thanksgiving with major peaks in demand, which are exacerbated by one-day special offers that are a feature of internet selling. The logistics structures and operations of some retailers are not sufficiently robust to respond to these demands.

Terminology

The major alternative channels of distribution were explained in Chapter 4. It is useful to be aware of the difference between these, in particular business-to-consumer (B2C) and business-to-business (B2B) e-commerce. B2C internet commerce is concerned with the direct interaction and commercial relationship between a business and the end consumer. This can be either the traditional retailer dealing privately with a member of the public, or a manufacturer or supplier dealing with a member of the public who is an end user. B2B internet commerce is concerned with the interaction and commercial relationship between businesses. These may be any type of business trading raw materials, components, spare parts, finished goods, business services or routine office items. Initial attention has been concentrated on the opportunities for developments in B2C e-commerce, but there are significant opportunities and implications for B2B e-commerce.

Home and mobile shopping

Non-store shopping, both home and mobile shopping, is an established alternative to shopping at retail shops and stores. The enablers for the initial development of home shopping were the widespread use of home computing, the internet with broadband and online banking. Mobile shopping (m-commerce) is the buying and selling of goods and services through wireless handheld devices such as mobile phones and tablets. The Covid-19 pandemic accelerated the use of home and mobile shopping. All of these developments have had a fundamental impact on logistics. The very nature of the final delivery operation has, for home delivery, altered dramatically, with wide implications for the whole of the supply chain.

The main consequence for logistics is the parallel increase in home delivery. In some sectors (e.g. white goods, brown goods) home delivery has been common practice for many years, but the advent of home shopping has substantially increased the demand for the home delivery of many other types of goods. The rapid growth in online selling companies, such as Amazon, and the fact that all major grocery

companies have wholly embraced the concept means that home shopping is now very common (see also Chapter 5, ‘The consumer’).

E-fulfilment (home delivery or the final mile)

E-fulfilment (or home delivery or the final mile) refers to the preparation and physical delivery of the product to the home. Strictly speaking, e-fulfilment refers to orders placed via the internet but these terms are used interchangeably. ‘The final mile’ is an expression used to accentuate the particular problems, and solutions, of delivery to the final consumer.

E-fulfilment requires some fundamental rethinking in logistics systems and operations that serve the home market. Some implications are that the customer may not be available to take and sign for goods, there may not be anywhere safe to leave the goods, and there may be restricted delivery time windows. Thus, new types of distribution systems may be required. Note also that customer ordering systems can be linked directly to manufacturers’ reordering systems, so goods ordered can flow directly from manufacture to the customer.

Internet orders tend to be small, with few order lines, few items per line, and are generally for individual items rather than whole cases. Thus, the picking workload and cost of operation are much greater for a given throughput of goods, compared to a standard operation. Picking solutions vary and can be based on standard approaches, and other technology might be used such as pick-to-light and robotics (see Chapter 21).

Although final mile delivery is seldom a dilemma if there is a householder to receive the goods, there are many occasions when this is an issue. Solutions for these and other home delivery problems include:

- urban or city warehouses
- purpose-built semi-trailers for use as mobile parcels sortation hubs
- the provision of secure boxes outside or attached to a property
- alternative points of delivery such as a place of work or a petrol station
- ‘in-home delivery’ whereby smart lock technology is used to provide temporary access to a delivery driver
- the gig economy and crowd-sourcing concepts have been applied to home delivery for the personalized delivery of internet orders (known as crowd-shipping or crowd-logistics)
- autonomous customer delivery options such as the use of autonomous drones and autonomous vehicles that can operate on existing roads and walkways

Chapters 5 and 21 provide additional discussion of e-fulfilment and the implications for logistics systems and operations.

Omnichannel fulfilment

Omnichannel fulfilment and marketing is aimed at a seamless approach to the consumer experience through all available shopping channels, such as mobile internet devices, computers, bricks-and-mortar shops, television, etc. There are significant technology implications.

An omnichannel approach uses software to track customers across all channels, not just one or two. All shopping channels should work from the same database of products, prices and promotions so that merchandise and promotions are not channel specific, but are consistent across all retail channels. There are major implications for the supply chain with this approach and that involves developing integration across the different channels – this has become known as omnichannel retailing, fulfilment or marketing. Thus, the provision of an integrated physical distribution channel needs to be established that comprises the supply of products to the end consumer using any or all of the available channels.

The key consideration, from a logistics perspective, is how to fulfil the final delivery/collection of the goods to/from the consumer in a seamless way, whether this is in-store, in the home or via a suitable collection point – and to develop a suitable and cost-effective supply chain that achieves this. Omnichannel fulfilment is discussed in detail in Chapter 12.

E-procurement

This is covered in Chapter 14, 'Procurement and supply'.

The digital supply chain

As with many evolving ideas and concepts that are associated with the supply chain, the basis for these developments is strongly associated with changing customer expectations. Customers choose and select products across multiple platforms and demand service that is both personal and fast. They also may have concerns about both product and supply chain sustainability. These requirements must be met in changing and challenging circumstances, including elongated and complex supply chains, disruptive events such as global health crises and political insecurity. These, in turn, may result in severe or sporadic supply shortages.

Although it may seem ambitious to try to accommodate all requirements such as these, there are existing and developing concepts that make this feasible. One key concept is the idea of the Fourth Industrial Revolution (4IR), also known as Industry 4.0, whereby developing digital technologies have begun to significantly alter the scope of what is achievable. These terms describe the way economies can develop through the integration of innovative technological, societal and business practices

to encourage a fresh combined approach to commerce and industry. Evolving from this is Supply Chain 4.0 (SC:4), which incorporates the combination of associated technologies that have enabled the introduction of an ‘era of digital transformation in new real-time data gathering across the supply chain, smart analysis, and algorithms to better simulate and predict different supply chain scenarios and foster data-based decision-making’ (PwC, 2020).

The remainder of this section considers these aspects of the digital supply chain. SC:4 is described, the various enabling technologies are listed and the associated resulting key outputs are briefly reviewed.

Supply Chain 4:0 (SC:4)

As indicated above, the concept of Supply Chain 4:0 (SC:4) describes how developing digital technologies can significantly alter the scope of what is achievable and attainable within the supply chain.

The move towards SC:4 is enabled by many different approaches and developments. These might be informational, through digital services such as logistical control towers using Big Data and the Internet of Things (IoT), or the use of internet-connected devices that interact automatically. In addition, there are digitally-enabled logistics services that can improve cross-border movements in a single simplified process based on technology enhancements. Innovative delivery options significantly change operational opportunities for physical shipments, including the use of drones and autonomous vehicles or 3D printing which eliminates the need to hold finished inventory. The implications on traditional distribution are immense.

One aspect of SC:4 that is already commonly discussed is that of sustainability and the circular economy – an important consideration for many manufacturing and logistics operations, where a key facet of their planning is to ensure that environmental concerns are catered for through the elimination of waste material, recycling and reduced emissions. Finally, the concept of the shared economy is also very much reflected in logistics developments. This not only includes shared warehousing and shared transport operations, already apparent in multi-user third-party logistics services, but also the increasing use of parcel collection from and delivery to the home and office – often enabled by smartphone technology.

Industry 4.0 and SC:4 encompass the age of smart machines, production facilities and storage systems that can autonomously exchange information, prompt actions and control operations without human intervention. This is enabled through the IoT and other interconnected networks of machine devices and vehicles, but this ‘revolution’ is seen as a clear separation between humans and machine robots. Industry 5.0 and SC:5 anticipates the next stage in the cycle, as man and autonomous machine are reconciled to work together, producing the synergy of human intelligence and cognitive computing interacting harmoniously. Manufacturing and distribution are

expected to reach new levels of speed and perfection while also protecting the environment through the incorporation of renewable energy and minimal waste.

Innovative technologies

The key contributors to the digital supply chain are the innovative technologies that make the concept feasible. These key technologies are described below.

Big Data

The term Big Data constitutes extremely large data sets that may be analysed by software designed to reveal patterns, trends and associations, especially relating to the movement of goods, human behaviour and interactions (e.g. from sensors, etc). This leads to Big Data analytics.

Big Data and Big Data analytics are feasible because the ability to store huge amounts of data has improved and the software to analyse it has become available. The basic idea is centred on the concept of sifting through terabytes of stored company data to find information of real value to the organization. The sheer scope and scale of the data and analysis are gigantic compared to previous capabilities. The data is stored on servers in gigabytes and terabytes. Experts in Big Data talk about different numbers of 'V's to help explain the concept. Typically, the 4Vs considered are: volume, variety, velocity and value:

- *Volume*: companies create and store vast amounts of data from multiple sources. Some of this data is stored for legal reasons such as company accounts, and other data may come from operational activities or even social media interactions with customers.
- *Variety*: the data stored by an organization may be stored in many different file types. Big Data software such as Apache™ Hadoop® provides a system to accommodate these variations. This is how they describe their software: 'The Apache Hadoop software library is a framework that allows for the distributed processing of large data sets across clusters of computers using simple programming models' (Hadoop, 2021).
- *Velocity*: data can be accumulated at extremely fast rates. For example, in a retail context when a promotional event such as 'Black Friday' occurs, sales data and feedback are flowing through the EPOS system and social media at a significantly faster rate than on a normal shopping day. Big Data can cope with these situations. Equally and importantly, this data can be analysed quickly to provide key management information.
- *Value*: equally, analysing Big Data can provide significant added value to an organization's management. For example, using huge amounts of EPOS data from

many different stores could lead to significant changes in how inventory is deployed both in the retail outlets and the distribution network that supports the retail operation.

It is important to note that Chapter 13 contains a section on the typology of operations which are classified as the 4Vs (volume, variety, variability and visibility). Although similar, the two sets of Vs are not the same.

Artificial intelligence (AI)

Artificial intelligence (AI) is the ability of a computer, or a robot controlled by a computer, to use machine learning to complete tasks that are usually done by humans who use human intelligence and discernment to undertake the task successfully. For example, home-based assistants (e.g. Amazon Echo) can link with home smart appliances, identify stockouts and automatically reorder (e.g. milk in fridge). Also many facets of warehouse operations can be controlled by AI such as the execution of orders to meet customer deadlines, automated equipment capacities and labour availability, as well as controlling ‘swarms’ of robots and other machinery.

Internet of Things (IoT)

The Internet of Things (IoT) describes the network of physical objects (i.e. ‘things’) that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet, e.g. shelving, vehicle sensors and telematics. This is also known as machine-to-machine (M2M), the industrial internet and Industry 4.0. They all refer to the linking of ‘smart’ machines via the internet to achieve greater industrial efficiency and effectiveness or improved services for consumers. In an industrial context suitably equipped and connected machines can communicate their maintenance and productivity status on a frequent basis. The machines can provide alerts of faults and productivity in real time. Other, wider, potential applications include: the monitoring of vulnerable old people or children remotely by healthcare professionals without the need for the doctor or the patient to travel to a health clinic; or domestic heating appliances which could adjust heating or cooling relative to the changes in weather as they occur.

AI is an area of innovation and huge potential. It attempts to programme machines to mimic human intelligence, and progress has been made towards machines ‘learning’ from experience. The possibilities of combining AI with the IoT along with advances in robotics offers much scope for dramatic and innovative opportunities.

Cloud computing

Cloud computing is a development that allows companies to utilize software packages, access remote servers and store data using the internet rather than servers in their premises. As mentioned in the section on Big Data, companies are generating

remarkable volumes of data that they would like to store and manipulate. Cloud computing helps provide this functionality by storing data on remote servers accessible via the internet. In a similar fashion, companies are able to access very expensive software systems on a pay-as-you-go rental basis rather than purchasing the software outright. This gives them access to the latest versions of the software without continually spending large sums of money on upgrading. This may be useful for both start-up enterprises and more established businesses.

Control towers

The essence of the control tower concept is to provide supply chain visibility across divisions, countries and transport modes. The heart of the control tower is an information hub supported by a set of detailed decision-making rules and a trained team of operators. For example, supply chain and logistics decisions could be made automatically (by AI) from Big Data systems to deliver customer service while minimizing inventory.

Blockchain

A blockchain is a permanent digital record of transactions that is stored across a distributed or decentralized network of computers. The blockchain is not split across many computers, but copied to all computers in the link – a single source of information on which all stakeholders can rely.

Distributed order management

DOM systems are designed to arrange orders across the multiple systems and processes utilized by those involved in replenishing an order. DOM can analyse every transaction and determine the most efficient shipping location considering multiple factors, including speed of delivery, the distance between the shipping point and the customer, as well as available stock levels. This clearly requires a unified view of stock across multiple channels in order to know exactly where the products are located.

Digital marketplace

A digital marketplace is a technology platform to improve or simplify buying logistics requirements. Examples in logistics include a freight exchange/marketplace, an e-forwarder and a tender platform (for outsourcing).

Crowd-shipping

Crowd-shipping, also known as crowd-logistics, is ordinary citizens using social networking collaboratively to act as couriers, creating new informal logistics networks for local distribution of small items ordered online, i.e. small parcels.

Robotics/automation

Many warehouse and logistics jobs can be undertaken by robots, e.g. container stacking, warehouse put away, picking and packing.

Autonomous vehicles

Autonomous vehicles are vehicles and drones (self-driving robots) which are used for delivery purposes.

3D printing

3D printing, also known as ‘additive manufacturing’, enables the remote production of three-dimensional objects. This can eliminate large elements of an upstream supply chain.

