GWYNNE RICHARDS

ONLINE RESOURCES

WAREHOUSE MANAGEMENT

4TH EDITION

THE DEFINITIVE GUIDE TO IMPROVING EFFICIENCY AND MINIMIZING COSTS IN THE MODERN WAREHOUSE

KoganPage

PRAISE FOR *WAREHOUSE MANAGEMENT*

This book is both an essential textbook for students and a valuable handbook for practitioners. All of the most important warehousing concepts are thoroughly explained, and drawing on his specialist knowledge and experience, Gwynne Richards uses case studies to bring them to life for the reader. Highly recommended reading!
Clare Bottle, Chief Executive, United Kingdom Warehousing Association

Warehouse Management, fourth edition, is an essential 'one-stop shop' for both experienced practitioners and those who want to fully understand the fundamentals of how to manage a business storage facility. This is a technical topic, yet the book is accessible, with industry terms clearly explained and examples of best practice provided. *Warehouse Management* is a must-read for everyone in the supply chain and logistics industries, business students and those who want to understand more about how to operate a warehouse.
Phil Wood, Strategic Programmes Director – Northern Europe, Mondelēz International

This fourth edition of *Warehouse Management* is very welcome and provides great insight into all aspects of the subject. I know from my work with Gwynne Richards at The University of Warwick that his students appreciate the book as a source of reference during their studies. It is an invaluable addition to the bookshelves of students and experienced practitioners alike.
David James, VP of Subsidiary Development and Management, KNAPP AG

The publication of the fourth edition of *Warehouse Management is timely*.
We have learnt a huge amount about supply chain logistics generally, and warehouse operations specifically, during the challenging COVID-19 pandemic period. In this context, Gwynne Richards brings his unique and unrivalled knowledge of the subject to this new edition. It can be read equally profitably by supply chain practitioners and students alike.
Edward Sweeney, Professor of Supply Chain Management, Heriot Watt University

Warehouse management, fourth edition, is a truly comprehensive piece of work. It caters for all aspects of the logistics and supply chain world, from the basic industry terminology to the latest in robotics. My daughter has just started a career in logistics and has found the book to be an invaluable reference.
Gordan Knox, Chief Operating Officer, FitFlop

Fourth Edition

Warehouse Management

The definitive guide to improving efficiency and minimizing costs in the modern warehouse

Gwynne Richards

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Online resources

The above symbol indicates that a video of the equipment or process discussed is available. All the videos can be accessed at **https://vimeo.com/showcase/wm**. The password is W4r3h0us3v1d30s.

Schools and universities that have adopted the book in their curriculum can access PowerPoint slides on the Kogan Page website at **www.koganpage.com/WM4**.

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Introduction

What is a warehouse?

A warehouse should be viewed as a temporary place to store inventory and as a buffer in supply chains.

> It serves as a static unit – in the main – matching product availability to consumer demand and as such has a primary aim which is to facilitate the movement of goods from suppliers to customers, meeting demand in a timely and cost-effective manner. In today's e-commerce world we also need to think about reverse logistics and the handling of returns.
>
> (Adapted from Van den Berg, 2011)

When people are asked to define a warehouse, the word 'storage' is always first on the list. In a perfect supply chain there shouldn't be a need for warehouses as products will be manufactured 'just in time' and shipped directly to the customer.

I certainly prefer the following dynamic definition.

Primarily, a warehouse should be a trans-shipment point where all goods received are despatched as quickly, cost-effectively and efficiently as possible. They are not there to store goods ad infinitum.

Today's warehouses, distribution and fulfilment centres are becoming key to ensuring that customer expectations of on-time, in-full, damage-free deliveries are met.

This has resulted in greater investment in technology and automation with companies building warehouses and fulfilment centres closer to the point of need.

Some might argue that the miniaturization and digitization of products will reduce the need to hold inventory; however, the OECD suggests that global freight volumes are expected to triple between 2018 and 2050, thus necessitating the requirement for warehouses for the foreseeable future.

When I wrote the third edition of this book four years ago, I talked about how technology and automation will play a part in warehouse operations in

the future; however, today we are already experiencing a significant shift towards advanced technology such as vision systems, full automation and robotics.

COVID-19 has also had a significant part to play in the increase in e-commerce sales and a move towards greater use of automation and advanced technology within the warehouse. E-commerce sales volumes that were predicted to become the norm by 2026 are suddenly a reality. Based on the US Census Bureau, there was more e-commerce growth in the first six months of COVID-19 than the previous five years combined.

In the UK this growth caps a standout year in e-commerce, with online retail sales growth for the full year up 36 per cent year on year – the highest annual growth seen since 2007 according to IMRG. This being the case, automation will play a much larger part in the warehouse of the future.

According to Statista, the size of the warehouse automation market worldwide will more than double from $13 billion in 2019 to $27 billion in 2025, and according to ReportLinker (2020) the Global Warehouse Robotics Market is expected to grow from $3.546 billion in 2019 to $7.953 million by the end of 2025 at a compound annual growth rate (CAGR) of 14.4 per cent. Some countries are more advanced than others in terms of introducing automation; however, the growth of e-commerce will certainly concentrate the mind in this area as volumes increase significantly.

The basic processes within warehouses have remained relatively the same over time. We receive goods into the warehouse, we process and pick orders, we replenish, include some value-adding services and then we despatch the product. Advances in warehousing today tend to relate to the increased use of technology and automation, increased speed and accuracy, improved performance measurement and the effective management of resources.

In this fourth edition of the book we have retained the core concept of discussing each warehouse process in turn, together with putting the role of the warehouse into context within the overall supply chain. We also concentrate on the many challenges faced by warehouse managers specifically in the area of e-commerce.

In this edition we have increased the number of case studies from companies who have achieved improvements and cost savings through the introduction of new technology and equipment, leaner processes and environmental initiatives and added more videos. The old adage of ‘a picture paints a thousand words’ is true; however, videos are even more powerful in terms of sharing knowledge

The warehouse continues to play a major role within supply chains and will continue to do so for the foreseeable future, although these warehouses will appear in different guises.

The growth in fulfilment centres for e-commerce, for example, is certainly changing the warehousing landscape. Finished stock needs to be held as close to the point of use or consumption as possible to reduce ever-increasing transportation costs and to meet increasingly demanding customer delivery requirements. This has led to many warehouses transforming into cross-dock and trans-shipment centres, fulfilment centres, sortation and consolidation points, and reverse logistics centres, as well as fulfilling their roles as storage facilities.

Some retailers are also utilizing their stores as fulfilment centres to further enable them to meet exacting delivery lead times. Items can now be despatched from the warehouse, the distribution centre or the fulfilment centre, direct from the supplier or from the store – whichever is the nearest point to the customer. By introducing a 'click and collect' service, they can provide a more flexible service to their customers.

As a result, managers need to have a greater understanding of the various roles that warehouses can fulfil and how these affect the business and the supply chain as a whole. There is also a requirement for greater visibility within the supply chain. The deployment of artificial intelligence (AI) will have a profound effect on supply chains going forward.

No two operations are exactly the same, even within the same company, although the underlying principles remain. This book aims to share these principles and enable managers and students to get a better understanding of how to achieve best-in-class status.

It aims to further update readers on current and potential future advances in warehouse management whilst tackling the issues that are challenging today's managers.

These include the pressure on managers to increase productivity, reduce cost and improve customer service at least cost to the environment whilst ensuring the health and safety of staff employed in the warehouse.

The author and contributors have a number of years' experience in managing and consulting on warehouse operations. This book is written from the perspective of hands-on operators and aims to share past experiences and knowledge gathered over recent years.

Having moved into consultancy, the author is continually updating his knowledge in this rapidly changing sector of logistics. This book also draws

on the knowledge and experience of colleagues and peers and features the results of recent studies and surveys from all over the globe.

Warehouses evolve. Technology has moved on apace and, as a result, opportunities to improve efficiency and effectiveness within the warehouse are constantly being introduced. This, together with increasing demands from customers and internal pressures to reduce costs yet improve service levels, can prove a significant challenge to warehouse and logistics managers everywhere.

The introduction of sophisticated automation, robotics and advanced software systems into warehouse operations can potentially have an effect on logistics operations comparable to the introduction of the wheel millennia ago. These advances in technology are likely to lead to a significant reduction in staff and improved efficiency. This comes at a cost, both monetary and human, however. As a result, suppliers of automation and robotics are looking at ways to make their product offering more attractive, including leasing and short-term rental rather than outright purchase. Companies also need to think about retraining and redeploying staff.

Not all warehouse operations are likely to benefit from such advances or can afford large investments in technology. This book will examine the basic processes required to manage a warehouse effectively. In fact, these processes need to be in place in all warehouses prior to any thoughts of introducing new technology.

Automating a bad process might make it quicker but certainly doesn't make it more efficient. The author recognizes the huge diversity in warehouse operations globally and although the book discusses current concepts and technologies, it concentrates in the main on how all warehouses can become more efficient and effective, irrespective of budget.

Logistics is very much about trade-offs. This book will examine these in detail, as they will affect how warehouse and logistics managers approach their jobs and the decisions they take. Major trade-offs include:

- cost versus service;
- storage capacity versus speed of put-away and retrieval;
- speed versus accuracy;
- lower inventory versus stock availability;
- efficiency versus responsiveness;
- volume purchases versus storage cost and availability; and
- transportation costs versus storage costs.

These trade-offs appear both within the warehouse itself and also between the warehouse operation and other logistics services.

This book has been written in such a way that it will be a useful reference point for staff involved in the day-to-day operations of a warehouse, senior managers, designers and planners, external agencies who require a basic understanding and, finally, those who are considering a career in warehousing and logistics.

Through the use of case studies and examples, the author shares fundamental tools and processes that have been prevalent in the industry over the years and have been instrumental in assisting managers to increase efficiency and reduce costs.