Digital supply chain: key aspects

What does a digital supply chain look like? The use of an amalgam of the many innovative technologies outlined above implies the need for a very different structure and operational approach. Yet in many ways there is a natural progression that has occurred and is still occurring. It is the linking of these new ideas and techniques that is the key to any fundamental change. The digital supply chain can be characterized in several different ways but there are five major elements that can be considered as key to the formulation of an autonomous and self-optimizing supply chain:

- *Supply chain transparency and sustainability*: this involves multi-level data flow and seamless connection of all data across the supply chain for products, logistics, customers and finance, together with a completely transparent and sustainable supply chain that includes the reuse of materials and the integration of suppliers and other players.
- *Closed loop and integrated planning and execution*: end-to-end planning from customers to sub-suppliers covering all planning time horizons. This is to include integrating financial and capacity plans, demand and supply balancing, collaborative workflows and automated decision-making using advanced analytics.
- *Smart logistics flows*: includes inbound and outbound transportation considering all modes; automated warehouses, transport management systems (TMS) and warehouse management systems (WMS); optimized and dynamic distribution; omnichannel order management.
- *Dynamic supply chain segmentation*: this involves the use of segmentation strategies to support key business requirements, covering all realistic service, margin, cost and inventory parameters; the adoption of supply chains that are

flexible and which can be further segmented for each customer order, as well as reshaped for alternative market conditions and product components.

- *AI-driven supply chain management*: data networks and AI connect along the supply chain to provide enhanced demand forecasts via demand sensing. Patterns and trends can evolve based on machine learning within the supply chain and trigger appropriate responses. This enables a fully autonomous supply chain, making appropriate and effective optimization decisions.

Introduction

Terrorist attacks and crimes against vehicles and property have sadly become almost an everyday feature of life in today's world. The costs associated with the disruption caused by these events are difficult to quantify but are all too real to the victims. Management time, replacement of assets, service failures, increased insurance costs, legal costs and general upheaval are some of the consequences that may be expected.

Since the attacks on the World Trade Center in New York and the Pentagon in Washington, DC on 11 September 2001, the whole area of logistics security has attracted a lot of attention from national governments. One direct response to these terrorist outrages was a number of initiatives instigated by the United States government. Customs–Trade Partnership against Terrorism (C–TPAT), Free and Secure Trade (FAST), Container Security Initiative (CSI) and Advanced Manifest Regulations (AMR) – the ‘24-hour rule’ – were introduced to reduce the likelihood of another attack. As we all know, terrorist attacks have by no means been limited to the United States, and this has led to questions being asked about supply chain vulnerability. The Covid-19 global pandemic and the containment measures enacted by many governments have wreaked havoc on supply chains worldwide which in turn has also led to concerns about supply chain vulnerability.

The aim of this chapter is to provide an outline of the measures that should be considered when planning logistics security and safety. The most common areas and equipment are briefly described, but any specialist requirements are not covered.

International security measures

Given that the United States is one of the largest economies in the world and was the victim of the 11 September 2001 attacks, it seems appropriate to look in more detail at some of the measures that the United States has put in place to avoid any further attacks.

It must be understood that the regulations briefly outlined below are continually being developed and enhanced. For more details visit the US Bureau of Customs and Border Protection (CBP, 2021).

Customs–Trade Partnership against Terrorism (C–TPAT)

This is a voluntary system established by the United States Bureau of Customs and Border Protection (CBP). It aims to create an environment of close cooperation between US importers, carriers and international exporters to the United States. Participants are required to conduct a comprehensive assessment of security in the supply chain (SC), submit an SC security profile questionnaire to CBP, develop and implement a programme to improve security, and communicate C–TPAT guidelines to other companies in the participant's SC. In return, C–TPAT participants benefit from expedited cargo release, a reduced number of inspections, an assigned C–TPAT supply chain security specialist, access to the C–TPAT membership list, eligibility for account-based processes, an emphasis on self-policing, and access to 'FAST' lanes along the Canadian and Mexican borders.

Free and Secure Trade (FAST)

This initiative covers the borders between the United States and both Canada and Mexico. It aims to offer faster clearance of C–TPAT participants' cargoes at these borders. Certified C–TPAT truck operators are allowed to use dedicated lanes, which expedites the clearance process. It is aimed at increasing SC security without unnecessarily hampering trade.

Container Security Initiative (CSI)

Under this system, customs officers from CBP are stationed around the world at the major departure ports of containers bound for the United States. As almost half of all imports by value into the United States arrive in ISO containers by sea, this is seen as a major step in preventing suspect containers being dispatched to the United States. CSI is based on four main elements:

- the use of intelligence and automated information to target containers that pose a risk of terrorism
- the pre-screening of these target containers at the port of departure rather than when they arrive in the United States
- the use of detection technology to pre-screen these suspect containers quickly
- the use of tamper-proof containers

At the time of writing, CSI is based at 58 seaports in various countries, where it performs targeted screening covering the full scope of conventional threats and weapons of mass destruction. X-ray and radiation detection equipment are used to examine containers consigned to the United States. It covers approximately 80 per cent of containers bound for the United States (CBP, 2019).

Advanced Manifest Regulations (AMR)

These US regulations require both importers and exporters using any mode of transport to send electronically advance information regarding the cargo to be shipped. If the information submitted is incomplete, misleading or late, it can lead to the CBP issuing a 'no load' order to the carrier. It could also result in the cargo receiving additional inspection by customs officials or a withholding of permission to unload the cargo at a US port. The CBP require the advance information to be submitted using the automated manifest system. The timings are:

- 24 hours before loading for sea vessels
- four hours before 'wheels up' generally, but from some closer countries it may be 'wheels up' only for aircraft
- two hours prior to arrival for rail
- one hour before arrival for trucks not covered by FAST.

FAST truck carriers need to submit information only half an hour prior to arrival.

Strategic security measures

Supply chain vulnerability

The vulnerability of networks has increased as a result of longer, leaner supply lines between focused facilities within consolidating networks.

CRANFIELD CENTRE FOR LOGISTICS AND SUPPLY CHAIN MANAGEMENT, 2003

The findings of the above study, which are still valid today, illustrate that while many risks to supply chain integrity come from the external environment there is growing evidence that the very structure of supply chains themselves is a cause of vulnerability. The emphasis on leaner inventories and outsourcing to third-world countries has created a situation where supply lines are longer and inventories leaner. Therefore, when the supply chain is broken due to inclement weather, political instability or, for example, the Covid-19 epidemic, the consequences for individual businesses, industries or economies may be disastrous. The purpose of the study was to provide

managers with some practical tools to ensure the resilience of their supply chains. Four levels of risk were identified as:

- Level 1 – process/value stream
- Level 2 – assets and infrastructure dependencies
- Level 3 – organizations' and inter-organization networks
- Level 4 – the environment

Recommendations from the study suggest that there are four issues that may generate improved supply chain continuity management. They are:

- risk awareness among top managers
- risk awareness as an integrated part of supply chain management
- understanding by each employee of his or her role in risk awareness
- understanding that changes in business strategy change supply chain risk profiles

Ensuring the integrity of supply chains is a strategic issue and should focus the minds of senior managers. The problems associated with extended vulnerable supply lines has always been an issue for military logisticians. Many military campaigns have failed because extended supply lines were broken and armies isolated. This research suggests that commercial supply lines are no less vulnerable.

The phrase 'black swan event' has been widely used to describe events that have a high impact on an organization but a low frequency of occurrence (the phrase derives from the fact that in some regions of the world black swans are rare). However, over the last 20 years or so such events appear to be happening more frequently than expected. Disasters include natural events such as volcanic eruptions but also events that could be related to human mismanagement of the environment. The central point is that natural disasters appear to be increasing in frequency; some may be attributed to better reporting of disasters, but not all. So black swan events may not be so unusual in future. To help deal with this phenomenon and how it might impact supply chains, the consultancy firm Deloitte (2012) published advice on supply chain resilience. It proposed four pillars of supply chain resilience:

- 1 Visibility:** the ability to monitor and track supply chain events so that corrective action may be taken quickly.
- 2 Flexibility:** being able to utilize alternatives in the supply chain to help minimize or avoid disruption – for example, alternative points of manufacture or alternative modes of transport.
- 3 Collaboration:** developing collaborative relationships with supply chain partners to help minimize the impact of any event – for example, alternative sources of supply.

- 4 *Control*: ensuring that policies and procedures are in place, that they are actively monitored and effective corrective action is taken promptly.

During 2020 and 2021 supply chains around the world were severely disrupted due to the actions of governments attempting to protect their people from the spread of Covid-19. Global economic activity was curtailed due to closing certain businesses and restricting the movement of populations. Trade imbalances emerged as different countries enforced or relaxed differing levels of restrictions leading to shipping containers being stranded and causing shortages elsewhere in the world. As a result many companies are reviewing the structure of their supply chains. At the time of writing it is hard to say exactly what the long-term effects of these reviews will lead to in terms of changes. However, it seems reasonable to suppose that some measure of re-shoring of outsourced manufacturing and increases in inventory (and thus expense to the business) will form part of the solution. Supply chain vulnerability has rapidly moved to the top of the agenda not only for companies but for governments as well due to its impact on almost everybody.

Piracy at sea

This is dealt with in Chapter 26.

Tactical security measures

Vehicle and driver security

Vehicles may be attacked because the thieves wish to steal the load, the vehicle itself or both. In recent years commercial vehicles have been targeted by thieves either to dismantle or to sell on intact. Sometimes vehicles are dismantled, loaded into containers and shipped abroad with extraordinary speed. In this type of situation, speed of response is essential. On other occasions, vehicles are simply driven away, sold in countries where checks on ownership are lax and never seen again. Therefore, when specifying vehicles, one should consider security of the vehicle, the load carrying area and the driver.

Vehicle cyber security

Vehicles being produced today contain sophisticated levels of electronics and communications technology. This includes the methods used to gain entry to a locked vehicle and to start it. The vehicle thief today is more likely to use a laptop computer than to physically attack the vehicle. The Motor Insurance Repair Research Centre

(Thatcham Research as it is generally known) has identified four key security concepts to help prevent such attacks. These are:

- firewalls to limit access to the vehicle communication system
- security gateway using a network structure to separate safety relevant elements, infotainment and the internet
- secure communication which secures the vehicle's internal communication between control units
- control units: single control units using powerful encryption electronics

THATCHAM, 2021A

The keys

Obviously, if a thief has access to the vehicle's keys then the thief's job is made very simple. Never leave keys in the ignition, and ensure that keys are securely locked away in the office when vehicles are at base. Keys should only be issued to known drivers or those with clear authority. A commonly used ploy is to pose as an agency (temporary) driver in the early hours of the morning, who requests the keys and drives away with a valuable vehicle and load.

These days, many vehicles have what are known as keyless entry and start buttons rather than a key. Vehicles fitted with these systems use a key fob that transmits radio waves to effect entry. Unfortunately, criminals have adapted and contrived several ways of overcoming the security element of this system. There are various tricks used, which centre on remotely obtaining the entry code of the vehicle without the owner realizing. In addition, cars sold in the last 15 years or so have been equipped with a standard diagnostic port that allows authorized technicians access to the vehicle's software to diagnose problems. Criminals have devised software to allow them to access this to overcome the vehicle's security, unlock the doors and start the engine. It is possible to fit a lock to these diagnostic ports. Naturally, vehicle manufacturers are modifying their systems to cope with these problems as they are identified but it is not much help to those who have older, more vulnerable vehicles. The best advice is to be aware of your environment when accessing your vehicle and take good care of your key fobs; but a determined criminal has the advantage of surprise. It is possible to buy a modified high-security key fob that links to the vehicle alarm and prevents criminals scanning the radio signal when you access your vehicle.

Windows

Windows should be etched with the registration number of the vehicle. It is worth remembering that rubber surrounds to windows may simply be cut away, allowing access. Small panel vans with glass in the rear doors should be replaced with vans with complete steel door panels. Existing windows may be protected by grilles or bars if necessary.

Where vehicles have a walk-through arrangement between the driving area and the load area, a bulkhead should be installed that hinders easy access to the load.

Immobilization

The aim of this type of security is to prevent the vehicle being driven away – or at least to buy time. It does not prevent the vehicle being unloaded where it stands. There are many types of immobilizer to choose from, but these are the more common varieties:

- steering locks
- air brake immobilizers
- starter motor immobilization
- fuel valve immobilization
- wheel clamps
- kingpin locks

Vehicle alarms

As with immobilizers, there are several different types of alarms for different circumstances. An alarm system will be either manual or automatic. The manual system relies on the driver to activate it before leaving the vehicle, and the automatic system sets itself. The manual system's weakness lies in the fact that if the driver fails to activate it then it is of no use. The use of automatic systems overcomes this problem but can be more costly to install.

Depending on the level of security required, alarm systems may require an independent power source, which is housed in a secure area of the vehicle. Commercial vehicles that have their batteries exposed would be vulnerable to the power supply being cut and the alarm deactivated. Even cars that have their batteries secure under the locked bonnet are not immune from someone cutting the power supply from beneath the car. A four-hour back-up requirement is specified by the British Standard BS6803. This standard also specifies a minimum 115 dB(a) for audible warning alarms, but often the output is higher. As with the power supply, the audible alarm should be housed in a secure area of the vehicle to avoid the wires to the sounder being cut by a would-be thief.

The alarm wiring system may be of the single or twin circuit variety. Single circuit wiring may be suitable for cars, but twin circuit wiring is required if the driver's compartment needs locking while the loading area is open. Most security specialists recommend that the wiring is closed-circuit, which means that the alarm is activated if the circuit is broken by someone cutting the wires. Monitor loops are another way of protecting the wiring from attack. Open-circuit wiring does not provide this type of protection.

Alarm contacts should be fitted to all points of access into the vehicle. Some urban delivery vehicles have been robbed while they are stuck in slow-moving traffic. If this is a possibility then consideration should be given to fitting a rear-door ignition alarm. This alarm will sound if the rear doors are tampered with while the engine ignition system is still running, thus alerting the driver and hopefully warning off the criminals.