The book concentrates on the areas that challenge today's warehouse and logistics managers. These include:

- improving efficiency and productivity whilst reducing costs;
- improving quality and accuracy;
- the challenge of reduced lead times from customers;
- technological advancements;
- workforce availability and management;
- health and safety; and
- effects on the environment.

Chapters 1 and 2 of the book discuss the roles of the warehouse and the warehouse manager in today's supply chain. Within these chapters we also examine one of the main challenges for warehouse managers – attracting and retaining quality staff.

Chapters 3 to 7 analyse the individual processes within the warehouse, outlining areas where costs can be reduced whilst productivities increase through the use of technology and improved methods.

Chapters 8 to 10 explore in detail equipment utilized within the warehouse, including warehouse management systems, handling and storage equipment.

Chapters 11 and 12 discuss how to resource and calculate the costs of a warehouse.

Chapter 13 looks at performance measurement in detail.

Chapters 14 and 15 provide an insight into areas that currently take up a significant percentage of a manager's time today. These include health and safety and the continuing pressure on companies to reduce the effects of logistics operations on the environment.

The final chapter looks at current advances in warehousing and attempts to predict the future. Areas discussed in previous editions are now becoming commonplace and therefore a new way of thinking is required.

The book has been written by a UK-based author and has contributors from the United Kingdom, Europe and the United States. They have all worked and lectured in many different countries. It is hoped that this book will be read globally and that the information provided will resonate with warehouse operators, students and management teams worldwide. Previous editions have been translated into a number of different languages.

Books such as this are an excellent resource for today's managers; however, they need to be used in conjunction with other easily accessible resources. These include discussions with your peers, staff on the warehouse floor, the suppliers of warehouse equipment and consultants – all of whom have a wealth of experience to share with today's managers. Attending training courses to update your knowledge is also beneficial when things are changing so rapidly.

A large glossary of terms and acronyms can be downloaded for free from the following website: www.howtologistics.com.

There are online resources available for operators, including warehouse audits, space calculations and lists of useful websites. Many of these can be accessed free of charge.

Where you see the following symbol ▶ followed by a number, you will be able to access a video of the equipment or process discussed by linking to this url: https://vimeo.com/showcase/wm. The password is W4r3h0us3v1d30s. Note that the websites of all the video contributors are listed at the back of the book. More videos and case studies can be accessed from these sites.

PowerPoint slides can be accessed from the following Kogan Page url to aid schools and universities who have adopted the book in their curriculum: www.koganpage.com/WM4

Two sister publications, *The Logistics and Supply Chain Toolkit* and *The Logistics Outsourcing Handbook* are also available from Kogan Page.

01
The role of the warehouse

Introduction

Warehouses have, in the past, been constantly referred to as cost centres and rarely adding value. The movement of production to lower-cost countries, a significant growth in e-commerce and increasing demands from consumers has seen a step change in warehouse operations. Warehouses are now seen as a vital link within today's supply chains. In fact, as stated in a recent survey by Motorola:

> Warehouses are no longer necessary evils that are fundamentally cost centers. Warehouses today can drive competitive differentiation and, by doing so, increase profitable growth.

The way consumers shop today, their behaviour and expectations, are having a significant effect on how retailers are engaging with their customers. Retailers and manufacturers have to become more innovative within their supply chains and therefore pressure remains on managers to increase productivity and accuracy, and reduce cost and inventory whilst improving customer service in the face of significantly reduced order lead times. The role of the warehouse in a supply chain has never been more visible to the general public with the onset of COVID-19 bringing the logistics industry into even sharper view, and is now being touted as a driver of future economic recovery.

As an introduction to the main aspects of the book, we set the context by examining the role of the warehouse in today's society and its likely place within future supply chains.

We will also look at the factors involved in choosing a suitable location for a warehouse and how many warehouses might be required.

We have also included four examples of specialist warehousing and expanded on these. We believe that the same underlying principles apply whatever type of warehouse you operate. The role of a supply chain, and therefore a warehouse within that chain, is to deliver the right products, in the correct quantity, to the right customer, at the right place, at the right time, in the right condition, at the right price – the seven rights of customer service. We can also include an eighth 'right' today, that being 'at the right cost environmentally'. The warehouse plays a significant role in this. Delivering the right product in the right quantity relies on the warehouse picking and despatching products accurately. Delivering to the right customer at the right place, on time, requires the product to be labelled correctly and loaded onto the correct vehicle with sufficient time to meet the delivery deadline. The warehouse also has to ensure the product leaves the warehouse clean and damage free. In order to deliver at the right price we require a cost-efficient operation that provides value for money.

Finally, the warehouse has to play its part in ensuring that the supply chain is operated in an environmentally friendly way through the use of alternative energies, improved efficiency, waste management and committed staff.

The warehouse is therefore crucial in delivering the perfect order – that is, On Time, In Full, Damage Free and with the Correct Paperwork. In the past, warehouses were seen mainly as stockholding points, attempting to match supply to demand and acting as a buffer between raw material and component suppliers and manufacturers and between the manufacturers and the wholesalers, distributors and retailers and/or consumers. Stock visibility along the supply chain was limited and information flow was very slow, resulting in companies holding more stock than necessary.

Warehouses also fulfilled a major role in storing raw materials. As land and buildings were relatively cheap, the cost of holding significant quantities of raw materials and finished stock was seen as the norm and totally acceptable.

Production runs in those days were very long as it was an expensive process to change machinery, models, colours, styles, etc. The economy was also seen as supply-driven with manufacturers producing products in the hope and expectation that retailers would stock them and consumers would buy them.

As a result, there was a large proliferation of warehouses, not all of which were fit for purpose and stockholding increased appreciably.

In today's market with expensive land, buildings, labour and energy costs, together with the introduction of concepts such as just-in-time (JIT), efficient consumer response (ECR) and quick response (QR), companies are continually looking to minimize the amount of stock held and speed up throughput. The use of tools such as postponement – where products are finalized in the warehouse, not at the manufacturing location – are becoming commonplace.

We have gone from a 'push' to a 'pull' supply chain over recent years. In fact, the phrase 'supply chain' can be a bit of a misnomer; rather, it should be called a demand chain, with consumers holding sway.

In the past, manufacturers produced goods and passed them onto the retailers, expecting them to sell as many of their products as possible. The manufacturers operated a large number of local warehouses and delivered product direct to store.

This situation changed in the 1980s when retailers took significant control of their supply chains and began to build national and regional distribution centres. This changed the face of warehousing with a move towards larger, multi-temperature sites owned by the retailers and in many situations operated by third-party logistics companies.

These sites continue to grow, with Tesco building a 1.2 million square foot warehouse at Teesport in the United Kingdom and Target in the United States operating a 3.4 million square foot import warehouse and distribution centre in Rialto, California. Amazon has built a 2 million square foot warehouse at Tilbury, near London. The location of these warehouses is also part of a movement towards port-centric logistics.

Budget supermarket retailer Lidl is operating a warehouse at London Gateway, the United Kingdom's newest port complex. The siting of warehouses close to ports is not confined to seaports; we are also seeing a growth in logistics centres in and around airports.

CASE STUDY Tradeport Hong Kong

Background

Established in 2001, Tradeport Hong Kong is the only regional distribution centre located at Hong Kong International Airport (HKIA), which is the world's busiest

cargo airport. Serving 100+ airlines collectively flying direct to over 190 destinations worldwide, including 40 cities in Mainland China, HKIA handled over 4.5 million tons of air freight during 2016.

The Tradeport operation is a premium-grade logistics centre comprising 300,000 square feet of space from where they provide customers with logistics solutions, including vendor-managed inventory, kitting, pick-and-pack services.

With its unique on-airport location and highly secure TAPA (Class A)-certified facility, Tradeport provides logistics services for products that are time-critical, fast-moving and valuable – for example, electronics, luxury items and industrial parts.

Strategically located at the heart of the Pearl River Delta region of southern China, Tradeport's hinterland embraces a population of 100 million people, increasingly inter-connected by high-speed rail, road and bridge infrastructure networks.

The challenge

Tradeport's initial discussions (back in 2004) with Eurocopter Asia (now Airbus Helicopters Asia) identified a need to provide a storage-and-service solution for critical spare parts and emergency handling service for over 1,500 helicopters operating in the Asia Pacific region. The spare parts portfolio consists of 16,000 stock-keeping units (SKUs) with inventory replenished on a weekly basis via consolidated air freight shipments from France and Germany. The geographic territory to be serviced from the Hong Kong hub includes 30 countries reaching from North Asia down to Australasia and across the Pacific Ocean.

According to Even Lam, Tradeport's chief operating officer:

> *The demands were very challenging, including extremely high requirements for speed of response and service levels. The emergency response element for Aircraft on Ground (AOG) scenarios requires parts being picked and packed, ready for despatch on the next flight out, within a maximum of just two hours from the phone call requesting support; with the service available around-the-clock, 24/7/365, including on public holidays.*

The solution

Tradeport worked with the customer on developing solutions for the challenging service requirements. It was clear that taking a proactive, collaborative approach to tackling the issues would be critical to achieving a successful outcome.

Due to the 24/7/365 service requirements, Tradeport management engaged closely with all key members of the front-line operations team throughout the solution development process, in order to finalize a solution that would work for all stakeholders in the project.

Successful employee engagement resulted in a creative solution for staff involved in the call-out roster, including targeted changes to remuneration and company provision of mobile equipment, together with training from the customer.

The benefits

During the past decade, the scope of the programme has developed and grown in line with the customer's business needs. The Tradeport spare parts operation is now internationally recognized as providing some of the best service levels across the entire network of Airbus Helicopters.