The internal spaces inside the vehicle may be protected in several ways, as listed below. However, it is important to note that commercial vehicle bodies that have glass fibre roofs are vulnerable to being cut open and may need protection through the addition of steel mesh. Similarly, load protecting curtains are vulnerable to being cut by sharp knives. Neither the glass fibre roofs nor the curtains will be protected by internal space detectors.

Internal space detectors include:

- *Ultrasonic detectors*: these work by emitting and receiving high-frequency sound waves. They are activated by air movement inside the space being monitored.
- *Inertia sensors*: these sensors work by monitoring vibration levels. Vibrations caused by someone attempting a break-in will trigger the alarm system.
- *Break-glass detectors*: these clever devices recognize only the sound of breaking glass and work if a window is broken (but not if the rubber surround is cut out).
- *Dual tec sensors*: these work by using two different types of sensors that only trigger if they both detect something is amiss. These types of sensor obviously reduce false alarms.
- *CO₂ detectors*: these devices are used to detect unwanted human passengers (stowaways).

The alarm system can be fitted with a pager that alerts the driver, when away from the vehicle, if the alarm system is activated. Alternatively, a radio panic alarm allows the remote activation of the alarm system – if the driver feels that is needed. If required, the driver's personal security may be enhanced through the fitting of a panic button that sounds an audible alarm when pushed.

Further detailed and up-to-date advice and information on vehicle alarms and security may be obtained in the UK from Thatcham Research (Thatcham, 2021b). The driver's behaviour while going about daily duties can help avoid many opportunist-type crimes. The following is a list of dos and don'ts, as produced by Logistics UK, formerly the Freight Transport Association (FTA):

- Lock your vehicle and its load space whenever it is left unattended – even when making a delivery.
- Do not leave windows open when away from the vehicle.

- Lock the doors while sleeping in the cab; reverse the vehicle close to a wall or other barrier to prevent access to the rear doors; remember the top of the vehicle will remain vulnerable.
- Remove the ignition keys and lock the door when you go to pay for fuel. Also remember to lock the fuel cap when you put it back on.
- If anti-theft devices are fitted to your vehicle – use them!
- Never leave the vehicle unattended in a secluded area or, at night, in an unlit area. Try to keep your vehicle in sight if you leave it unattended.
- Never leave vehicle keys hidden for collection by a relief driver.
- Don't leave trailers unattended in lay-bys. Where possible use prearranged secure parking areas for overnight stops. Particularly avoid using insecure casual parking places as a routine practice.
- Don't chat about your load or your intended route in public or over the radio. Avoid asking unknown people for advice on local off-road parking facilities. Remember that the first breach of security occurs when the existence of the target becomes known to the thief.
- Do not carry unauthorized passengers in your vehicle.
- After a driving break or other stop where the vehicle is left unattended, look out for signs of tampering with doors, straps or sheets – someone may be back to finish the job later.
- Be vigilant and cautious when returning to the vehicle alone. Check for other suspicious vehicles nearby or persons in the immediate vicinity, particularly if seen taking undue interest in the vehicle. Note descriptions, registration number, etc. Get assistance from other drivers if seriously concerned or telephone the police for advice.
- In the event of a breakdown, consider the possibility of tampering or sabotage. Always take into consideration the security of the load if it is necessary to leave the vehicle.
- Treat unsolicited offers of assistance from unknown persons with caution and treat signals from other drivers that something is amiss with your vehicle with extreme caution.
- If you make the same journey frequently, consider whether the route/schedule can be varied, if this is possible or permitted.
- Where high-value loads are carried, travel in convoy with other known and trusted drivers if possible. Beware of bogus officials or staff – ask for identification. Carry a 'vulnerable load' card for production if stopped by the police – if in doubt keep going to the nearest police station!

- On arrival at your delivery destination, do not allow yourself to be persuaded to leave your vehicle in charge of anyone else or to deliver to any other location unless certain that such action is legitimate.
- Never leave valuables on view in your cab, whether these are loose equipment or your personal belongings.
- Look out for and report any security defects on your vehicle – faulty locks, bolts, straps, anti-theft devices, etc. Report unserviceable security equipment at once and insist on prompt rectification.
- Keep documentation about the load in a secure place. This can be used as authority to collect goods.

Further useful information may be obtained from the Logistics UK (formerly the Freight Transport Association) website (Logistics UK, 2021).

Satellite tracking/in-transit visibility

There are many systems available on the market today that allow operators to track their vehicles while away from base. Some use geostationary satellites and others use different technologies. For operators who need real-time visibility of their vehicles for service or security reasons, these systems are readily available at a reasonable price.

As mentioned in the list above, maintenance of anti-theft equipment is extremely important and should be included as a regular service item when vehicles are being maintained. Any vehicle-based equipment will be exposed to the elements to a far greater extent than static equipment and will require a higher level of maintenance as a consequence.

Journey management

This is a formal system for managing journeys by road in areas with poor road infrastructure, hazardous terrain such as deserts, and/or hostile people. It is a fact that accidents related to road transport are the biggest single health and safety problem in such regions.

There are many different systems in place but they all focus on systematically managing the individual journey to help minimize the possibility of anything going wrong. Typically, bases from which these journeys may start or finish will have formally trained journey managers whose responsibility it is to manage the journey.

Drivers of any vehicle, whether it be a truck or a smaller vehicle, are required to submit a written journey plan prior to departure which will outline details such as the origin and destination, locations along the route where breaks will be taken or fuel tanks refilled, any known hazards on this route and the names of all the passengers. Contact telephone numbers and agreed times for checking in will also be included.

The journey manager will be responsible for checking the vehicle with the driver to ensure that items such as spare wheels, first aid kits, torch (flashlight) and water (e.g. 10 litres per passenger) are on board. The driver will be held responsible for ensuring that the journey plan is followed and phoning in to report progress, problems or arrival at the destination. The system outlines procedures for the journey manager to follow in the event that a driver fails to phone at the appointed time. Ultimately this will trigger 'man lost' procedures and a search will be put in motion. Driving at night is banned for all but the most urgent journeys, and even these must be authorized by a senior manager. In the event of problems such as breakdown or getting lost, driver and passengers are instructed to stay with the vehicle and not wander away in search of help. It is important to understand that the above is only an overview and that the system must be clearly documented and contain detailed instructions for those who need to use it.

The distribution centre

The very nature of distribution centres (DCs) presents many headaches from the point of view of security. Access for large vehicles 24 hours a day requires large access gates that may be left open most of the time. Company employees, visiting drivers, customers, suppliers' representatives, contracted maintenance staff such as tyre fitters, and agency staff will all require access to the site at different times of the day. Most will be going about their business in a diligent fashion but this freedom of access also allows criminals similar freedom. Stories of commercial vehicles being driven away in broad daylight under the eyes of the DC staff are all too commonplace. The following are some suggested actions that will help reduce or eliminate this possibility.

Distribution centre location

Insurance companies are able to categorize different areas into those that are more or less likely to suffer from criminal activity. The same will be true for different areas within a region. DCs are located, by and large, in the best location to service their customers cost-effectively. In many cases the opportunity will not exist to relocate the DC. However, where it does, the level of crime in the target location may be worth considering, along with all the other factors.

Fencing

Perimeter fencing should create an effective barrier to the would-be criminal. Security experts recommend that palisade fencing topped with barbed wire and at least 2.4 metres high should be used. The top of this fencing should be angled outwards and all the links in the fencing should be welded to minimize the possibility of the fence being dismantled from the outside.

It is most important that vehicles are not parked next to the fencing. The vehicles could aid the criminals in their endeavours either by shielding them from view or by acting as a platform for them to gain access to the site. Do not stack pallets or other materials against the fencing, as these too could be used in a similar fashion. Once fencing has been installed, ensure that it is well maintained.

Gates

There is little point in having good fencing if the gates to the distribution centre are left wide open at all times. Electric sliding gates are expensive but very effective. If the price of electric gates is prohibitive then any gates that are fitted should have their hinges and bolts secured to prevent them being lifted off.

Pedestrians will require access, and this could involve them having to pass through a secure gatehouse where they are booked in and out by a competent security guard. Regular employees could be issued with swipe cards or identification cards complete with photographs to speed their access. The close control of visitors will discourage all but the boldest criminal, but it also helps from a health and safety point of view in the event of a fire or other serious incident.

Some high-security establishments photograph all visitors every time they visit, and in some cases a video of all people and vehicles visiting the site is made and retained for a given period, say four weeks.

Road blockers that raise and lower may also be used to protect entrances, but these are very expensive as well as being very effective.

Closed-circuit television (CCTV) and intruder alarms

The security of perimeter fencing can be enhanced through the use of intruder alarms that are activated when the beam is broken. In the same way, CCTV can help improve security, but again it is expensive. There are some shortcomings with CCTV. They are:

- The monitors need to be constantly viewed for them to be effective.
- Tapes need to be managed carefully to ensure that they do not get taped over or wear out. CCTV footage is normally stored digitally these days, which helps to mitigate this problem.
- If the criminal is dressed in dark clothing at night with the face disguised, the images are of little value for identification after the event. If the monitors are being watched constantly then immediate action can be taken.
- If the equipment is not turned on then its value is compromised.
- The positioning of cameras needs to be well thought through. This is not only to ensure that the cameras have a good field of vision but also to ensure that they can be seen but not attacked and put out of action. The sight of CCTV cameras can have a deterrent value in itself.

- Where intruder alarms and CCTV are used, advertise the facts prominently through the use of signs to aid the value of the deterrent.
- As an aid to yard management and site security drones are increasingly being used (see Chapter 22).

Security guards

Employing your own guards will be expensive if 24/7 cover is required. However, employed guards of the right calibre will know your business and your staff and can be an asset. Contract guards who visit the site on a mobile basis are an alternative, but the danger is that they fall into a routine visiting time that the criminals simply avoid. In this regard you get what you pay for, and the decision must be made in the light of the level of security required.

Lighting

Criminals in general do not like to operate where the area is well lit. Ensure that there is sufficient lighting to deter would-be thieves. In residential areas, lighting may also be a nuisance, so this must be borne in mind when positioning lights. Lights that are activated by heat or movement are an alternative to full-time lighting.

Personnel

Extreme care should be taken when recruiting new staff. Criminals have been known to insinuate themselves into the organization by applying for jobs either as direct employees or through employment agencies. The following useful advice regarding recruitment was prepared by Logistics UK, formerly the FTA:

- Take references from all previous employers.
- If possible speak person to person with the previous employer and discuss the applicant's work record and character.
- When checking references by telephone, obtain the number you need from a telephone directory. Any number supplied by the applicant could be that of an accomplice.
- Do not accept open references, such as 'To whom it may concern'.
- Beware of unexplained gaps in the employment record – query them.
- Avoid employing anyone with a known record of alcohol abuse, extreme habitual gambling or serious financial irresponsibility. A stable domestic background is to be preferred.
- Insist on seeing the applicant's original birth certificate, not a photocopy.

- Check driving licences thoroughly. Compare the date of birth against the birth certificate. An ordinary licence will expire the day before the holder's 70th birthday.
- Examine the licence closely in a strong light for signs of alteration, discoloration or erasure. Be suspicious of stained or damaged licences. Check for endorsements, photocopy the licence and retain this on file.
- Be suspicious of duplicate licences, which usually have 'duplicate' printed on them. Most duplicate licences are issued for quite legitimate reasons but disqualified drivers have been known to apply for and receive a duplicate licence before their trial and use this to gain employment.
- Obtain a photograph of the applicant and get the applicant to sign it in your presence.
- Exercise special care when recruiting temporary drivers, unless they are personally known to you.
- Agency drivers should be employed only from reputable agencies whose staff are vetted and ideally fidelity bonded. In any event, all agency drivers should be photographed before being allowed to drive any company vehicle. Driving licences should be examined, as described above. Do not rely on the agency to do this for you.

Further useful information may be obtained from Logistics UK (Logistics UK, 2021).

Safety in the distribution centre and warehouse

Despite the increased use of automation and mechanical handling equipment in distribution centres and warehouses, there are still many potential hazards involved. The increased speed of operations required these days has also created a new set of hazards. Some of the hazards that are still very common include manual handling injuries, vehicle reversing incidents, the misuse of fork-lift trucks, unstable racking, and personnel slipping, tripping and falling, to name a few.

The causes of accidents in the workplace usually relate to the working environment, the task or the personnel involved. Many of the hazards that have the potential to cause accidents should be identified and hopefully eliminated through the formal use of risk assessments. Senior site management need to define health and safety policies and practices clearly. These should be reinforced through the clear allocation of responsibilities, the use of safe working practices, the provision of well-maintained equipment and personal protective equipment (PPE), and regular safety training. Senior managers should visibly support sound health and safety practices and set an example by their own actions. The standard of health and safety management achieved will be directly related to their level of support and action.

Health and safety issues

Some of the most common health- and safety-related issues are listed below. This is intended as a general guide to some of the more common issues. It is by no means an exhaustive list, and professional detailed advice should be sought on these matters if there is any cause for concern.