Tradeport's chief executive officer, Kenneth Bell, adds:

> *Engaging the key stakeholders from the outset – including our staff, who ultimately have to deliver on these high service standards, day-in and day-out – was a fundamental step in empowering the whole team with the confidence to make it happen.*

The trend towards outsourcing Western production eastwards has resulted in companies having to hold higher levels of finished goods stock than previously. This is to cover the extended lead time between production and final delivery.

Containers from Shanghai to the United Kingdom, for example, can take upwards of 31 days, not including clearance at the port of entry.

VIDEO 1i Samsung television supply chain

Video 1i shows a Samsung television being moved between a UK port and a customer. Note the role of warehouses in this operation including at the store.

The United Kingdom's exit from the European Union together with the impact of COVID-19 on international trade, a blockage at the Suez Canal and turmoil in many countries potentially point towards bringing production closer to the point of consumption.

It will be interesting to see whether the Biden administration will continue with an 'America First' policy, persuading US companies to transfer production

back to the United States. All of this could well have an impact in the future as we see unparalleled uncertainty within today's supply chains.

What we are also seeing is the evolution of warehousing as shown in Figure 1.1.

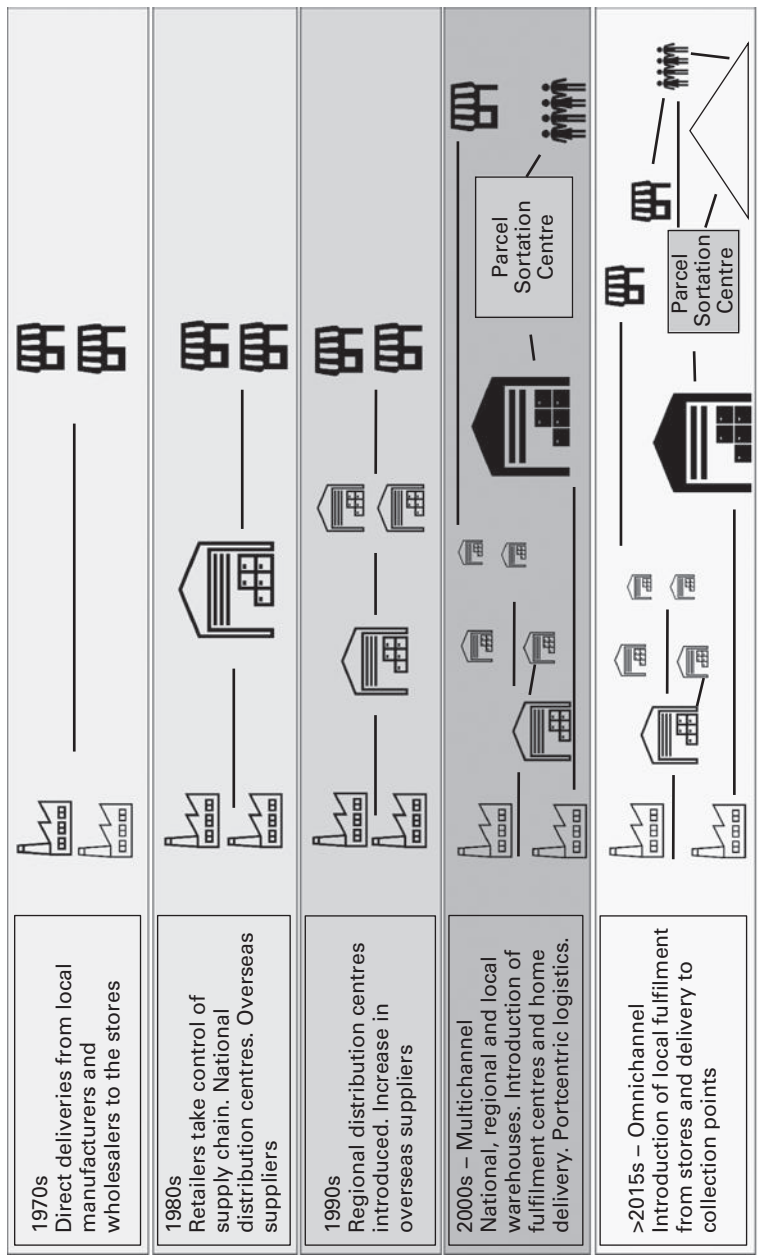


Figure 1.1 Evolution of warehousing

SOURCE Adapted from JLL.com

Types of warehouse operation

There are many different roles for a warehouse in today's supply chain. As can be seen in Figure 1.2, warehouses can be operated by raw materials suppliers, component and finished goods manufacturers, wholesalers, retailers and companies involved in reverse logistics. The warehouses can be owner operated or subcontracted to logistics service providers.

These warehouses fulfil the following roles.

Raw materials storage

These warehouses store raw materials and components either close to the point of extraction or close to the manufacturing point. Raw materials must be held in order to ensure continuous production. These materials include plastics, precious metals, sand, aggregates, cocoa and other food ingredients, etc. Food products may also be purchased in advance to guarantee supply in the event of poor weather conditions and possible conflict.

Storage facilities can include buildings, tanks, hoppers and open spaces.

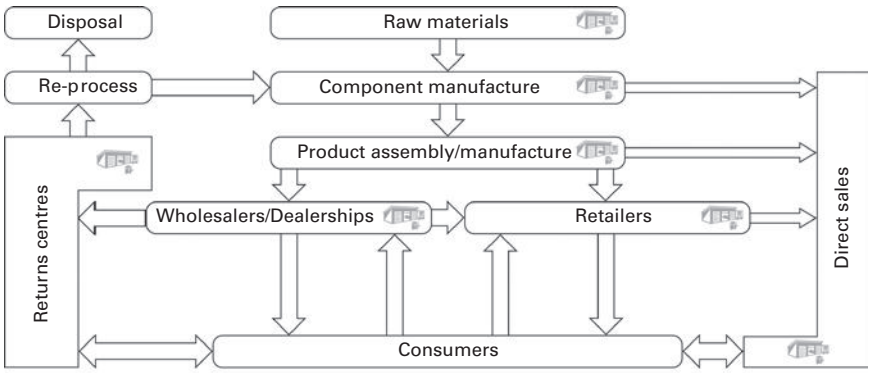
Intermediate, postponement, customization or sub-assembly facilities

These warehouses are used to store products temporarily at different stages in production. These centres are also used to customize products before final delivery to the customer.

Postponement and sub-assembly activities can include the following:

- specific packaging or labelling being changed or added, eg for store-ready items or printing in different languages;
- computer assembly to include different graphics cards, memory chips, software, etc;
- product bundling for promotional activity;
- country-specific items being added such as electrical plugs; and
- special messages being added, eg stencilling of greetings messages on mobile phones.

Figure 1.2 Warehouses in the supply chain



Finished goods storage

These warehouses store products ready for sale, on behalf of manufacturers, wholesalers and retailers. They provide a buffer or safety stock for companies, enabling them to build up stock in preparation for new product launches, expected increases in demand and to deal with seasonality.

Consolidation centres, sequencing centres and transit warehouses

Consolidation centres receive products from different sources and amalgamate them for onward delivery to the customer or onto a production line. This can include JIT centres where automotive parts are delivered to a warehouse where they are brought together and sequenced for delivery onto the production line.

They can also be retail stock consolidation warehouses where products from different suppliers are consolidated for onward delivery to the stores. Rather than deliver part-loads to the National (NDC) or Retail Distribution Centres (RDC), manufacturers deliver to these consolidation facilities where their stock is amalgamated with other suppliers for onward delivery to the NDC or RDC. These differ from cross-dock centres in that product can remain in the centre for a period of time awaiting call-off from the final destination. Many of these consolidation centres are operated by third parties.

Trans-shipment or break-bulk centres

Trans-shipment centres receive products in large quantities from suppliers and break them down into manageable quantities for onward delivery to various locations.

Cross-dock centres

Cross-dock centres are seen as being the future for warehousing alongside fulfilment centres. ECR and QR within retail require operations to be able to move goods quickly through the supply chain.

According to Datex Corporation there are four main scenarios where cross docking is used most frequently:

1. When the demand for any given inventory item is stable and shows strong consistency. These items can be placed on a reoccurring fulfilment schedule using cross docking. This eliminates the need for surplus inventory to be stored in case of out-of-stock situations.
2. When handling time-sensitive and perishable inventory. Due to the reduced shelf life, inventory needs to reach retailers with a reasonable remaining shelf life. By foregoing storage and utilizing cross docking, delivery time is reduced. This provides the goods with a longer sales window.
3. Because customers cannot expect a specific inventory item to be in stock, cross docking can be utilized to quickly deliver bulk shipments of varying inventory on a reoccurring schedule. In this case, out-of-stock scenarios are not a concern and storing surplus inventory is not necessary.
4. When fulfilling orders for which customers are willing to wait. With items such as appliances and furniture, customers typically expect to wait a short time for delivery. Rather than storing these large items in-store or at a distribution centre, retailers can efficiently fulfil orders from a single facility using cross docking to help reduce the delivery period.

Cross docking requires deliveries into these centres to be already labelled and ready for onward delivery. Here the items are identified and consolidated with other deliveries, ready for despatch. Items should remain in the warehouse for as short a time as possible. Same-day receipt and despatch is the target.

Although companies are beginning to realize the efficiency of cross docking, there are a number of barriers to a successful introduction. These can include warehouse management systems support, quality control systems, reliability and cooperation of suppliers and carriers, warehouse design and uncertain demand. Cross-dock warehouses or trans-shipment centres are also utilized in outlying geographic areas to transfer products onto local, radial distribution vehicles. This trans-shipment process can take place either inside or outside the warehouse. Swap bodies or demountable bodies can also be used together with stand or drop trailer systems. Typical cross-dock products are perishable items such as fruit and vegetables, flowers, meat and fish, which need to be moved quickly through the supply chain. Statistics suggest that WalMart uses cross docking for around 85 per cent of its goods, whilst the number is about 50 per cent for its rival Kmart.

Sortation centres

Sortation centres are used in the main by letter, parcel and pallet distribution companies. Goods are collected from all parts of the country, delivered into hubs or sortation centres, sorted by zip or post code, consolidated and delivered overnight to their respective distribution areas for onward delivery. These operations are increasing and the hubs are getting bigger in order to cope with the growth in e-commerce.

Today's retailers are also moving towards automated sortation centres with pallets being de-layered on entry, the use of mini-load systems for temporary storage and retrieval and finally automated pallet build on exit.

Figure 1.3 shows a Hermes parcel sortation centre.

Fulfilment centres

The growth of e-retailing has seen an increase in the number of customer fulfilment centres. These warehouses have been designed and equipped specifically to manage large volumes of small orders. Videos 1ii and 1iii show the fulfilment operation of an internet retailer called i-herb.com and how it has moved from a person-to-goods system to that of a goods-to-person system.

Figure 1.3 Parcel sortation hub

SOURCE Courtesy of Hermes

VIDEO 1ii iHerb.com person-to-goods system

VIDEO 1iii Video case study of Perfect Pick – iHerb.com

These centres can also double up as returns processing centres, as e-commerce has a larger percentage of returns than bricks and mortar retail activities.

Reverse logistics centres

The growth of e-retailing and specific environmental legislation such as the European Union's Waste Electrical and Electronic Equipment (WEEE) Directive (2007) has compelled companies to focus time and energy on reverse logistics. Today, companies recognize that returning product to stock or disposing of it quickly can positively affect cash flow.

As a result, a number of warehouses have been set up specifically to deal with returned items. Third-party contractors are providing a service to retailers where customers return unwanted or defective items to the stores; the items are then consolidated and sent to the returns centre, where they are checked and repackaged, repaired, recycled or disposed of.

Waste legislation has also resulted in large quantities of returned packaging having to be disposed of in an environmentally friendly manner. This includes sortation by type and use as fuel or recycled material. There are case studies in the environmental section that go into more detail on this subject.

Other reverse logistics processes include the return of reusable transit packaging equipment such as roll cages, barrels, kegs, pallets, tote boxes and trays. When used in the food industry added services include washing and sanitizing the items before they re-enter the supply chain.

For example, XPO Logistics, a 3PL, service and maintain more than a million roll cages, as well as 230 million trays, flower buckets and dollies for Tesco. Recent and planned initiatives include the development and implementation of a live data capture system and the trial of a segregation system to improve the quality and value of plastic waste.

Public sector warehousing

Outside the commercial world there are also warehouse operations that support the public sector, armed forces and the third sector.

The increasing number of natural disasters such as earthquakes, droughts and tsunamis is resulting in third-sector organizations opening up warehouses in strategic locations across the globe. This ensures that they are closer to the disaster areas and thus able to react quicker.

Other public sector warehouses will store supplies for local government facilities such as schools and offices. Products will include stationery, uniforms, furniture, computer hardware and software, etc.

All the warehouse operations mentioned above can either be owned or leased by the principal or owned, leased or operated by third-party companies on behalf of a principal.

Warehouses operated by third-party logistics providers are either dedicated operations on behalf of a single customer or can be shared-user or public warehouses where a number of different customers share resources and are accommodated under one roof.

These include:

- companies with different products but with common customers such as retailers or automotive manufacturers;
- companies with the same or similar products delivering to common customers, eg tyre manufacturers, bicycle manufacturers, pharmaceutical companies and consumer goods companies;

- companies needing similar types of service, eg fulfilment or returns processing; and
- companies requiring the same environmental conditions, eg hazardous goods, explosives or temperature controlled.

Users of shared-user warehouses are, in the main, companies looking for economies of scale through sharing facilities, equipment and labour costs. They can also be start-up operations where the scale of business doesn't warrant a dedicated facility initially.

Why do we hold stock?

A supply chain with the minimum amount of stock within its pipeline is utopia. Unfortunately, this happens very rarely. Our society and our markets are not predictable and therefore we need to hold stock at various stages within the supply chain. Increased consumer demand for greater choice has resulted in a proliferation of product ranges and sizes leading to unprecedented demands on storage capacity.

Reasons for holding stock are as follows.

Uncertain and erratic demand patterns

Suppliers of ice cream, suntan lotion, umbrellas and the like will potentially experience erratic demand patterns based on the changeability of the weather. Other unpredictable sales can revolve around the launch of a new product and the progress of a team in a major competition such as football's World Cup or baseball's World Series events.

Trade-off between transport and shipping costs, justifying larger shipments

The ability to move product in large quantities tends to attract lower costs per unit. The trade-off here is between the cost of storing additional units compared with the higher cost of transport for smaller, groupage-type deliveries. If the transport cost is very attractive, then additional storage space will be required. There also has to be a strong conviction that all the items purchased will be sold.

Discounts via bulk buying

The possibility of reducing the unit rate through buying in greater quantities is always an attractive proposition for buyers. This can, however, have a negative effect overall if the company fails to sell all of the additional units purchased or has to sell at a loss to clear the warehouse. In this situation it is our contention that the whole-life cost of the item is calculated before the decision is made to purchase additional quantities. These costs will include additional storage and handling costs, obsolescence, damage, working capital interest, possible discounted sales and disposal costs. A trade-off exists between lower unit purchase costs and increased storage costs per unit. I'm sure there are many warehouses out there holding obsolete stock due to the overenthusiasm of procurement and sales staff!

CASE STUDY

A recent example was a company that had the licence to utilize the images from a well-known film franchise on its packaging. They had an issue with a lack of space within the warehouse, yet they were still holding packaging relating to episode one of the film franchise whilst episode four had just come out in the cinema. This packaging, which had been over-ordered due to a significant discount, was completely obsolete, although it could be sold to a recycling company, thus freeing up space and recovering at least some of the cost. Companies will always end up with surplus stock if they have forecasted incorrectly – it is how quickly this is resolved that makes the difference between an efficient operation and one with insufficient space.

Fluctuation in the price of raw materials and finished goods

Certain products fluctuate in price significantly and can also be affected by weather conditions. Companies might therefore buy significant quantities when the price is advantageous or when weather conditions dictate. This will necessitate additional storage capacity.

Distance between manufacturer and the end consumer

As mentioned earlier, the distance finished stock has to travel today requires a greater amount of stock to be held in the local warehouse. Lead times can be anything between four and eight weeks depending on the manufacturer's location. The trade-off here is between more expensive local suppliers and producers and increased costs in transport and inventory holding costs. COVID-19 saw a significant increase in container shipping costs from the Far East due to delays at ports, a shortage of containers and a reduction in services.

Cover for production shutdowns

Many manufacturing companies and sectors continue to shut down their operations for vacations, machine maintenance and stock counts. As a result, retailers and wholesalers need to build up stock prior to the shutdown period to ensure stock availability for their customers. Manufacturers will also build up a stock of components to ensure that their production lines are not brought to a standstill as a result of supplier shutdowns.

Ability to increase production runs

Changing or adjusting production lines in order to accommodate changes in models, colour, design features, etc is expensive. The longer the production run is, the lower the cost per unit to produce. However, the trade-off here is between the lower cost per unit versus the additional cost per unit for storage.

To manage seasonal production

Certain food and drink products are produced at specific times of the year and therefore need to be stored until required.

High seasonality

Seasonality can be a period of time such as summer and winter or a specific date in the calendar such as Easter, Valentine's Day, Independence Day, Singles' Day, Eid, or Chinese New Year. Figure 1.4 shows the stock build-up for a chocolate manufacturer in the run-up to Easter. As can be seen, pallet storage ranges from 500 pallets to a staggering 10,000 pallets at peak.

Figure 1.4 Seasonality: chocolate

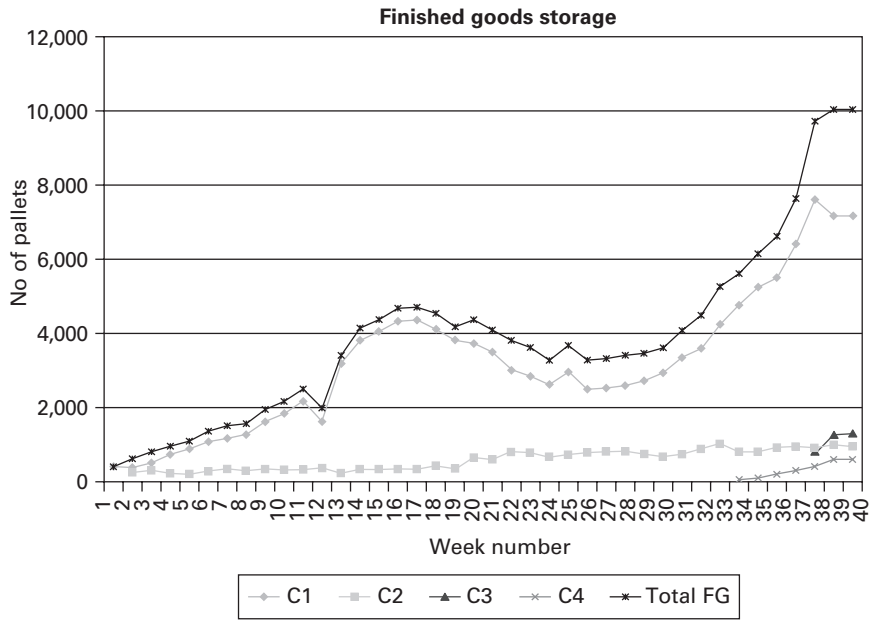
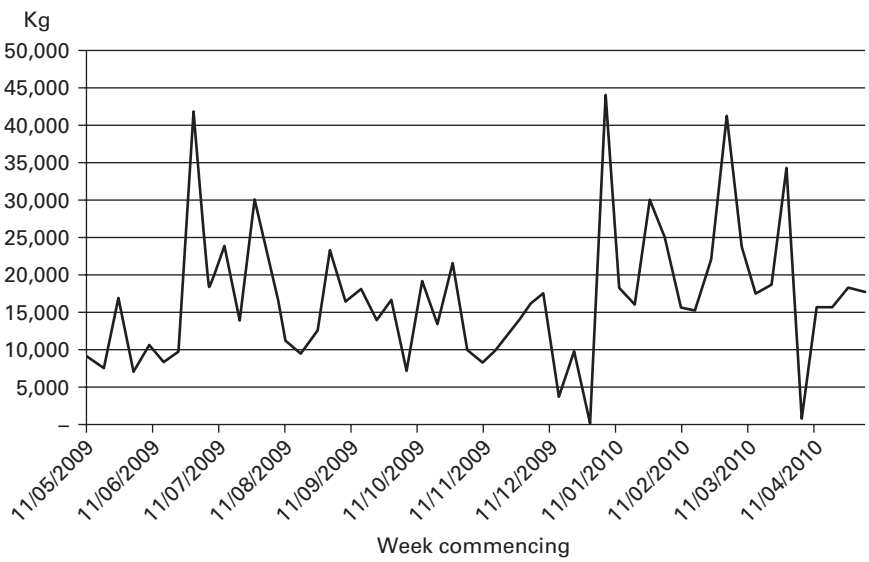