The working environment

- Lighting levels should be sufficient.
- The integrity and strength of the warehouse floor are important for a number of reasons:
 - pallet racking will apply point loadings
 - a level floor will avoid the possibility of people tripping or fork-lift trucks and loads being destabilized
 - level floors are critical where tall stands of racking need to be at right angles to the floor
- Vehicles and pedestrians should be separated both inside the distribution centre or warehouse and outside in the yard. Ideally this will be achieved through the use of physical barriers, but pedestrian walkways should be clearly marked on the floor as a minimum. Vehicle and pedestrian lanes should be kept clear of obstructions at all times.
- An untidy working area must be avoided. Pallets should be neatly stacked, waste packaging and rubbish should be placed in an appropriate area, spillages of any kind should be cleared up promptly, and fire exits should be free of all impediments.
- There should be sufficient natural ventilation in any area where humans are working. Local exhaust ventilation should be installed over battery-charging areas.
- Suitable and sufficient toilet, washing and rest facilities must be available for use by all staff.
- It may be necessary to isolate certain types of stored products in separate areas. These might include hazardous chemicals, flammable materials or high-value items. This will allow management to better apply any special regulations regarding the safe handling of these materials.

Equipment

- All equipment used should be well maintained and fit for purpose. This will include all mechanical handling equipment, lifting straps or chains, conveyors,

shrink-wrap machines, heavy vehicles used in the yard to shunt trailers, and so on. A scheduled maintenance scheme should be in place for all equipment.

- All pallet racking should be suitable for the products stored. The racking must be inspected by a competent person on a regular basis. Any necessary repairs should be carried out with a minimum of delay, as pallet racking collapses can be catastrophic. Unstable pallets or loads on pallets should not be put away before either the pallet itself is changed or the load is made safe.
- Block stacking of pallets one on top of another should only be to a height relative to the strength of the pallet(s) and loads at the bottom of the stack. As a rule of thumb, four high does not usually present any problems so long as the point regarding the strength of the bottom pallet(s) and loads is borne in mind.
- Safety-related equipment such as fire extinguishers, sprinkler systems, alarm systems, emergency lighting, first aid kits, eyewashes, emergency showers, signage and PPE should all be in place if required and serviced regularly.

Personnel

- All personnel should receive regular health and safety training. Specific personnel such as fork-lift drivers should have certificates of competence for the equipment they operate. Large goods vehicle drivers should also have the appropriate licence.
- There should be certain people who are trained as safety officers or first aiders, or trained to do specific jobs such as changing fork-lift batteries.
- Breaches of health and safety rules and regulations should be dealt with through visible disciplinary action, which in some cases may result in dismissal.
- Scheduled health checks should be made. Hearing and eyesight tests are obvious, but maintaining the general level of staff health is also important to avoid lost working days. General lifestyle advice and stress counselling could be made available. The vital indicators such as blood pressure, weight and temperature should be checked regularly by trained staff.
- Some companies have policies regarding the misuse of alcohol, tobacco and recreational drugs. They often include random checking of individuals.
- The selection of personnel is important, as having workers with the right behaviour traits can help create a safe working environment.
- In some high-security facilities there may be a requirement for personal searches of staff and their belongings. This needs to be carried out following strict legal and locally agreed guidelines. Ideally it should be included in individual contracts of employment.

Legislation and regulation

Many aspects of health and safety in the distribution centre/warehouse environment have been the subject of national and international legislation. Due regard should be paid to this legislation both when planning and when managing distribution centres/warehouses. The scope and scale of this legislation is vast, and there is not room to go into detail here. Therefore, professional advice should always be sought on these matters.

For further up-to-date advice and useful publications with regard to all health and safety matters in the UK visit the Health and Safety Executive website (HSE, 2021).

Logistics and the environment

42

Introduction

The environment is an important issue for governments, organizations, companies and individuals around the world. This has led to a plethora of initiatives for which the aims are similar to those set out in the 8th European Action Plan:

to accelerate the transition to a climate-neutral, resource-efficient and regenerative economy, which gives back to the planet more than it takes. It recognizes that human well-being and prosperity depend on the healthy ecosystems within which we operate.

EUROPEAN COMMISSION, 2020

Logistics is a key part of any solution as freight transport, warehousing and associated activities have wide-ranging impacts on the environment including, for example, the emission of greenhouse gases and particulates into the atmosphere, the use of limited mineral and other resources, the production of waste (e.g. from plastic packaging), noise and light pollution, and the impact on biodiversity (e.g. through land use). With regard to the first of these, there is a wide range of estimates for the extent of this impact in terms of the percentage of greenhouse gases emanating from logistics, depending on what is covered and how these are measured. However, it seems likely that freight transport and warehousing account for between 10 and 20 per cent of global greenhouse gas emissions (Egloff et al, 2020; Ritchie, 2020). The logistics sector is therefore seen as being very significant in terms of its environmental impact by international organizations and national governments. Logistics managers are thus under considerable pressure to reduce this impact due to regulation and financial pressures as well as the demands of customers, shareholders and other stakeholders.

Broadly speaking, environmental impact may be divided into the internal environment, i.e. inside the organization, and the external environment, which encompasses everything that is outside the organization. The internal environment is concerned with health and safety issues such as noise levels, the handling of dangerous substances and occurrences, as well as risk assessments and safe systems

of work (see Chapter 41 in particular). Naturally, some issues are of concern to both the internal and the external environment, such as noise pollution and emissions of substances into the atmosphere or watercourses. This chapter concentrates on issues relating to the external environment.

International agreements and governmental actions

There have been numerous international agreements on climate change, one of the most notable being the Paris Agreement of 2016. This was a legally binding international treaty, adopted by 197 parties (governments and the European Union), with the goal of limiting global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. This target necessitates a significant reduction in the emission of greenhouse gases which include carbon dioxide, methane, nitrous oxide and fluorinated gases (used for example in refrigeration). Under the Agreement, individual governments submit their nationally determined contributions (NDCs), which are mandatory, plus their long-term low greenhouse gas emission development strategies (LT-LEDS), which indicate how the mandatory reductions in emissions fit into their overall plans. The national governments (and the European Union in conjunction with its 27 member states) set out various measures in order to achieve their commitments under such international agreements. These are typically a mix of targets, regulations, financial charges and taxes, financial incentives and infrastructure investment:

- *Targets.* Dates may be set by governments as to when they plan to achieve net-zero carbon emissions, plus interim dates when specified percentage reductions will be met. Net-zero means any emissions would be balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere, such as planting trees or using technology like carbon capture and storage. These overall targets may be broken down by industry specific targets.
- *Regulations.* These are used to prevent activities that may be harmful to the environment, such as:
 - For new internal combustion engines, the European Union restricts the emissions of toxic and greenhouse gases (e.g. carbon monoxide, nitrogen oxides, particulates, ammonia and methane). These limits have been progressively tightened from Euro 1 in 1992 through to Euro 7 due in 2025. Some cities ban, or charge extra for, entry of older high-emission vehicles. Similarly, road taxes may be higher for high-emitting vehicles.

- Permissible vehicle weight and dimension limits may be adjusted downwards to limit the size of trucks (particularly in town centres) or upwards to reduce the overall number of truck movements.
- There are normally strict controls on any pollution from factories or warehouses that may enter nearby watercourses.
- Mandatory requirements for companies may include energy usage and carbon emission reporting, as well as independent energy audits. Examples are the Energy Savings Opportunity Scheme (ESOS) and the Streamlined Energy and Carbon Reporting (SECR) scheme in the UK.
- *Financial charges and taxes.* These are designed to discourage activities harmful to the environment, for example:
 - Road tax may be higher for high-polluting vehicles and trucks may be charged for the distance that they travel, particularly on major roads.
 - There are many reuse, recycling and recovery regulations such as the EU's Waste Electrical and Electronic Equipment (WEEE) Directive. This sets requirements for the percentage of electrical and electronic equipment that must be collected compared to the amount put on the market. The collected waste materials (e.g. metals) are recovered and recycled, with the cost being borne by manufacturers, importers and retailers. There are similar schemes for packaging material in order to reduce the amount of packaging ending in landfill, with the cost being borne by raw material manufacturers, converters (e.g. box makers), packers/fillers (e.g. product manufacturers that package goods) and retailers. Such schemes are typically based on the principles of the 'polluter pays' and collective responsibility (i.e. the cost is spread between those companies involved in producing the waste). The cost of compliance acts as a deterrent to producing any unnecessary waste.
- *Financial grants and incentives.* In addition to financial charges and taxes aimed at discouraging activities that are detrimental to the environment, there are various financial grants and incentives to encourage environmentally friendly operations. These include for example:
 - grants and payments to encourage a modal shift from road transport to rail or water transport, as detailed in Chapter 28
 - road tax reductions or exemptions for electrically powered vehicles
- *Investment in infrastructure and research.* This includes investment in, for example, the decarbonization of electricity supplies (e.g. through use of wind and solar technology), the expansion of rail networks, rail electrification and the provision of networks of charging points for electric vehicles. Governments also often fund research and pilot projects, such as for sustainable fuels for trucks, aircraft and ships.

There are also numerous non-governmental bodies involved in reducing the environmental impacts of logistics activities. These include for example:

- The International Maritime Organization (IMO) has required ships to use very low sulphur fuel oil (VLSFO) from 2020 in order to reduce the amount of sulphur emitted into the atmosphere. Sulphur can cause respiratory problems and lead to acid rain, which damages ecosystems and buildings.
- Various organizations certify the environmental friendliness of new and existing warehouses (e.g. LEED and BREEAM – see Chapter 23).
- ‘Design for recycling’ is a concept adopted by a number of industries, such as automotive and plastics, to promote the design of goods so that they can easily be recycled, thus helping the ‘circular economy’ (i.e. reuse of materials). The Institute of Scrap Recycling Industries (ISRI) in the United States offers a ‘design for recycling’ award.
- The Science Based Targets initiative (SBTi) helps companies set emission reduction targets in line with the Paris Agreement. This initiative is a partnership between CDP (formerly the Carbon Disclosure Project), the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF).

These examples are just a few of the many international, governmental and organizational initiatives that are taking place to reduce the impact of economic activities, including logistics operations, on the environment.

Industry actions

Companies are thus regulated, taxed, incentivized and supported so that they take actions that help the environment. Most companies also wish to project an environmentally friendly image as this is what consumers and other stakeholders may expect. In addition, many companies see this as the correct approach for the sake of the environment itself. They therefore take a range of actions to protect the environment, as well as funding some of the non-governmental bodies mentioned earlier.

Some actions are easy for companies to decide on as they increase profits as well as benefiting the environment. For example, an efficient network design (as described in Chapter 10) not only reduces costs but also tends to reduce transport miles and thus greenhouse gas emissions. In fact, by modelling emissions from different combinations of warehouses and transport links, it is possible to optimize the design based on emissions and/or costs. For global operations, location decisions such as ‘near-shoring’ or ‘re-shoring’, whereby manufacturing may be moved nearer to the

main market or back to the market itself if manufacturing has moved overseas, should be considered. With complex products, it is often found that materials, components and sub-assemblies are moved many times between different countries before the final product is assembled. Such networks should be examined carefully to identify whether a more environmentally friendly approach can be achieved at reasonable cost.

In the remainder of this section, the various actions that can be taken within specific areas of logistics networks are examined.

Transport mode

A key decision affecting the quantity of greenhouse gases emitted is the choice of transport mode. For short and medium distances, the main alternatives are often between road, rail and waterborne transport, with the latter two modes being the more environmentally appropriate. One example of this modal choice is for containers arriving by ship into Rotterdam or Antwerp. They may be moved to inland destinations by road vehicles, by freight trains or along the River Rhine by river barges. For domestic transport, an example is the movement of supermarket and other goods from the Midlands of England to Scotland. It is a distance of about 300 miles, with some companies opting for road transport and others for rail, using for example Daventry and Mossend (Scotland) intermodal rail terminals.

For long-distance transport, maritime shipping is more environmentally appropriate than air freight and therefore this needs to be an important consideration in designing global movements in addition to the normal trade-off between speed and cost.

In calculating the effect of transport mode choice (and other logistics decisions) on the emission of greenhouse gases, it should be remembered that carbon dioxide (CO_2) is not the only greenhouse gas. As it is the main source of global warming, however, other gases are converted to CO_2 equivalents (CO_2e) in accordance with their greenhouse effect (with for example fluorocarbons, often used in refrigeration, having an effect per tonne released many thousands of times greater than CO_2). These figures may then be used to compare different transport modes in terms of the tonnes of CO_2e per kilometre moved in order to determine the impact on global warming.

Transport efficiency

An important issue with all transport modes concerns the load factor (i.e. how full is the road vehicle, train, ship or aircraft). For example, a road vehicle or train that is only 50 per cent full may emit almost as much greenhouse gas as one that is 100 per cent full. It is therefore important to utilize these transport assets fully.

For road freight, which is the most common mode used and therefore the main overall emitter, there are various measures that can be taken to improve load factors, such as:

- *Return loads.* In order to reduce ‘empty miles’ running, many companies pick up from suppliers after they have delivered to customers. Other options are to use third-party logistics companies who have many customers and can therefore find return loads more easily or to use digital freight exchanges to find suitable loads.
- *Collaboration.* Some companies actively collaborate in terms of their road fleet planning in order to optimize their combined freight movements and available vehicles, achieving significant improvements in load factors.
- *Vehicle and package types.* For example, the use of double-deck trailers, which can carry roll-cage pallets two-high, can greatly increase load factors in the right circumstances. In terms of packaging, space can be saved by the use of slip sheets rather than pallets (thus saving the typical 150 millimetres height of each pallet). The latter may be critical in allowing for an extra level of pallet loads in a box trailer or container.