Figure 1.5 Seasonality: apparel and equipment



Large sporting events can also have an impact on the requirement for additional storage. This includes the World Cup, the Olympics, Super Bowl final and World Series baseball, etc. Figure 1.5 shows the activity of a clothing manufacturer leading up to the two distinct seasons of summer and winter collections.

Spare parts storage or maintenance stores

To ensure an uninterrupted production line operation, manufacturers need to hold stock of spare parts just in case an item becomes defective. This can be expensive but the trade-off here is between the cost of the part together with its holding cost and the potential breakdown of the production line and the consequences that brings with it. This doesn't mean, however, that these items should not be reviewed regularly and decisions taken as to whether to stock them or not. The decision to stock the parts and in what quantities may well be managed by the supplier under a vendor-managed inventory (VMI) agreement. The supplier will decide on the type and quantity of parts to be stored based on historical usage information across a number of companies. Things to take into account include supplier lead time and machine failure rate. The advent of 3D printing could have a significant effect on this sector in the future.

In the meantime there remains a requirement for the storage of spare parts and therefore companies are looking at technology to reduce the cost of these types of operation where products are stored just in case rather than just in time.

An interesting example is the following case study where a company has used 5S techniques to find waste within their operation. Having done so they then needed to find a solution.

CASE STUDY ApexSupplyChain.com/Actylus (courtesy of Apex Supply Chain Technologies, Inc)

Munters: A global OEM's approach to process savings

Problem: Munters' old bin system required manual scanning and cost hours of labour each day. Solution: WESCO implemented the ACTYLUS™ Smart Bin System to eliminate manual scanning and stock-outs and recover valuable floor space.

Result: Munters recaptured 700+ employee hours/year and saved nearly $44,000 in labour costs.

Today's lean-focused OEMs are always on the lookout for ways to eliminate waste and optimize productivity. Many use the 5S method of workplace organization with its mantra, 'A place for everything, and everything in its place.'

For Munters, a global manufacturer of air treatment and climate control solutions, this focus on lean and 5S is a daily practice. Its Amesbury, Massachusetts, plant manufactures massive air treatment units for some of the world's largest and most demanding customers. Meeting their deadlines can have significant financial implications, so it's crucial that supplies for each project are always in the right place, at the right time.

Finding a better bin system

One process that Munters wanted to improve through the 5S method was how the company managed its OEM electrical inventory. Production workers were required to scan low bins on a daily basis, which meant they had to walk to a cabinet, pick up a scanner, walk back to their station, scan the bin's barcode, then make another round trip to return the scanner. At that point, a supervisor would have to enter those orders into the ERP system. This cost the company roughly 3½ hours of lost labour each day – that's 728 hours a year.

This process often led to over-ordering, since production workers were more focused on preventing costly stock-outs, not inventory carrying costs. This resulted in a significant amount of safety/reserve stock, excessive inventory costs and the need for extra storage space.

WESCO's Supply Chain Solutions team had recently learned about the ACTYLUS™ Smart Bin System from Apex (as seen in Figure 1.6).

These cloud-based devices constantly monitor bin levels and send replenishment orders directly to WESCO's ERP system. Kevin Spearman, Materials Analyst Supervisor, Global Operations, decided to give them a try and track his results. A short time later, WESCO had implemented 10 ACTYLUS units to automate supply replenishment orders for Munters' production lines and panel assembly area.

Immediately, Spearman began seeing the results. The first obvious win was a reduction in wasted steps by the staff. Since the units are located near the point of use, employees can now pick up supplies in seconds. ACTYLUS eliminates barcode scanning and all those wasted steps, providing even more productivity gains.

Figure 1.6 Apex Corporation's ACTYLUS™ Smart Bin System

In total, Munters employees will save more than 101,000 steps a year – that's 700 employee hours that can be channelled back into production. And since supervisors no longer manually enter orders into the ERP, they can now turn their focus to more productive tasks.

In all, Munters gained 108 square feet of productive floor space by reducing reserve stock. With real-time visibility into supply levels, WESCO can now help Munters achieve the lean cost savings and efficiency it needs to compete in the global marketplace. WESCO has also been able to reduce delivery runs from five days a week to four – a 20 per cent saving in the account's operational costs.

According to Spearman: 'ACTYLUS wasn't just a great fit for our 5S programme, we also saw ROI in 2½ months.'

A further enhancement with these bins is the use of infra-red beams to record whether the correct number of items have been extracted from the bins. Utilizing pick to light the infra-red system removes the requirement of turning the light off as this is done automatically as the picker's hand is removed.

Work-in-progress storage

Many companies will part-build products in anticipation of orders. The chocolate manufacturer mentioned above produces the two halves of the Easter egg prior to receiving any firm orders. This enables them to complete the process at a later date, once they know the type of packaging, style and insertions required.

Investment stocks

A number of products can increase in value the longer they are held in storage. These include fine wines and spirits, cigars, precious metals and stones, antiques and fine art.

Document storage

Both public bodies and private companies have an obligation to store documents over a period of time. These can include correspondence, invoices, accounts, contracts, etc. This can be a legal requirement. Other examples include evidence storage and patient records by the emergency services.

Maturation and ripening

Some products require longer-term storage in order to improve the quality or the maturity of the product. Examples include certain meats and cheeses.

Consignment stock

There are examples where manufacturers will utilize their customers' warehouses to store their goods. This is called consignment stock where the customer only pays for the stock once it has been used or consumed. This takes pressure off the supplier to hold more stock and ensure delivery on time whilst the customer has available stock within the warehouse but has yet to pay for it, thus increasing flexibility and improving cash flow.

Where customers are quite a distance away from the supplier this can reduce transportation costs significantly.

Warehouse location

With logistics operations becoming increasingly globalized a key factor in locating operations is the total cost of operating in any given market. Traditionally, it tended to be rent, local taxes and service charge costs that were taken into account; however, these factors can often mask other key factors such as the cost of labour employed in the warehouse, the cost of electricity and the cost of fuel for vehicles.

New data from Savills World Research as referenced in Figure 1.7 below demonstrate the effect of these non-property costs on the total operational cost. The data analyses warehouse costs in 54 markets across 21 countries.

Warehousing property costs are highest in the largest world cities where big populations and constrained land supply meet high demand from consumers and businesses. Four markets stand out above the rest: London, Tokyo, Hong Kong and Singapore. All have total costs well above $20 per square foot. A full list of land and tax costs can be found in Appendix I.

In Figure 1.7 we have combined property and tax costs with labour and energy to show total warehousing operational costs, having given a higher weighting to labour costs as the primary cost component for occupiers.

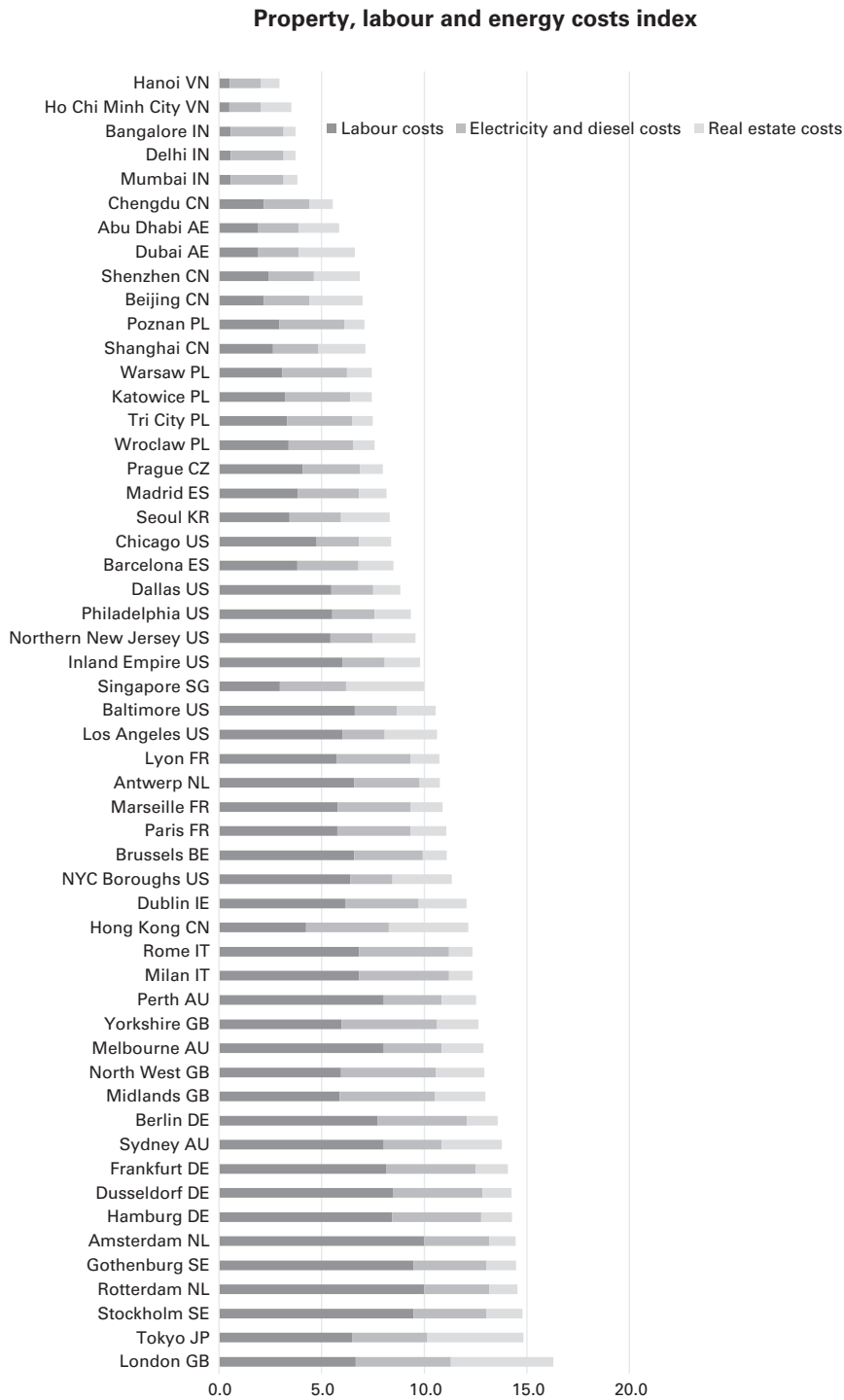
Low costs make Vietnam highly attractive to multinationals setting up operations in the country. India, where low warehousing property costs are offset by higher fuel costs, is the second cheapest location in the sample.

In the UAE, higher property costs (most notably in Dubai) are offset by very low energy costs, making it one of the cheapest locations for warehousing operations globally. The UAE has seen stable warehouse occupancy and rents, with take-up led by e-commerce companies.

Turning to Europe, labour costs are the key differentiating factor between Central and Eastern and Western Europe. Low labour costs in Poland mean total warehousing costs are comparable to those of China. In Western Europe, high labour costs in Sweden, the Netherlands and Germany, mean cities from these countries account for 7 of the top 10 most expensive locations by total cost.

Locating a warehouse strategically and in the most cost-effective geographic location is one of the most important decisions a company will make. For example, in terms of fulfilment centres, because of the nature of deliveries, an important criteria is the need to be located near to the motorway/highway network and to the parcel hubs to delay the latest collection

Figure 1.7 Property, labour and land cost index (courtesy of Savills)



time from the parcel companies and therefore enable companies to introduce a later order cut-off time for next-day delivery.

For example, Shop Direct – the UK's second largest pureplay e-tailer – has its fulfilment centre on the same site as Yodel's parcel distribution hub.

Grocery retailers with online sales will have a requirement to be much closer to their customers due to the different temperature regimes of the products being delivered. As a result we are seeing some retailers bringing their e-com order fulfilment back in store.

The selection of a warehouse location requires multiple criteria to be assessed, including both quantitative and qualitative data.

Many companies will look at the location and size of customers, which, although relevant, is not as important as it would be when locating a retail outlet. According to a European survey carried out in 2016 by Prologis and EFT, the key factors shaping location choice included proximity to economic centres, transport and land costs, and the presence of modern and efficient infrastructure. Positioning to serve global trade routes is also important as is access to highly skilled staff.

Favoured locations include those within the Benelux countries and in Central and Eastern Europe (CEE). Many of these locations are oriented along international and global trade flows and are near Europe's major consumer markets. Other factors include transportation costs, land cost, skilled labour availability, travel minimization and overall cost of operation. The environment will also play a part in the decision-making process. The following are specific factors that need to be taken into account when deciding on a warehouse location:

- cost of land, rent and rates;
- access to transport networks;
- proximity to multimodal hubs;
- availability of affordable, skilled labour;
- languages spoken;
- transport links for staff;
- availability of funding, grants, etc;
- availability of existing buildings;
- availability and cost of utilities including telecoms;
- availability of finance and resources;
- goods traffic flows;

- proximity to ports and airports;
- location of suppliers and manufacturing points; and
- the potential neighbours (eg proximity to oil storage depots can be a negative factor, as ASOS found out to their cost during the Buncefield oil disaster).

This criteria has ensured that, in general, the prime locations for warehouse deployment have not changed dramatically for decades. However, the rise of online retail has turned this model on its head.

In a Savills survey of the UK, the top nine requirements for e-retailing operations in terms of location were as follows:

- land/rent/lease costs;
- access to affordable labour;
- expansion space available;
- close proximity to parcel hub;
- close to motorway network;
- central location (covering all the United Kingdom);
- close proximity to consumers;
- government incentive; and
- close proximity to higher skilled labour.

Today, goods ordered online can be delivered directly to customers, same day, whether to their home or office (or increasingly to other locations such as lockers, click and collect in other retailers' premises and even the boot of your car), with no intermediate stages. Online retailers have relied heavily on the existing post and parcel network; however, some, like Amazon, are introducing their own network of courier deliveries.

CASE STUDY

Amazon coped with a single logistics centre in Bad Hersfeld for seven years before opening a second in Leipzig in 2006. Amazon itself expedited this development with the launch of Amazon Prime in its home country, the USA, in 2005 and Germany in 2007. Users of this service, which include almost half of the 41 million households in Germany according to current estimates, receive their goods the next working day or the same day. To guarantee this service it requires

larger warehouse inventories than previously and distribution centres located closer to the customers and hence in cities and conurbations. According to MWPVL, Amazon now has 73 warehouse units in Germany, including properties in surrounding areas of Berlin, Hamburg and Munich.

Amazon is not alone in requiring more logistics space in other locations in order to fulfil its service promise. The company established a sector standard so successful that it was adopted by other retailers. Consequently, these retailers now also require additional logistics space. In turn, Amazon subsequently went a stage further and introduced its Prime Now service in many major cities, which offers the delivery of a specific assortment of products within a time frame of a few hours. In Germany, this service launched in 2016 in Berlin and Munich and would be unthinkable without urban logistics space for the 'last mile' delivery. These units, which are even smaller than the regional distribution centres, are now the final link in the supply chain. Here, the goods are unloaded from lorries onto delivery vans, freight bicycles or similar and delivered to the address specified by the customer.

Another example of this is in Tel Aviv where a microfulfilment centre has been built in an old underground parking lot. It has been designed with three temperature zones. This underground dark store will store fresh, ambient, chilled and frozen food items and provide a one-hour grocery delivery service within Tel Aviv.

Demirel *et al* (2010) provide a comprehensive list of criteria for location decision-making (see Figure 1.8).

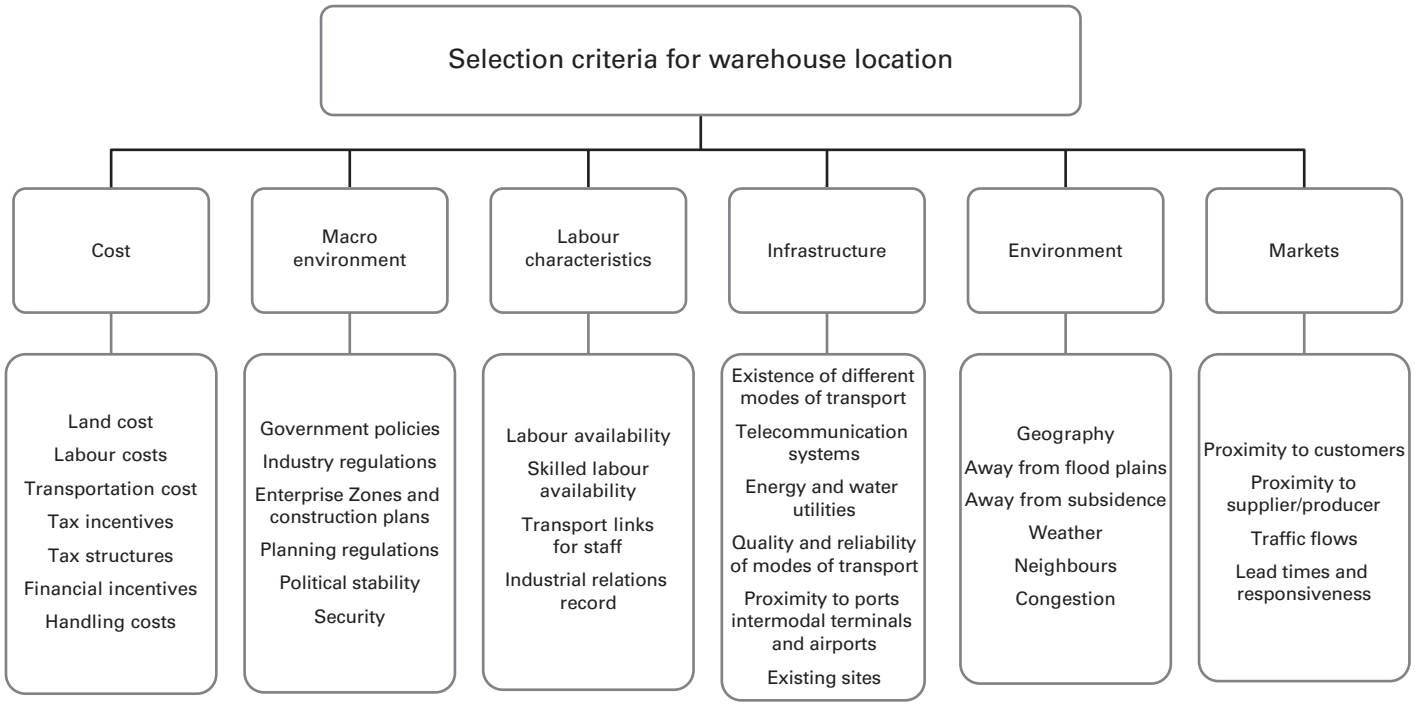
Fortunately, the decision on where to site a warehouse does not have to be totally manual as there are a number of software programs available that will take the majority of these criteria into account and produce a number of viable alternatives.