Alternative fuels

Internal combustion engines (e.g. those fuelled by diesel and petrol) produce a number of emissions that are a cause for concern. The main culprits and their effects are:

<i>Emission</i>	<i>Main effects</i>
Carbon monoxide	Toxic
Carbon dioxide	Implicated in global warming
Oxides of nitrogen	Photochemical smog and ozone formation
Volatile organic compounds	Photochemical smog
Sulphur dioxide	Acid rain
Particulate matter	Respiratory problems

It is little wonder, in view of the above, that attention has turned to finding an alternative fuel to power road vehicles. Before discussing alternative fuels, it is worth explaining that the quality of road fuels and engines has been dramatically improved in the last 30 years. In the main, this has been achieved by:

- reducing the sulphur content in diesel fuel
- fitting catalytic converters to petrol engines
- high-pressure fuel injection systems
- the use of computerized engine management systems
- selective catalytic reduction (SCR) systems fitted to trucks to reduce nitrogen oxide emissions

The increase in road congestion and the number of vehicles on the roads has meant that these approaches have become even more crucial.

There are many alternative fuels being developed currently for all modes of transport. This section concentrates on road freight, which being the main mode used is the major freight transport emitter, accounting for nearly 5 per cent of global greenhouse gas emissions (Ritchie, 2020). Alternative fuels for maritime, air and rail freight transport are described in the relevant chapters (26, 27 and 28 respectively). For road freight, the main options for alternative fuels can be classified as follows.

Fossil fuels

Some alternative fossil fuels to petrol and diesel offer benefits in terms of less harmful emissions, including:

- *Liquefied petroleum gas (LPG)*. This is a mix of propane and butane gas, produced as a by-product of the petroleum and natural gas production processes. The gas is held at high pressure in a metal container in liquid form. It is a fossil fuel and therefore emits carbon dioxide when burnt but generally lower levels of nitrogen oxides. LPG engines tend to be quieter than diesel engines and also benefit from readily available refuelling locations, especially in continental Europe.
- *Compressed natural gas (CNG)*. Natural gas is mainly methane and is used for a variety of purposes including electricity generation, industrial processes and domestic/commercial heating, as well as for transport. Natural gas is used in a combustion engine in the same way as petrol and LPG, that is to say, it requires a spark to ignite it (rather than compression as in diesel engines). Refuelling times can be much longer than for diesel unless fast-fill equipment is used (which compresses the gas in advance and holds in storage tanks). From an emissions point of view, natural gas performs well in comparison to petrol and diesel and is increasingly seen as a viable alternative for commercial vehicles, particularly those working in urban areas. However, CNG-powered trucks require roughly five times the volume of fuel storage than a diesel-powered truck, thus affecting freight payload and capacity.
- *Liquefied natural gas (LNG)*. This is basically the same fuel as CNG, the only difference being in the way it is stored and supplied. LNG is stored at a temperature of -162°C in liquid form and so takes up much less space than CNG. Refuelling times are very similar to diesel, although the person refuelling has to use protective equipment for safety reasons (e.g. to protect from extremely cold pipework).

LPG, CNG and LNG are all more flammable than diesel and are therefore regarded as more hazardous in that respect. However, the use of both CNG and LNG in particular have become increasingly popular as operators of commercial vehicles have become convinced of their environmental advantages, especially in urban areas.

Biofuels

A range of biofuels is available, including:

- *Biodiesel*. This is a fuel that is refined from various vegetable-based oils such as soybean, palm and rapeseed. It performs much like diesel fuel and is currently used in a limited way. Various blends of biodiesel and diesel are commercially available, for example, B5 is a 5 per cent blend and B20 is up to a 20 per cent blend. Carbon dioxide and many other harmful gas emissions are reduced in comparison to diesel, but nitrogen oxide emissions tend to be increased. Although biofuels from plants may be viewed as a renewable source, there are questions over the use of land for these crops rather than for food production.
- *Bioethanol*. Ethanol is produced by fermenting agricultural crops rich in sugar or starch (e.g. sugarcane and corn). It is an alternative fuel to petroleum and it may be used in a mixture with petroleum or on its own. However, it must be used in engines adapted for its use. The advantages and disadvantages are broadly the same as those described for biodiesel.
- *Biomethane*. This is methane that is produced by the anaerobic digestion of organic matter such as sewage, farm and food waste, and from landfill sites. As it is methane, the burning and use properties are similar to natural gas. However, biomethane is regarded as a sustainable fuel as it is reusing resources. It also replaces the natural decomposition of organic matter which would release methane into the atmosphere – a gas about 20 times more powerful than carbon dioxide in its greenhouse effect.

Synthetic fuels

This term normally refers to fuels that are manufactured by a chemical process from coal, gas or biomass feedstocks (i.e. as raw materials) into a liquid fuel similar to diesel or petrol. As they are manufactured to a set specification, they typically burn cleaner with fewer toxic emissions and particulates, and producing less carbon dioxide. These fuels include:

- *Hydrotreated vegetable oil (HVO)*. This is made by a two-stage process involving saturating feedstocks at high temperature and then ‘cracking’ to remove impurities. It can be used in place of diesel and has benefits in terms of lower harmful emissions as well as longer storage times and improved use in cool climates.
- *Dimethyl ether (DME)*. This is a synthetic fuel that can be substituted for diesel or LPG or as a hydrogen-rich source for fuel cells. It may be made from coal, natural gas, black liquor (a by-product of paper pulp manufacturing) or biomass. DME is a gas that becomes a liquid under low pressure similar to LPG. It is suitable for use in specially designed compression ignition engines due to its high

cetane factor, which is equal to or greater than conventional diesel. Compared to diesel fuel, DME produces less nitrogen oxide and particulate emissions but has half the energy density, meaning that fuel tanks need to be double the size.

Lithium-ion batteries

Electric power has been used for decades in freight transport (e.g. for milk floats in the UK), originally employing lead-acid batteries, but nowadays generally lithium-ion batteries. No carbon dioxide, particulates or toxic gases are emitted but they do have a limited range. This makes battery power very suitable for urban use. With current battery technology, lithium-ion batteries are only suitable for light commercial vehicles (i.e. vans) as many heavy batteries would be required for heavy goods vehicles, greatly impacting on potential payload. The carbon footprint of the technology is largely dependent on the source of electricity to charge the batteries, ranging from zero carbon dioxide emissions for wind power through to very significant emissions if the source is coal power. The mix of source electricity varies greatly between countries. Another factor is the availability of rare metals (e.g. cobalt) for battery production. There are various hybrid uses of this technology, such as petrol/battery hybrids and bio-mechanical hybrid electric-assisted pedal cargo bikes.

Hydrogen fuel cells

These produce electricity to drive a vehicle by means of a chemical reaction. Hydrogen is supplied to the cathode and oxygen to the anode in the cell, with the resulting reaction forming an electric current, plus water as the by-product. There are no other tail-pipe emissions. The carbon footprint is therefore dependent on how the hydrogen is originally produced. The two main methods are from methane, which produces carbon dioxide as a by-product, or by means of electrolysis to split water into hydrogen and oxygen. If the latter process is powered by renewable energy sources (e.g. wind or solar) then this is known as 'green' hydrogen. One issue, however, is the energy lost in the processes of first converting electricity into hydrogen and then again back from hydrogen to electricity in the fuel cell. If used extensively, a lot of renewable energy would thus be required to provide hydrogen fuel for truck fleets.

Electric road systems (ERS)

One proposal to overcome the above energy loss is to use a catenary-wire system (i.e. overhead electric wires as used on railways) to provide electricity directly to trucks. This would require investment in such infrastructure and would therefore only be suited to the main road networks. However, it could be combined with battery technology to provide the flexibility needed for road transport collections and deliveries. As with other electric systems, the carbon footprint would be dependent on the sources of electricity used.

Other transport initiatives

There are many other initiatives designed to make road freight transport more environmentally friendly. These include:

- streamlining the vehicles to make them more aerodynamic and thus improve fuel efficiency (see Figure 42.1)
- noise reduction of engines and braking systems
- use of environmentally friendly lubrication oils
- alternative technologies, such as liquid nitrogen and biomethane, for refrigeration of temperature-controlled vehicles

Figure 42.1 An articulated vehicle designed to be more aerodynamic



SOURCE Mercedes-Benz Classic

Warehousing

While transport is rightly seen as a major source of emissions, it has been estimated that about 13 per cent of global supply chain greenhouse gas emissions emanate from logistics buildings (World Economic Forum, 2009). There are many measures that can be incorporated into the design of new warehouses to reduce their environmental impact and these are described in the 'Develop environmental aspects' section of Chapter 23. Many of these aspects can also be incorporated into existing

warehouses (see later in this chapter for a methodology to do this, in the section ‘Energy audits and emission-reporting schemes’).

In addition, there are various fuels that can be used for fork-lift and other trucks and these are explored in the ‘Alternative fuels for warehouse trucks’ section of Chapter 19.

Packaging

Packaging is important to logisticians for a number of reasons. The shape of the package may define how effectively the products are loaded into transport containers such as cartons or vehicles. For example, a cylindrical-shaped product is unlikely to fill a given cubic capacity as well as a rectilinear shape. This has implications for how much product can be stored or transported in a given space and, as all storage and transport resources have a finite size and weight restriction, filling these spaces effectively is extremely important. The greater the quantity of products stored or transported in a given cubic capacity, the more the associated unit costs and environmental impacts may be reduced.

Packaging is also important in protecting the products from damage in transit and even pilferage. Packaging in the form of unitized containers, whether they are pallets or reusable containers, often requires return transportation to the point of origin to facilitate reuse. One exciting potential aspect of the widespread adoption of 3D printers is that in-transit packaging could be significantly reduced, and in some cases eliminated, as the final products could be manufactured on site. Nevertheless, the raw materials such as resins, bulk powders and filaments used by 3D printers would still need to be transported and packaged.

Many industries have developed forms of packaging that do all that is required of them while in transit between the point of origin and the end user but do not warrant the expense of returning them to the point of origin. In order to avoid using the packaging only once and then consigning it to the rubbish tip, waste packaging needs to be returned up the supply chain, or at least the obligation to do this needs to be dealt with. For example, it is possible under the UK regulations to pay to join a compliance scheme that helps discharge the organization’s obligations in this regard, as mentioned earlier.

For specific packaging and waste aspects of warehouse operations see the ‘Packing and added-value services’ section of Chapter 21.

Reverse logistics

For the most part, logistics management is about moving goods from raw materials through production and onward to the end customer. However, there are occasions

when it is necessary to move goods in the other direction as well. These circumstances are generally referred to as reverse logistics and usually relate to:

- the return of unwanted, faulty or wrongly picked items
- product recall for quality or safety reasons
- end-of-life products for recycling or disposal
- unit loads (e.g. pallets and trays)
- used packaging (e.g. returned by stores), as mentioned in the preceding section

An important part of environmental management in logistics is designing effective ways in which these reverse flows are handled. For example, where appropriate:

- collections from customers or stores should take advantage of any empty, or part-empty, transport legs
- unwanted, faulty or wrongly picked items should be refurbished and reused
- end-of-life products should be disassembled and materials recycled (in fact, they should be designed with this in mind)
- unit loads should be repaired and/or cleaned, and then reused
- packaging should be recycled or reused

The handling and disposal of waste and returned goods have attracted a great deal of legislation and media attention, which means that this process needs to be addressed carefully.

Environmental management systems (EMS)

An EMS is a framework that enables a company or organization to monitor and control its environmental impact on a continuous basis. There are many frameworks available covering the whole supply chain as well as specific functions within it. Some of these are described below.

ISO 14000

This is a series of voluntary standards issued by the International Organization for Standardization (ISO) that provides a framework for managing environmental issues rather than establishing performance requirements. The approach is defined in the introduction of the standard's specification. It is seen as an iterative process that starts with the creation of an environmental policy by the organization. This leads to planning how the organization will meet its legal obligations as well as any targets it

wishes to set, which in turn leads to implementing and operating the plan. Implementation will pay due regard to the organizational structure and allocation of responsibilities. Training and communicating with staff, control of relevant documentation and operational controls must all be covered in the implementation.

Once the system has been set up, it is then formally monitored through an auditing process, which should identify corrective actions that need to be taken. Top management is required to review the performance of the system formally on a regular basis. This review may lead to the policy or objectives being changed or updated in the light of auditing reports or changing circumstances. This process should encourage a commitment to continuous improvement in environmental management as well as ensuring that the organization is not exposed by failing to meet its legal and moral obligations.

Carbon footprinting

The Carbon Trust defines this as follows:

A carbon footprint measures the total greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product and is expressed as a carbon dioxide equivalent (CO₂e).

CARBON TRUST, 2018

Carbon footprinting is mandatory for some companies, particularly those listed on the London and New York stock exchanges and those listed in the European Economic Area. Other companies may choose to measure their carbon footprint as part of their corporate social responsibility. Carbon footprints may be calculated at the level of an organization or of an individual product or service. It is possible to calculate the overall impact of the total supply chain, including the contribution of suppliers, end users, emissions throughout the life of the product or service and end-of-life emissions.

Depending on the scale and scope of the organization, calculating a carbon footprint for a complete supply chain is a complex and daunting task, not to mention the cost and time involved. However, it may produce tangible benefits by: reducing waste; using alternative materials, suppliers or processes; and improving the company's public image. Information on carbon emissions is available from a wide range of sources and there are a number of organizations that provide services in this area.

As an example of the type of information available, Table 42.1 shows conversion factors for carbon dioxide equivalent (CO₂e) emissions in kilogrammes (kg) typically produced by different size road freight vehicles and at different loading factors (i.e. percentage full). The full tables break down the CO₂e emission figures into CO₂, CH₄ and N₂O levels across a range of vehicles but for ease of illustration only a

selection of common diesel vehicle types and their KgCO₂e are shown here. These formulae may be used to help calculate carbon footprints or, as in the table, to estimate savings for particular initiatives: by simply identifying the number of vehicle kilometres saved through the implementation of a given initiative and multiplying the saved kilometre figure by the relevant conversion factor to arrive at the number of kilogrammes of CO₂e emissions that have been avoided. These conversion factors are updated annually.

Table 42.1 Conversion factors for calculating KgCOSUB₂e savings

Vehicle type	Gross vehicle weight	% weight laden	Vehicle km saved	Kg CO ₂ e per vehicle km	Total kg CO ₂ e saved
Rigid	>3.5–7.5 t	0%	×	0.44863	=
		100%	×	0.52563	=
Rigid	>17 t	0%	×	0.77439	=
		100%	×	1.10921	=
Articulated	>3.5–33 t	0%	×	0.64607	=
		100%	×	0.96235	=
Articulated	>33 t	0%	×	0.65224	=
		100%	×	1.07635	=

SOURCE Adapted from tables available at Department for Business, Energy and Industrial Strategy, 2020

Science based targets

These are targets set by companies and organizations with the aim of reducing carbon emissions to the scale required to meet international agreements on climate change, such as the Paris Agreement to keep the global temperature increase to within 2°C (and preferably 1.5°C) of pre-industrial levels. A detailed methodology has been issued by the Science Based Targets initiative (SBTi), mentioned earlier in this chapter. This sets targets based on the required carbon reductions for each industrial sector based on scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA). These targets take into account the ability of each sector to reduce greenhouse gas emissions through improved efficiency and new technology, as well as allowing for future growth projections of that sector in various geographic markets. Targets are set both for the end-year goal (e.g. 2050) as well as regular milestones up to that date.

Other types of target include projected dates for achieving zero carbon or net-zero carbon emissions (where the latter allows for offsetting any carbon emissions).

Energy audits and emission-reporting schemes

In many countries, mandatory reports have to be completed, particularly by larger companies: for example, the Energy Savings Opportunity Scheme (ESOS) and the Streamlined Energy and Carbon Reporting (SECR) schemes in the UK. These can act as useful base frameworks for companies' own environmental management systems and be expanded to cover what is relevant for the particular operations involved.

For functional areas within logistics, there are also many specific frameworks that have been developed. As an example, the following methodology has been designed to undertake energy audits of existing warehouses. This comprises eight steps:

- 1** Establish energy usage, e.g. gas and electricity consumed.
- 2** Identify end-use consumption types, e.g. heating, ventilation and air-conditioning (HVAC), lighting, fixed materials handling equipment, mobile equipment, and plug loads (for computers, security, etc).
- 3** Establish energy consumption for each type, e.g. by measurement, calculation or estimation.
- 4** Identify energy conservation opportunities (ECOs) for each type, e.g. by means of an energy survey through on-site observations and discussions carried out by a multidisciplinary team.
- 5** Predict energy savings of each ECO and the financial costs or benefits.
- 6** Categorize ECOs by type of spend, e.g. minimal spend, incremental spend, capital spend, lease/rental cost.
- 7** Evaluate ECOs in business terms, e.g. return on investment, reliability of financial and energy estimates, likely persistency of the energy saving through its lifetime.
- 8** Rank the ECOs on the above basis and formulate a timed action plan.

ADAPTED FROM DHOOMA AND BAKER, 2012

Performance measures and benchmarking

Performance measures act as a useful tool to monitor logistics activities in environmental terms on an ongoing basis. For example, measures with regard to road transport operations may include:

- miles per gallon, or litres per kilometre, of fuel used
- percentage of fleet using less polluting fuels
- percentage of truck fleet in different emission regulation bands (e.g. Euro 1 through to the planned Euro 7 in Europe)
- average life of tyres expressed in miles or kilometres

- percentage of tyres remoulded or regrooved
- amount of waste lubrication oils generated by the operation
- utilization of vehicle load space expressed as a percentage
- percentage of empty miles or kilometres run by vehicles
- targets for reducing waste packaging
- targets for reducing noise levels

It is often useful to benchmark these performance measures against comparable operations and various schemes are available to do this, such as the Logmark supply chain benchmarking scheme operated by the Chartered Institute of Logistics and Transport (UK).

Humanitarian logistics

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Introduction

Since the dawn of man, groups of individuals have been motivated to assist other groups of humans less fortunate than themselves. In 1847, for example:

The plight of Ireland had by now attracted attention from charitable and religious groups. The 'British Association for the relief of the extreme distress in the remote parishes of Ireland and Scotland' had collected over £470,000, including £2,000 from Queen Victoria and £1,000 from Baron Lionel de Rothschild. It worked through the local relief committees, storing and distributing supplies. Subscriptions came from countries as far away as India, Russia and Australia.

LITTON, 1994

The cause of this charitable activity was the Great Famine in Ireland between 1845 and 1850. It is estimated that 25 per cent of the population of Ireland died or was displaced during this terrible period. Many of the issues that emerged during this tragedy will ring bells for humanitarian aid workers today: political indifference or interference, transport and distribution issues, shortage of funds, cultural barriers, and well-meaning but ultimately ineffective activities of private groups of individuals.

In the modern era, the origins of today's organized humanitarian effort may be traced back to the Biafran War in Nigeria (1967–70). Since then, the field of humanitarian logistics has become central to the delivery of emergency aid as well as regular programmes of relief and assistance. The list of non-governmental organizations (NGOs) involved in the humanitarian effort is very long, with many United Nations agencies leading the field. This has become the source of the problems associated with a lack of coordinated effort leading to considerable waste in the process of delivering the aid, whether it be medical, food or developmental. The technical abilities of some of the dedicated people who become involved in such activities have been called into question in the past. The need for logistics expertise and professional training is self-evident. This is even more important given the extreme environments

that aid workers are often forced to endure. Extremes of temperature and weather, war or political unrest, poor infrastructure, terrain and equipment all contribute to the difficulties.

The problems experienced by the aid agencies during the Southeast Asian tsunami in 2004 highlighted an urgent need for coordination of effort and training of personnel. Much can be learnt by the sharing of expertise from both the commercial and military sectors who themselves have also faced and overcome similar difficulties.

Another key issue is the cost of delivering both the goods and personnel to the area where they are most needed. Many estimates of the amount of money spent on logistics have been made with estimates as high as 80 per cent of the total cost of humanitarian work having been cited. This number may be exaggerated but the most revealing point is that most NGOs do not actually know, with any level of accuracy, how much they spend on logistics.

As with so many areas covered in this book there is insufficient space available to cover all aspects of this fascinating and relevant area of logistics. The aim of this chapter is to highlight some of the key areas of difference from wholly commercial logistics operations and to describe some of the basic methods used in humanitarian logistics.

Key facts

To provide a sense of scale and scope, some key facts highlighted in the *State of the Humanitarian System* report (SOHS) in 2018 are:

- approximately 569,700 field personnel working in the sector
- funding for the global humanitarian effort in 2017 was US \$27.3 billion
- 201.5 million people in need of humanitarian assistance
- three governments provided 59 per cent of all government funding, namely the United States, Germany and UK, while governments and EU institutions provided 76 per cent of the 2017 total funding
- the United Nations Humanitarian Response Depot (UNHRD) network managed by the World Food Programme (WFP) has pre-positioning sites at Panama City (Panama), Accra (Ghana), Las Palmas (Spain), Brindisi (Italy), Dubai (United Arab Emirates) and Kuala Lumpur (Malaysia)

Key differences

Probably the most obvious difference between commercial supply chains and humanitarian supply chains is the issue of profit. In humanitarian logistics the profit

imperative is replaced by the necessity of delivering diverse aid services in a timely manner to alleviate human suffering. Speed of response in both fields is often a prerequisite.

Balcik and Beamon (2008) identified four differences that apply to humanitarian logistics:

- unpredictable demand in terms of timing, geographic location, type of commodity and quantity of commodity
- short lead time and suddenness of demand for large amounts of a wide variety of products and services
- high humanitarian stakes regarding timelines in the face of a sophisticated global media and the high anticipatory attention of the donors
- lack of initial resources in terms of supply, human resource, technology, capacity and funding

It also needs to be understood that emergency relief agencies are involved in providing a broad spectrum of goods and services that cover the fundamental needs of human beings in disaster situations, which include food, water, sanitation, shelter and healthcare. Some agencies specialize in providing for the needs of one group of people, such as children, while others specialize in vital services such as medical care. There are almost inevitably duplications of effort and shortages in any emergency. Nevertheless, they all try to adhere to the code of humanitarian principles of humanity, impartiality, neutrality and independence. Humanitarian principles will understandably colour the decision-making process and therefore the outcomes of the humanitarian logistics effort, but have little or no relevance in a commercial supply chain operation. That is not to say that commercial supply chains are somehow unethical or unprincipled, because that is simply not true. Commercial operations have to adhere to a strict legal and ethical framework but their very *raison d'être* is not founded on a structure of ethical principles but rather the commercial imperative of profit. This is another major difference between them.

Humanitarian supply chain

According to the Logistics Operational Guide (LOG), the component elements of the humanitarian supply chain are as follows:

- assessment and planning
- procurement
- warehouse and inventory
- transport
- fleet management

- cold chain
- customs
- distribution
- monitoring and evaluation

It will be immediately apparent to anyone with some understanding of supply chains that this process includes many of the different elements of a commercial supply chain. However, the differences in use of terminology in humanitarian circles may be confusing to somebody who works in the commercial field. For example, the use of the term ‘distribution’: in commercial circles this would include ‘warehouse and inventory’ and ‘transport’ as integral parts of physical distribution. However, in humanitarian logistics circles ‘distribution’ refers only to the final handing over of the goods to the beneficiaries, with ‘warehouse and inventory’ and ‘transport’ deemed to be completely separate and discrete activities in their own right.

The UN World Food Programme (WFP), the Lead Agency and Agency of Last Resort for the Logistics Cluster (see below for a fuller explanation of the Logistics Cluster) defines logistics as that range of activities that includes preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance.

Key terms

As with most fields of endeavour there are some key terms that are worth explaining. Some terms used commonly in both the field of humanitarian logistics and commercial logistics mean different things and may cause confusion if not clearly explained.

Distribution

In the commercial field this is taken to mean the process of storing, transporting and delivering finished products to the customer. However, for aid workers the meaning of distribution is generally limited solely to the final carefully structured activity of handing over the food or medical assistance to the beneficiary. Any activity prior to this final stage is generally referred to as transport.

Beneficiary

These are the people who directly benefit from the activities of the aid agencies. Some may see these people as the customer, but other than the fact that they are the *raison d'être* for the whole enterprise and benefit directly, they do not pay for the service so they are not technically the customer (see the discussion in the section on

‘The humanitarian aid customer’). However, it is entirely appropriate that they are treated with the same levels of service, courtesy and respect as a paying customer would be.

Donors

These are the individuals or organizations (including governments) that provide the funds to finance the humanitarian effort. In a very pure sense they may be considered as the customers of the aid agencies as they pay for the service, although others known as beneficiaries benefit from the activity. Many donors have become much more demanding and enquiring when it comes to knowing what happens to the money and resources they provide.

Internally displaced person (IDP)

An IDP is an individual who has been driven from their normal place of residence by a catastrophic event but remains within the confines of national boundaries.

Kits

These are pre-packaged collections of products that may relate to certain basic activities such as new-born baby kits, hygiene kits for adults and emergency health kits. The kits are packed in advance and contain items that are commonly required in a given situation. The kits are then transported to the field for distribution or use. The contents of the kits are decided in advance, packed and stored ready for emergency distribution at a later date.

Extended delivery point (EDP)

A term used by UNICEF to describe long-distance delivery points for distribution to beneficiaries relative to the central warehouse.

Surge capacity

‘Surge’ is defined by the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) as:

the swift deployment of experienced coordination experts and other specialized humanitarian personnel. Surge capacity is used when there are unforeseen emergencies and disasters, when an existing crisis deteriorates, or when a *force majeure* affects an office.

Rapid-onset disasters

These are usually disasters related to natural events such as earthquakes, extreme adverse weather conditions or volcanic eruptions. In other words, the disastrous event happens quickly with little or no prior warning.

Slow-onset disasters

As the term suggests, these disasters provide some early warnings signs such as the consequences of a prolonged drought leading to famine and failing crops. In a similar vein, deteriorating political situations that lead to armed conflict and inhabitants leaving their normal places of residence and becoming refugees tend to develop at a slower but inexorable pace.

The humanitarian aid ‘customer’

An important difference between commercial and humanitarian aid supply chains relates to the identity of the customer. A commercial supply chain delivers goods and services to a customer and is clearly tasked with profitably fulfilling the customer service promise. However, in relief agency circles the definition of the customer is far from clear-cut and is a source of both confusion and continued debate. There are two candidates: 1) the individual or organization that provides the funds or supplies that the relief organizations deliver, i.e. the donor; 2) the individuals or organizations that receive the benefits supplied by the relief organizations, i.e. the beneficiary. The following quotation appears to come down on the side of the recipients of aid who are known as beneficiaries:

The customers in the relief chain are the aid recipients. It is important to note here that donors play such a large role in the humanitarian relief sector that the vast majority of NGOs currently regard donors (not aid recipients) as customers. From this perspective, the NGOs manage a service chain, providing the service (for donors) of delivering aid to aid recipients.

BEAMON AND BALCIK, 2008

To be entirely fair to the authors, this quotation is taken slightly out of context. Nevertheless, it neatly encapsulates the problem. It must be clear to all that the beneficiaries have little or no discretionary powers in what is delivered, where it is delivered and how it is delivered. They also do not pay for the goods and services. On the ground, aid agencies do consult the local population where they can but this local involvement in rapid-onset disasters can only be limited (for more information on this subject see the CHS Alliance website).