Many of these systems work on the basis of volume centre of gravity calculations that locate the warehouse at the centre of supply and demand by minimizing distances to customers and from suppliers.

A more accurate method is to utilize the cost centre of gravity calculation, which locates the warehouse at the centre of supply and demand by minimizing transport costs to customers and from suppliers.

Route planning and optimization software will produce a viable location; however, supply chain optimization tools will further enhance this decision.

Figure 1.8 Factors determining the location of a warehouse



SOURCE Adapted and reprinted from *Expert Systems with Applications: Multi-criteria warehouse location selection using Choquet integral*, Tufan Demirel, Nihan Çetin Demirel, Cengiz Kahraman, May 2010, with permission from Elsevier

Using software to determine warehouse location

The aim of facility location studies is to 'optimize' the logistics network. This is a complex mathematical problem because the number of facilities, their size and locations are all inextricably linked, even before considering the impact of factors such as land values. The optimum solution may be driven by cost, by service level or by aspects such as the capital investment available.

There are a variety of different software solutions available, ranging from the simple to the very sophisticated. They differ in aspects such as the number of product types and the different types of supply chain facilities that can be modelled, whether they can examine multiple different scenarios in batch runs, whether they can consider capacity constraints and/or influence supply choice, and finally whether they use the road network or crow-fly distances. The costs of using such software and the time required to set up more detailed models, vary considerably.

Because it is such a complex problem, any steps that can be taken to simplify the process without losing key attributes should be taken. For example, in deciding where to locate a warehouse within a particular country, it may be more appropriate to use landed cost at ports and airports, rather than replicating the international supply chain within the model. Another area to consider is the granularity of demand geography, the flows that are appropriate, and the difference that additional detail is likely to make.

The data required for this type of study includes: demand and supply locations along with measures such as volume, weight, number of deliveries/collections, product types and the different transit units (items, cartons, totes, pallets, sea containers) that are used in different parts of the supply chain; costs for warehouse facilities and the capacity of any existing locations; inventory costs, particularly if the number of locations is going to be reduced or increased; the balance between the costs of trunking and secondary distribution is key; and future volume forecasts for the expected lifetime of the facilities are also required. Other factors to be considered include order lead times, the inclusion of non-stocked locations such as cross docks, along with practical aspects such as land and staff availability.

Most of the different software solutions will be based on 'pipeline' modelling, that is on the average cost over a period, a year or a calculated average day, of transporting X amount of volume over Y one-way distance. It is important to double check input calculations as the resulting figures will probably not be familiar when compared with metrics from the daily operation.

In reviewing the results from any model, it will be appropriate to carry out 'what-if' analysis on assumptions made within the model, particularly sensitivity analysis with respect to external cost inputs such as fuel prices and exchange rates, and to use a vehicle scheduling package to confirm resource requirements. Other risk analysis may include business continuity if moving to a single stocked location.

Number of warehouses

A Prologis analysis from 2016 concluded, after taking all variables into account, that for each additional billion pounds in online retail sales, around 775,000 square feet of additional logistics space is required compared with traditional retail. Given the current sales of approximately EUR 70 billion, this means a logistics space requirement of more than 5 million square metres for Germany alone. However, current developments suggest that the Prologis estimate was too conservative with recent work from CBRE, a global property advisor, suggesting that 1.29 million square feet for every £1bn extra spent online is a more realistic figure given recent take-up levels. It will be interesting to observe how this metric evolves given the impact of COVID-19 on warehouse demand and also the level of online retail around the world.

Overall, this has meant that demand for warehouse space has grown significantly as the rate of online retail around the world has increased too. In Europe demand for warehouse space has increased by 102 per cent since 2012 with 2020 being a record year as new leases were signed on 293 million square feet of new warehouse space of which 25 per cent were in Germany and a further 17 per cent in the UK.

In the UK, where online retail growth has been the highest in Europe and reached 28 per cent of all retailing, the impact on warehouse demand has been most pronounced. Indeed, 2020 saw 50.1 million square feet of new leases signed, a new record, and 33 per cent of those new leases were apportioned to online retailers, also a new record in terms of the number of warehouses and overall costs.

In today's e-commerce world, customers tend to place significant weight on quick and cheap delivery. Delivery from a local fulfilment centre is almost always much quicker than shipping from a central location. As such, operating multiple warehouses can improve the customer experience. We can see from Table 1.1 that most costs are higher if multiple warehouses are

Table 1.1 Comparison between many and fewer warehouses

Criteria	Many warehouses	Fewer warehouses
Inventory costs	Higher	Lower
Customer reaction time	Quicker	Slower
Facility costs	Higher	Lower
Inbound transport cost	Higher	Lower
Outbound transport cost	Lower	Higher
Systems cost	Higher	Lower
Risk	Lower	Higher

chosen; however, all of these costs can be offset by a significant reduction in local transportation costs and improved service. As with most areas of the supply chain, there is a trade-off here.

With multiple warehouses you can draw on a buffer of inventory stock kept in another location if there is an issue with one of the other warehouses. For example, Ocado suffered a major fire at its Andover location in the UK, which destroyed the warehouse. Having another southern fulfilment centre in Erith, Kent, enabled the company to fulfil orders from there whilst they set up a temporary warehouse in Andover.

In terms of inventory, we need to be able to calculate by how much we will increase or reduce our safety stockholding when we change the number of warehouses operated.

One way of doing this is by using the Square Root Rule, which was first introduced by David Maister in 1976. Maister's rule enables companies to quickly calculate the reduction or increase in safety stock required when the number of warehouses is changed.

It states that the total safety stock in a supply chain is proportional to the square root of the number of locations at which a product is stored. The calculation is as follows:

$$\text{Reduction in stockholding (\%)} = [1 - (\sqrt{x} \div \sqrt{y})] \times 100$$

(y = original number of warehouses; x = proposed number of warehouses)

This calculation cannot be used in isolation. Other factors, such as supplier and customer lead times, the product itself (different types of electrical plug, for example), transport costs and distribution centre costs also have to be taken into account.

The rule is based on the assumption that the amount of safety stock in each existing warehouse in the system is approximately the same.

Supply chain trends affecting warehouses

This section examines current trends within today's supply chain and how these are likely to affect warehouse operations.

The e-commerce phenomenon will continue to grow both for business-to-business (B2B) and business-to-consumer (B2C) sectors. From a convenience point of view and under greater environmental pressure, grocery home shopping and delivery will also grow significantly.

This will necessitate more fulfilment centres and returns processing facilities.

Retailers and manufacturers will continue to look for further cost savings as markets become even more competitive. Warehouses will be expected to be more efficient and cost-effective, with the likely closure of inflexible buildings and inefficient operations.

Retailers will continue to take stock out of the supply chain, leading to increases in stockless depots, trans-shipment and consolidation centres and cross-dock operations.

The cost of transport and stock-reduction targets could potentially bring manufacturing closer to the consumer. Eastern Europe has recently become a centre for manufacturing within automotive and electronics and nearshoring is becoming a distinct possibility with US and European companies bringing some production back to their shores.

The increase in port-centric logistics has resulted in companies building large warehouses as close to the ports of entry as possible. As mentioned, Tesco's 1.2 million square foot warehouse at Teesport, UK, is a typical example.

The miniaturization of products such as mobile phones, DVD players and computers, together with the increasing use of electronic media for listening to music and reading books via downloads, is likely to result in less space required for these types of products but greater security.

The sustainability agenda will also play its part within the supply chain. This will result in the development of further brownfield sites, linkages to rail and potentially canal and river networks, and self-sufficiency in terms of energy use.

Future warehouses will be expected to be carbon positive, which will be backed up by legislation in the future. UK retailer John Lewis built a new

distribution centre in the United Kingdom with a view to significantly reducing its carbon footprint. Early results showed savings of 18 per cent in energy costs, 45 per cent in water usage, an overall reduction of 40 per cent in CO_2 emissions and a cost saving of circa £250,000 per annum.

It is expected that new warehouses will be targeted with having their own means of power generation, be it solar or wind, and may also convert waste into power. Greater collaboration within the supply chain, both vertically and horizontally, will lead to greater consolidation and an increase in shared-user operations. This is likely to lead to a reduction in the number of smaller warehouses and the construction of purpose-built centres.

The ability for companies to work closely with each other and trust each other will be a major factor as to how quickly this collaboration takes place. We are already hearing of UK retailers sharing transportation capacity for delivery to stores.

The growth of e-fulfilment and its effect on the warehouse

In 2020 e-commerce sales as a percentage of total retail sales in the US was 21.3 per cent, up 44 per cent on the previous year. In February 2021 e-commerce as a percentage of total UK retail sales reached 36.1 per cent, the highest on record. E-commerce sales are expected to grow from £34 billion in 2021 to £150 billion in 2024.

With regard to warehousing, pure internet traders have had an advantage in developing purpose-built facilities according to a recent TI report whereas existing retailers and manufacturers who are selling online need to adapt existing logistics systems and facilities to meet these new demands or create new ones to accommodate the move to multichannel retailing.