The donor, on the other hand, does pay for the goods and services either directly or indirectly. In the past decade or so many donors have become ever more enquiring about how their money or supplies are used. It could be said that a humanitarian relief organization is in many ways acting as a third-party logistics (3PL) provider does in a commercial supply chain. Indeed many high-profile commercial logistics organizations have become increasingly involved in the organization of humanitarian aid operations. One example is Kuehne+Nagel (a freight management company) who have set up the Kuehne Foundation. In 2011 the Kuehne Logistics University in Hamburg, along with INSEAD Business School, established a research centre for humanitarian logistics. Its key aim is to improve the efficiency and effectiveness of the delivery of aid and for donors to see their donations achieve the best value outcome possible.

Commercial supply chains are constructed and operated on the basis of delivering the customer service promise. Humanitarian supply chains need to be constructed and operated on the basis of what is best for the beneficiaries in a given disaster or development situation. However, they do not always get what they need or what they want. Donors supply cash, supplies or other resources such as skilled personnel or specialist equipment. As they are paying for the service of aid delivery they have a powerful voice in what happens. This is much more closely aligned to the definition of a customer in the commercial world.

Whether donors or beneficiaries are the customer is more than an academic point. Two things are important. First, that the beneficiaries get the aid they require in a timely and effective manner. Second, that effective performance is clearly demonstrated so that the donors continue to donate to enable future relief efforts to be successful. Clearly, an accommodation needs to be made between the needs and wants of the donors and the beneficiaries.

The Core Humanitarian Standard (CHS) on Quality and Accountability

In 2013 the Joint Standards Initiative surveyed 2,000 humanitarian aid practitioners which ultimately led to the production of the CHS. The survey revealed that there was a desire for a more formal, unified quality standard for the delivery of humanitarian aid. The CHS lays out nine commitments that both individuals and organizations can use to improve the quality and effectiveness of the humanitarian aid that they provide. It is designed to facilitate a greater accountability by these organizations for the standard of service they provide to the communities affected by the disaster. Various appalling scandals involving aid workers exploiting vulnerable refugees have forced the humanitarian aid community to act.

At the core of the standard is the humanitarian code of principles whereby communities and people affected by the crisis must be treated with humanity,

impartiality, neutrality and independence. In addition, the nine commitments are as follows:

- 1 Humanitarian response is appropriate and relevant.
- 2 Humanitarian response is effective and timely.
- 3 Humanitarian response strengthens local capacities and avoids negative effects.
- 4 Humanitarian response is based on communication, participation and feedback.
- 5 Complaints are welcomed and addressed.
- 6 Humanitarian response is coordinated and complementary.
- 7 Humanitarian actors continuously learn and improve.
- 8 Staff are supported to do their job effectively, and are treated fairly and equitably.
- 9 Resources are managed and used responsibly for their intended purpose.

CHS ALLIANCE

Performance measurement

As already discussed, some adequate method of performance measurement is essential to monitor ongoing logistics operations. At the operational level in aid organizations, performance measurement of logistics activities may be in place and data collected but the question remains whether or not any meaningful management action results from the collection of this data. Indeed, one outstanding question relates to whether or not any relevant performance measurement of logistics takes place at this level at all in some organizations. The reasons often cited for failure to actively monitor and measure logistics operations are the exigencies of working in a pressurized environment where lives are at stake. However, at a strategic level the measurement of performance is certainly a matter of concern for donors and increasingly they are demanding a more accurate and comprehensive account of how their money has been spent.

In response to this need, Anne Leslie Davidson (2006) suggested four key performance measures that emerged from her study of the International Federation of Red Cross and Red Crescent Societies (IFRC). They aim to measure logistics performance against three trade-offs: speed, cost and accuracy. The measures are not designed to be highly scientific but rather to provide a sense of an improving or deteriorating scenario. This may appear somewhat strange to a commercial logistician. However, it needs to be viewed in the light of the general absence of data from the front-line operation; the inevitable period of chaos following a rapid-onset emergency; the general lack of performance measurement in the sector; and the possible lack of logistics training among humanitarian logisticians at the point of delivery.

The four measures are:

- 1 Appeal coverage – which is further subdivided into percentage of appeal covered and percentage of items delivered. The first measures the quantity of items pledged by donors against the amount requested by the operation on the ground. The second measures the actual number of items delivered to the operation against what was requested. The first measures performance in procuring items from donors and the second measures the delivery performance.
- 2 Donation-to-delivery time – this measures the time taken to deliver the donated items to the point of need expressed as an average time or the median.
- 3 Financial efficiency – this is subdivided into three measures. The first two measure budgeted prices against actual prices paid for items. The third measures the ratio between total transport costs against total purchase price paid for delivered items. The expectation is for this ratio to reflect a reduction in transport costs as the emergency recedes over time.
- 4 Assessment accuracy – this measures how well field-operations staff estimated what was required to meet the needs of the emergency. This is expressed as positive or negative variances to the original budget.

Once the data is collected it may be consolidated in a scorecard (see Figure 43.1). The scorecard illustrated is the final scorecard. However, other scorecards were produced during this particular emergency at regular intervals to help the IFRC decision-making process.

Since Davidson wrote her thesis there has been other academic research into the area of performance measurement in humanitarian logistics but it remains another key area of difference between commercial supply chain operations and those of a humanitarian nature. In fact, Abidi and Klumpp (2014) observe that the main body of publications on this subject appeared after the problems experienced during the aftermath of the 2004 Asian Tsunami. Further to this, they note that the total number of research papers in this field was very low compared to other fields of logistics. Their paper includes a useful list of performance measures for humanitarian logistics, for those looking for further information.

Due to a lack of good performance measurement, another factor that has been identified is the need for visibility by donors of the relief agencies' activities that may cause the agencies to focus on emergencies with high media coverage to aid their fundraising activities. Clearly, this is a perverse incentive which does not lead to the efficient allocation of resources, with some emergencies receiving too much while others receive less. A credible practical performance measurement system might go some way to resolving this issue.

High staff turnover coupled with poor training and a lack of practical skills can all contribute to less than optimal performance. The nature of the environment in

Figure 43.1 South Asia earthquake final scorecard

South Asia Earthquake Appeal Date: October 9, 2005				
Status Update: Final Date: March 18, 2006	Operation Total (Weighted)	Priority 1 Housing	Priority 2 Kits & Sets	Total OP Target
Percent of Appeal Coverage (in quantity of items)				
After 1 week	63%	61%	77%	
After 2 weeks	47%	45%	18%	
After 1 month	74%	73%	51%	
After 2 months	91%	92%	71%	
After 3 months	93%	99%	100%	
Percent of Items Delivered (in quantity of items)				
After 1 week	6%	1%	4%	
After 2 weeks	9%	5%	2%	
After 1 month	33%	27%	8%	
After 2 months	48%	46%	19%	
After 3 months	67%	72%	47%	
Donation-to-Delivery Time				
Mean (# days)	33	35	29	
Median (# days)	28	31	24	
Financial Efficiency				
(Donor Cost – Budget Cost) / Budget Cost	–5%	–11%	30%	
Actual CHF Spent – Budget CHF	(3,510,849)	(5,209,538)	1,810,531	
Transportation Cost / Total Product Cost	10%	N/A	N/A	
Assessment Accuracy: Revised Budget / Original Budget				
After 2 week	131%	118%	365%	
After 1 weeks	139%	123%	377%	
After 2 month	148%	127%	493%	
After 3 months	158%	127%	493%	

NOTE CHF refers to Swiss Francs as this is the currency used by IFRC

SOURCE Davidson, 2006

which field staff work, along with real and present danger, does not help recruitment nor does it always attract the skills required.

Pre-positioning of resources

In the same way that commercial and military organizations move supplies forward close to where they are needed, the humanitarian community has adopted the same practice. The United Nations has established storage facilities in strategically useful locations around the world. There are facilities in Ghana, Panama, UAE, Malaysia, Italy and Spain and these are strategically located near the transport infrastructure so that aid can be delivered in their catchment area within 24 and 48 hours. They are called UN Humanitarian Response Depots (UNHRD) and are managed by the World Food Programme (WFP). Medical kits, shelter, ready-to-use foods and other

items needed in a disaster situation are stored ready for dispatch. The UNHRD in Brindisi, Italy also houses the Centre of Excellence for Training in Logistics. In Dubai the UNHRD is based in the International Humanitarian City (IHC) along with more than 40 NGOs and commercial entities. IHC has 93,000 square metres of warehouse space.

Similarly, the Association of Southeast Asian Nations (ASEAN) has opened a hub for humanitarian aid to assist the coordination of regional disaster response efforts.

The 'Global Mapping of Emergency Stockpiles' is a collaborative effort between government agencies, NGOs, clusters and UN agencies to improve the visibility of 'who has what and where' in the event of an emergency.

Assessment and planning

Once disaster strikes, speed of effective response is absolutely essential. However, there is never a substitute for planning and preparation. Ideally a certain amount of pre-disaster planning should already be in place but this is not always the case. Depending on the nature of the disaster, logistics personnel need to assess the impact of the disaster on their ability to operate effectively. In the case of natural disasters, the transport infrastructure may well have been seriously compromised and alternatives need to be found. The UN Logistics Cluster *Logistics Operational Guide* (LOG) provides useful detailed templates for conducting an assessment. Naturally consideration should be given to the following as recommended by LOG:

- numbers of affected population
- distribution plans
- materials required (commodities and supplies)
- electric power, hydro facilities
- water/sewage
- civil aviation, airports, alternative aircraft
- seaports
- railroads
- roads and bridges
- local trucking capacity
- transfer points
- communications
- coordination capacity
- warehousing

The LOG also outlines the following process that is recommended to be followed when undertaking a logistics assessment, following a disaster:

- clarify nature of intervention
- identify and mobilize resources and plan for assessment
- identify information needs and sources
- collect data and information
- analyse and interpret data and information
- report conclusions and provide a logistics response plan
- design/modify disaster response

The cluster approach

The cluster approach was introduced by the UN during its humanitarian reform in 2005. The idea is to improve capacity, predictability, accountability, leadership and partnership.

Both non-UN and UN humanitarian agencies who work in the major areas of humanitarian response cooperate together in clusters. A coordinating organization known as a cluster is formed when there is an obvious requirement for humanitarian response within a given area, when there are many players operating inside the same area or when local authorities require a coordinated approach.

The role of the cluster is to provide a single point of contact and accountability for providing the right amount and kind of humanitarian response. Clusters form partnerships between all the humanitarian agencies, governments and civil society. Full information on the approach can be found on the website of the UN Office for the Coordination of Humanitarian Affairs (UNOCHA, 2021).

The approach helps to avoid unnecessary duplication of effort by multiple agencies trying to achieve the same ends. Through cooperation and pooling of resources, wasted effort is eliminated or reduced. This is a major step forward in the effective delivery of humanitarian aid.

Distribution

As indicated earlier, in the field of humanitarian logistics the term ‘distribution’ has a specific meaning. That is not to say that professional humanitarian logisticians do not recognize that warehousing and transport form part of a wider commercial distribution activity – it is more that the specific activity of distributing the aid to the actual beneficiaries is more easily described as ‘the’ distribution.

Site selection

Clearly there are many diverse factors that need to be considered when choosing a site for distribution. A natural choice would be existing points where the local community might gather, such as market locations, but consideration needs to be given to other equally important issues such as the following:

- How far will the beneficiaries have to walk to the site?
- What is the condition of the local transport infrastructure for trucks to access the site? Due regard should be given to the possibility that beneficiaries walking to the distribution site may block the access for vehicles.
- The provision of shade, water and sanitation facilities for the beneficiaries.
- Is the location secure for the beneficiaries?
- An evacuation route for the staff in the event of disorder or attack.
- The proximity to military or sensitive sites.

It is extremely ironic (and quite tragic) that while the global agricultural effort is capable of growing sufficient food to feed the entire human population, in some agricultural supply chains as much as 50 per cent of what is grown is lost in the supply chain before it reaches the end user. In addition, affluent societies throw away alarming amounts of perfectly good food, either as simple waste or due to overzealous adherence to ‘best before’ end dates. Improvements in logistics and supply chain management tools and techniques could improve the former situation, and education about the appalling waste of food may improve the latter.

Further reading

The *Logistics Operational Guide* (LOG) has been produced through collaboration between many humanitarian organizations and facilitated by the Global Logistics Cluster Support Cell and the World Food Programme (LOG, 2016). The LOG contains a great deal of useful information regarding humanitarian logistics.

Another useful website is the CHS Alliance site (CHS Alliance, 2021), which deals with standards of quality and accountability for stakeholders in the humanitarian aid effort.

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ACRONYMS AND ABBREVIATIONS

This section is aimed at identifying many of the more common acronyms and abbreviations used in the industry. Most, but not all, of these appear in the text. Readers may consult this section quite independently.

2D	two-dimensional (e.g. 2D barcodes)
24/7	24 hours per day, 7 days per week
3D	three-dimensional (e.g. 3D printing)
3PL	third-party logistics service provider
4IR	Fourth Industrial Revolution
4PL	fourth-party logistics service provider
ABC	activity-based costing
ABC curve	Pareto or ABC inventory analysis
ADR	<i>Accord Dangereux Routier</i> (European agreement regarding the road transport of dangerous goods)
AFRA	average freight rate assessment (system)
AGV	automated guided vehicle
AI	artificial intelligence
ALNAP	Active Learning Network for Accountability and Performance (humanitarian)
AMR	1) Advance Manifest Rule; 2) autonomous mobile robot
APR	adjustable pallet racking
APS	advanced planning and scheduling
AR	augmented reality
artic	articulated (vehicle)
ASEAN	Association of Southeast Asian Nations
ASME	American Society of Mechanical Engineers
ASN	advance shipping notice
AS/RS	automated storage and retrieval system
ATA	1) Air Transport Association of America; 2) Admission Temporaire/Temporary Admissions carnet
ATP	<i>Accord Transport Périssable (Accord Relatif aux Transports Internationaux de Denrées Périssables</i> – European agreement regarding the international transport of perishable goods)
ATP	available to promise
AWB	air waybill
B/L or BOL	bill of lading
BAF	bunker adjustment factor
B2B	business-to-business
B2C	business to consumer
BER	block exemption regulation (EU)

BL	bill of lading
BLE	Bluetooth low-energy
BOM	bill of materials
BOPIS <i>or</i> BOPUS	buy online/pick up in store
BORIS	buy online/return in store
BREEAM	BRE Environmental Assessment Method
BREXIT	Britain's exit from the EU
BRI	Belt and Road Initiative (China)
BPM	business process management
BS	British Standard
BSI	British Standards Institution
CAD	computer-aided design
CAF	currency adjustment factor
CASS	cargo accounts settlement system
CBFLT	counterbalanced fork-lift truck
CBM	cubic metre
CBP	United States Bureau of Customs and Border Protection
CCTV	closed-circuit television
CD	compact disc
CDC	central distribution centre
CE	Conformité Européenne
CEO	chief executive officer
CEP	courier, express and parcel services
CFO	chief financial officer
CFR <i>or</i> C&F	cost and freight
CFS	container freight station
CHP	combined heat and power
CHS	Core Humanitarian Standard (on quality and accountability)
CIF	cost, insurance and freight
CILT (UK)	The Chartered Institute of Logistics and Transport (UK)
CIM	1) computer integrated manufacturing; 2) Convention Internationale concernant le Transport des Marchandises par Chemin de Fer (Agreement concerning International Carriage of Goods by Rail)
CIO	chief information officer
CIP	carriage and insurance paid to
CIPD	Chartered Institute of Personnel and Development
CIPS	Chartered Institute of Purchasing and Supply
CM	category management
CMI	co-managed inventory
CMR	Convention Relative au Contrat de Transport International de Marchandises par Route (European Convention regarding International Transport Contracts of Goods by Road)
CNG	compressed natural gas
CO	certificate of origin
CO ₂ e	carbon dioxide equivalent
cobot	collaborative robot

COD	cash on delivery
COGSA	Carriage of Goods by Sea Act (United States)
COI	cube per order index
COO	chief operating officer
COSHH	Control of Substances Hazardous to Health (Regulations)
CPFR	collaborative planning, forecasting and replenishment
CPT	carriage paid to
CRM	customer relationship management
CRP	continuous replenishment programme
CSCMP	Council of Supply Chain Management Professionals (United States)
CSI	Container Security Initiative
CT	community transit
C-TPAT	Customs–Trade Partnership Against Terrorism
CV	curriculum vitae
CVD	Customs Value Declaration
D2C	direct-to-consumer
DAP	delivered at place
DAT	delivered at terminal (replaced by DPU)
dB(a)	decibel
DC	distribution centre
DCF	discounted cash flow
DCM	demand chain management
DDMRP	demand-driven material requirements planning
DDP	delivered duty paid
DEF	diesel exhaust fluid (common trade name AdBlue)
DEFRA	Department for Environment, Food and Rural Affairs (UK)
DERV	diesel-engined road vehicle
DfT	Department for Transport (UK)
DHS	Department of Homeland Security (United States)
DMAIC	define, measure, analyse, improve and control
DME	dimethyl ether
DO	delivery order
DOM	distributed order management
DPP	direct product profitability
DPU	delivered at place unloaded
DRP	distribution requirements planning
DSD	demand standard deviation
DTC	direct-to-consumer
DVD	digital versatile/video disc
dwt	deadweight ton
EAN	European Article Number
EBQ	economic batch quantity
EC	European Commission
ECO	energy conservation opportunity
ECR	efficient consumer response
ECS	equipment control system
EDI	electronic data interchange

EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
EDP	extended delivery point
EEA	European Economic Area
EEE	electrical and electronic equipment
eFC	e-fulfilment centre
EFTA	European Free Trade Association
ELA	European Logistics Association
EMS	environmental management system
EOQ	economic order quantity
EPOS	electronic point-of-sale
ERP	enterprise resource planning
ERS	electric road system
ES	exponential smoothing
ESOS	Energy Savings Opportunity Scheme
ETA	estimated time of arrival
ETD	estimated time of departure
ETO	economic/technical/organizational
EU	European Union
EXW	ex works
FAME	fatty acid methyl ester (biodiesel)
FAS	free alongside ship
FAST	Free and Secure Trade
FCA	free carrier
FCL	full container load
FCPA	Foreign Corrupt Practices Act (United States)
FCR	forwarder's certificate of receipt
FEM	Fédération Européenne de la Manutention (European Federation of Material Handling)
FEU	40-foot equivalent unit
FFG	Freight Facility Grants
FG	finished goods
FGI	finished goods inventory
FGP	factory gate pricing
FIATA	International Federation of Freight Forwarders Associations
FIBC	flexible intermediate bulk container
FIFO	first-in first-out
FILO	first-in last-out
FLT	fork-lift truck
FMCG	fast-moving consumer goods
FMS	flexible manufacturing systems
FOB	free on board
FOC	1) fire officer's committee; 2) free of charge; 3) freight operating company
FOT	free on truck
FRES	Federation of Recruitment and Employment Services
FTA	Freight Transport Association (UK) (renamed Logistics UK)
FTL	full truck load

GA	general average (maritime shipping insurance)
GAA	general average adjuster
GATT	General Agreement on Tariffs and Trade
GCC	Gulf Cooperation Council
GDP	gross domestic product
GHG	greenhouse gas (emissions)
GIS	geographic information systems
GMOs	genetically modified organisms
GNSS	global navigation satellite systems
GPS	global positioning system
GRI	general rate increase
GRN	goods received note
GSM	global system for mobiles
GTIN	global trade item number
GVW	gross vehicle weight
HAP	Humanitarian Accountability Partnership
HAWB	house air waybill
HGV	heavy goods vehicle
HS	harmonized system (customs)
HS1	High Speed 1 (UK railway: London – Channel Tunnel)
HS2	High Speed 2 (UK railway: London – North of England)
HSE	1) Health and Safety Executive; 2) health, safety and environment
HSWA	Health and Safety at Work Act
HT	heat treatment
HVAC	heating, ventilation and air-conditioning
HVO	hydrotreated vegetable oil
I2M	inbound to manufacturing
IATA	International Air Transport Association
IBC	intermediate bulk container
IBP	integrated business planning
ICT	information and communication technology
IDP	internally displaced person
IEA	International Energy Agency
IFRC	International Federation of Red Cross and Red Crescent
IGD	Institute of Grocery Distribution
IHC	International Humanitarian City (Dubai)
IJPDLM	<i>International Journal of Physical Distribution and Logistics Management</i>
IMDG	International Maritime Dangerous Goods Code
IMF	International Monetary Fund
IMO	International Maritime Organization
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
ISPS	International Ship and Port Facility Security Code
ISRI	Institute of Scrap Recycling Industries (United States)
IT	information technology
ITS	intelligent transport systems

ITT	invitation to tender
IWW	inland waterways
JIC	just-in-case
JIT	just-in-time
KD	knocked down (dismantled)
KPI	key performance indicator
KWh	kilowatt hour
LC/LOC	letter of credit
LCL	less than container load
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LGV	large goods vehicle
LHV	longer and/or heavier vehicle
LiDAR	light detecting and ranging
LIFO	last-in first-out
LLOP	low-level order picking truck
LLP	lead logistics provider
LMS	labour management system
LNG	liquefied natural gas
LOLO	lift-on lift-off
LOG	<i>Logistics Operational Guide</i> (UN Logistics Cluster)
LPG	liquefied petroleum gas
LPI	logistics performance index
LPN	licence plate number (e.g. on pallet)
LSP	logistics service provider
LT	lead time
LTL	less than truck load
LT-LEDS	long-term low greenhouse gas emission development strategy
LTSD	lead time standard deviation
M2M	machine-to-machine
MAD	mean absolute deviation
maglev	magnetic levitation
MAM	maximum authorized mass
MAPE	mean absolute percentage error
MAWB	master air waybill
MB	methyl bromide (fumigation)
MBO	management by objectives
MES	manufacturing execution system
MFC	micro-fulfilment centre
MHE	materials handling equipment
MIS	management information systems
ML	machine learning
MOU	memorandum of understanding
MPE	mean percentage error
MPG	miles per gallon
mPOS	mobile point-of-sale
MPS	master production schedule
MRO	maintenance, repair and overhaul

MRP	materials requirements planning
MRPII	manufacturing resource planning
MSDS	material safety data sheets
MSRS	Mode Shift Revenue Support scheme
MSE	mean square error
NA	narrow aisle
NAFTA	North American Free Trade Agreement (replaced by USMCA)
NCPDM	National Council of Physical Distribution Management
NDC	1) national distribution centre; 2) nationally determined contribution
NFC	1) national fulfilment centre; 2) near-field communication
NGO	non-governmental organization
NPV	net present value
NTE	not to exceed (related to contract value)
NVOCC	non-vessel operating common carrier
OBD	on-board diagnostics
OCR	optical character recognition
OCTG	oil country tubular goods
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OLED	organic light-emitting diode
OM	operations management
OOG	out-of-gauge (cargo)
ORR	Office of Rail and Road (UK)
OSD	over, short and/or damaged (upon delivery)
OTIF	on-time-in-full
P&D	pick-up and deposit station
PC	personal computer
PESTEL	political, economic, socio-cultural, technological, environmental and legal
PLC	product life cycle
PM	particulate matter
PO	purchase order
POD	proof of delivery
POE	point (or port) of entry
POS	point-of-sale
PPE	personal protective equipment
PPT	powered pallet truck
PRC	People's Republic of China
PRN	Packaging Recovery Note
PSI	pounds per square inch
PSS	peak season surcharge
QA	quality assurance
QC	quality control
QFD	quality function deployment
QR	quick response
R&D	research and development
RaaS	robots-as-a-service

RDC	1) regional distribution centre; 2) radio data communication
RDT	radio data terminal
REC	Recruitment and Employment Confederation
RF	radio frequency
RFI	request for information
RFID	radio frequency identification
RFP	request for proposal
RFQ	request for quotation
RFS	road-friendly suspension
RH&D	receipt, handling and dispatch
RM	raw materials
ROCE	return on capital employed
RofW	rest of world
ROI	return on investment
ROL	reorder level
RORO	roll-on roll-off
ROS	return on sales
ROSCO	rolling stock leasing company
RPA	robotic process automation
RPC	Reduced Pollution Certificate
RT	reach truck
RTLS	real-time location system
S&OP	sales and operations planning
SAD	single administrative document
SBTi	Science Based Targets Initiative
SC	supply chain
SC:4	Supply Chain 4:0
SC:5	Supply Chain 5:0
SCEM	supply chain event management
SCM	supply chain management
SCOR® model	Supply Chain Operations Reference model
SCP	supply chain planning
SCR	selective catalytic reduction
SD	standard deviation
SDR	special drawing right
SECR	Streamlined Energy and Carbon Reporting scheme
SED	shipper's export declaration
SEM	Single European Market
SEMA	Storage Equipment Manufacturers' Association (UK)
semi	semi-trailer (articulated truck trailer)
SFI	Secure Freight Initiative
SKU	stock-keeping unit
SLA	service level agreement
SLAM	simultaneous localization and mapping
SLI	shipper's letter of instruction
SLSC	shipper's load, stow and count
SMC	slow-moving goods centre

SME	small and medium-sized enterprise
SOHS	State of the Humanitarian System (report by ALNAP)
SOLAS	Safety of Life at Sea (regulations)
SOP	1) sales order processing; 2) standard operating procedure
SOW	scope or statement of work
SRFI	strategic rail freight interchange
SRM	supplier relationship management
SSAP 21	Statement of Standard Accounting Practice 21
SSGC	ship-to-shore gantry crane
STC	said to contain
STGO	special types general order
SWL	safe working load
SWOT	strengths, weaknesses, opportunities and threats
tare weight	unladen or empty weight
TEN-T	Trans-European Transport Network
TEU	20-foot equivalent unit
THC	terminal handling charge
TIR	Transports Internationaux Routiers (International Road Transport Convention)
TKM	tonne kilometres
TL	truck load
TLC	total logistics concept
TM	tonne miles
TMS	transport management system
TOC	train operating company
TQM	total quality management
TUPE	Transfer of Undertakings (Protection of Employment)
UAE	United Arab Emirates
UFC	urban fulfilment centre
UK	United Kingdom
ULCC	ultra large crude carrier
ULD	unit load device
ULDR	Unit Load Device Regulations (IATA)
UN	United Nations
UN/EDIFACT	United Nations/Electronic Data Interchange for Administration, Commerce and Transport
UNHRD	United Nations Humanitarian Response Depots
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UPC	universal product code
USB	universal serial bus (common interface enabler for communication between computer devices)
USMCA	United States–Mexico–Canada Agreement (replaced NAFTA)
UWB	ultra-wide band
VAS	value added services
VAT	value added tax
VGM	verified gross mass (shipping containers)

VIN	vehicle identification number
VLCC	very large crude carrier
VLSFO	very low sulphur fuel oil (marine fuel)
VMI	vendor-managed inventory
VNA	very narrow aisle
WCO	World Customs Organization
WCS	warehouse control system
WEEE	waste electrical and electronic equipment
WES	warehouse execution system
WFD	Waste Framework Directive (EU)
WFGS	Waterborne Freight Grant Scheme
WFP	World Food Programme (UN)
WIP	work-in-progress
W/M	weight or measure (freight pricing)
WMS	warehouse management system
WRI	World Resources Institute
WWF	World Wide Fund for Nature
XML	extensible markup language
YMS	yard management system

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