The report suggests that the tipping point for dedicated e-commerce fulfilment centres is approximately 200,000 orders and that warehouses are in the region of 20–60,000 square feet.

There are significant challenges for warehouse managers when operating an e-fulfilment warehouse.

First, these warehouses are significantly impacted by seasonality. The demand on staff and equipment varies tremendously with the seasons: large, bulky items such as barbecues and garden furniture during spring and summer and much smaller electrical products during the run-up to Christmas. These have very different impacts on handling and storage equipment.

Second, the wide range of products stored requires warehouse managers to efficiently process low-value, single-item orders. This is one of the main challenges facing all warehouses today but in particular those dealing with internet orders. Picking and packing low-cost items utilize the same amount of labour and equipment as for high-cost items but the margin is going to be significantly different.

Third, as consumers flex their muscles in the market, accuracy and on-time delivery become paramount if companies are to retain the loyalty of their customers.

Inventory management is another challenge for the warehouse manager. The increase in the number of product lines will put pressure on the number of pick locations whilst slow-moving and obsolete lines can take up much-needed space in the warehouse. From a picking point of view, the proliferation of product lines will result in warehouse managers having to look at alternatives to ground-floor pick locations such as mezzanine floors, flow racking and carousels.

In order to release vital space to the warehouse operation, stock turnover has to be managed well and decisions made quickly regarding the disposal of non-moving stock.

As discussed earlier, one of the main by-products of e-commerce is a large percentage of returns. This can be between 30 and 40 per cent of outward volume. Significantly, many of the returns are good stock that can be resold but have to go through a thorough quality check.

Mark Hewitt, ex-chief executive of iForce in the United Kingdom, sees this developing interest in returns:

> There will be a growing demand for outsourcing e-fulfilment to companies that can also offer returns processing from the same facility, as this will drive down costs by enabling a more efficient process for putting returned goods straight back into stock.
>
> (Supply Chain Standard)

A number of the third-party providers are now assisting their clients with the disposal of the returned goods through having their own eBay stores.

Other possibilities include rewarding consumers for taking returns back to the store where they can be processed by the store staff.

Next-day delivery is seen as the norm, which puts further pressure on the warehouse manager to balance speed with accuracy. Allied to this is the requirement to be able to integrate systems with couriers and customer services to be able to track and trace the progress of each order.

According to Savills, there is no current 'blueprint' for the optimum e-fulfilment centre design. Different retailers adopt very different strategies. We are already seeing this in terms of the different automation systems being introduced by retailers into their fulfilment centres. This is discussed further in Chapter 6.

Companies such as Amazon have developed unique systems that are capable of handling extremely large volumes of different types of products (ranging from relatively small in size to larger goods).

Smaller businesses will carry out fulfilment in their retail premises until the volume makes this unmanageable. Many small logistics providers and mail fulfilment firms now offer e-fulfilment, typically in general warehouse premises used for other aspects of the business.

A number of multichannel operators have developed dedicated e-fulfilment centres, once online sales volumes have become large enough.

Others have adopted a strategy of keeping e-retail volumes and traditional store volumes together, either as an opportunity to utilize spare capacity or due to minimal advantage in separating channels. Superdry have recently amalgamated their wholesale, store and e-commerce stock together under one roof.

To summarize, there are three types of fulfilment centre:

- integrated fulfilment, where internet sales are carried out alongside existing retail operations;
- dedicated fulfilment, carried out in a purpose-built facility; and
- store fulfilment, which involves picking online orders from existing retail shelves for separate delivery ex store. A same-day courier service provided by Shutl boasts a record delivery time of 13 minutes 57 seconds for an online order using this channel!

The third option has been favoured in the past for launching the service and establishment of e-fulfilment but is least favoured for a substantive operation.

However as IT systems become more sophisticated, we are now seeing an amalgamation of the above with the system deciding on whether to fulfil the order from the fulfilment centre, the store or even the supplier, whichever is in close proximity to the consumer.

In this next section we briefly discuss four specialist types of warehousing: customs warehousing, refrigerated storage, fashion logistics and hazardous goods storage.

Specialized warehousing

Customs warehousing by Barbara Scott and Gwynne Richards

This section is written specifically for the United Kingdom. However, most countries will have some form of customs warehousing or Free Trade Zones.

Operating a customs warehouse can bring huge benefits to an international trade business by delaying the payment of import duty and avoiding it altogether in the case of goods re-exported outside the UK. This is particularly useful if the company importing goods is unsure of the ultimate destination of the products, ie whether they will be sold on the home market (in which case the duty must be paid) or if they are to be re-exported (duty unpaid).

This section deals only with customs warehousing, which is a regime for the importation and storage of products imported from outside the UK that are liable to customs duty or anti-dumping duty. It does not deal with excise duty products – oils, alcohol and tobacco – which are covered by other specific regulations.

Customs warehouses are operated by warehouse keepers who must be authorized by HM Revenue & Customs (HMRC). There are basically two types of customs warehouse. There is a public warehouse, which is operated by a warehouse keeper who holds goods belonging to a number of companies. Customs responsibilities lie with the warehouse keeper who must ensure that the goods are not unlawfully removed from the warehouse and must keep accurate stock records showing at all times the imported goods held under the customs warehouse procedure. The depositor of the goods in the warehouse is responsible for correctly declaring the goods to HMRC. There is also a private customs warehouse authorization, which is granted for one importer to store his own goods in his own warehouse. No special security measures (eg barred windows, separate areas, etc) are required and there is no time limit for storing the goods in the warehouse. A number of warehouse sites can be included under the same authorization.

As an example of a private warehouse, consider a business importing forklift trucks that are manufactured in China. The rate of duty at importation would be 4 per cent of the landed cost, insurance and freight (CIF) value. If the annual import value is £20 million, the duty cost will be £900,000. By obtaining an approval to operate a customs warehouse (on the importer's own site), the duty payments are delayed until such time as the forklift trucks are sold into the UK market. At that stage an import declaration is made and

the duty is paid; by using the duty deferment scheme, up to a further six weeks of cash flow benefit can be obtained. If the forklift trucks are exported outside the UK, no duty is payable. The cash flow savings and duty saving opportunities are obvious and this has become more significant since the UK has left the EU.

It is true to say, however, that obtaining approval to operate a customs warehouse is not without its difficulties. HMRC effectively hands over control of the border to the inland warehouse keeper so has to be absolutely certain that import charges will be accounted for correctly and that there is no risk of goods being inadvertently placed on the UK market without duty being paid.

The customs warehouse operator may have to invest in a duty management system that interfaces directly with the HMRC's computer system known as CHIEF (Customs Handling of Import and Export Freight) to enable the discharge of the goods to be reported and any duties and VAT calculated. Additionally, if there are daily removals of goods from the customs warehouse, the operator is likely to also need to be authorized by HMRC to use Customs Freight Simplified Procedures (CFSP) and Entry in the Declarants Records (EIDR); without these approvals, a full customs declaration must be submitted to and accepted by HMRC before goods can be removed from the customs warehouse. For EIDR, the operator will also be required to obtain HMRC approval as an Authorized Economic Operator (AEO). An AEOC is a trader or international trade service supplier who, by satisfying certain criteria, is considered to be reliable and trusted in their customs-related operations. AEOS status is an internationally recognized quality mark indicating that a company's role in the international supply chain is secure, and that customs controls and procedures are efficient and compliant.

Customs warehousing can bring substantial benefits both in controlling the flow of merchandise and savings in tax. A first step is to look at the business case and determine the costs and benefits. The use of a customs expert in this area is strongly advised.

Of course, a customs warehouse is only for the storage of goods, although certain 'usual forms of handling' such as repacking or labelling, may take place. If the goods are to be processed, then another customs procedure may need to be used. Post Brexit, the UK government has decided to establish Freeports or Free Trade Zones within the UK with at least one Freeport in each nation of the UK opening in 2021. Freeports are tariff free zones that are considered to be outside a country for customs purposes, allowing goods to be imported, processed and re-exported without any duties or taxes being paid. The UK Freeport locations will be in the Thames region, Liverpool city, the Solent, East Midlands airport, Felixstowe and Harwich, Plymouth, Teeside and the Humber.

Temperature-controlled warehouses by Chris Sturman

The growth in the refrigeration market, due to demand for food that can retain its freshness as opposed to produce with a shelf life, has placed increasing pressure on cold and chilled store operators.

Temperature-controlled warehouses are in the main chilled (approx. +2°C to +8°C) or frozen (approx. –18°C to –25°C), although some specialist facilities for fresh produce can be slightly higher at around +8°C. There can also be a requirement for heated or air-conditioned facilities for some product storage such as chocolate.

The key function of a temperature-controlled warehouse is to maintain the temperature of products at the level at which they were received. Blast freezing and tempering chambers are used for managing any change of temperature required and these activities should take place away from the main storage areas to minimize the risk of temperature deviation (+/–) to goods being held in stock. Cold chain management, to adhere to food safety regulations and maintenance of food quality and safety whilst managing significant energy and materials handling cost levels, are priorities.

At the same time, boards of directors and management need to assess fire and other serious business continuity risks, which are major issues facing both the food processing and storage and distribution industries in the United Kingdom. In particular, adherence to regulations relating to the use of ammonia as a refrigerant need to be assured, along with the competence of the company's own staff and any contractors used for design, installation and maintenance. A business continuity and disaster recovery plan is a core requirement of the business health and safety and good operating proactive regime, with clear management processes and staff responsibilities being clearly identified and staff involvement and training being prerequisites.

Materials handling and storage in a temperature-controlled environment

A wide range of storage media is used, all with the intention of optimizing storage capacity with accessibility, given the high capital and operating fixed and variable costs prevalent in the sector. The most popular are:

- Wide, narrow and very narrow aisle racking. Used in faster-moving operations, particularly in order picking by case and by unit. These suit secondary