4 Logistical Packaging for Food Marketing Systems

Diana Twede and Bruce Harte

4.1 INTRODUCTION

This chapter discusses logistical packaging and its role in food marketing systems. Logistical packaging is called by a number of different names, such as distribution packaging, transit packaging, industrial packaging, intermediate packaging and shipping containers. The term logistical packaging is used throughout this chapter as it stresses the importance of integrating packaging with all of the activities in a supply chain.

Supply chains range from hand delivery of a neighbour's garden vegetables to the importation of exotic and rare processed foods, using specialised trans-global distribution systems. Farm markets, conventional grocery stores, restaurants, fast food take-outs, food service institutions and direct marketing systems are supplied by a myriad of operational variations. They are also supplied by a wide range of package types, sizes and formats.

Logistical activities in a typical processed food supply chain begin at the farm. Commodities are transported to factories in bulk, or semi-bulk, packages, where the food is processed and packaged to add value. Unit loads are transported to wholesalers or retail distribution centres (RDC) where orders are picked into mixed loads, delivered to retail stores and broken down for retail display. There, consumers buy an assortment of packages and transport them home, where all of the packages are emptied, discarded and either shipped to a recycling facility or collected and transported to a landfill. This process is shown in Fig. 4.1.

Packaging affects the cost of every logistical activity in a supply chain, and has a significant impact on productivity. Transport and storage costs are directly related to the size and density of packages. Handling cost depends on unit loads. Inventory control depends on the accuracy of identification systems. Customer service depends on how well the packages protect products and how easy the package is to open, display and sell. The environmental impact depends on the materials, method of manufacture, reuse and disposal of the packaging.

The first section of this chapter discusses the functional requirements for logistical packaging to protect, add value and communicate. The second section discusses how packaging is related to the physical activities in factory operations, in transit, in warehouses and in retail stores. The third section discusses testing and evaluating packages for shock, vibration and compression performance. The final section describes the most common logistical packaging forms: corrugated fibreboard boxes, shrink-film bundles, plastic totes, stretch wrapping and pallets.

Food and Beverage Packaging Technology, Second Edition. Edited by Richard Coles and Mark Kirwan.

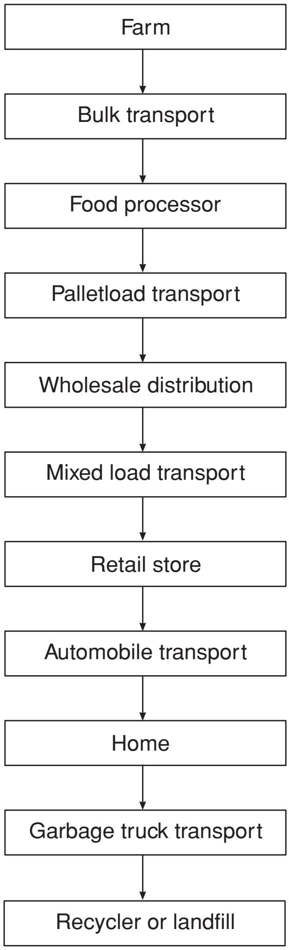

Fig. 4.1 Flow of food package from farm to landfill.

4.2 FUNCTIONS OF LOGISTICAL PACKAGING

There are three interrelated functions of logistical packaging: protection, utility and communication. There is an increasing trend to view packaging in terms of the functions and value that it provides, rather than just in terms of traditional materials. (Materials are discussed in the fifth section of this chapter.) Packaging is part of a total system, with responsibility to minimise the cost of delivery as well as to maximise sales.

4.2.1 Protection

The first function is to protect the food and the consumers. Protection is an important packaging function because spoilage and distribution damage is a waste of production and logistics resources. Replacement orders add further costs, and delays can result in lost customers. A loss of integrity in certain food packages can lead to product quality and safety issues. The type and amount of protection that a package is expected to provide depends on the characteristics of the product and the distribution environment with its associated hazards. A key aim of packaging is to provide the required protection using the lowest cost materials. The relationship can be conceptualised thus:

$$\text{Product characteristics} + \text{logistical hazards} = \text{package protection}$$

The relevant product characteristics are those that deteriorate or can be damaged over time. Food products are particularly vulnerable to biological and chemical changes that can affect quality and food safety. The hazards of the distribution environment range from exposure to extreme temperatures, dynamic forces, and insect infestation to ambient foes, such as oxygen, moisture and time. The preservation ability of food packages and their characteristics and properties of packaging importance are discussed elsewhere in this book. It is important to note here that the required length of a food package's shelf life is directly related to how long it is in storage, transit and on the supermarket shelf. Short temperature-controlled channels for fresh food require less shelf life from their packages.

Protection from dynamic forces, handling impacts, in-transit vibration and warehouse stacking is usually provided by the shipping container. Testing can determine how much abuse a product can withstand, and can be used to predict how well its package will prevent physical damage, such as bruising, breaking, denting and smashing. Some standard dynamic tests are described in the fourth section of this chapter.

The dynamic hazards of a logistical system and hence the most appropriate tests conducted depend on handling, and, the types of transportation and storage used. Firms that use a number of different types of distribution channel may need a different type of package for a variety of specific conditions.

Damage is a symptom of an underlying problem that can be solved by changing the packaging or by changing distribution practices. In many cases, it costs less to reduce the hazards than to improve the packaging. For example, it costs less to reduce the force exerted by a clamp truck than to switch to stiffer boxes. Alternative methods of transportation (e.g. special equipment, refrigeration and/or dedicated carriers) and storage racks in warehouses can reduce damage; appropriate hygiene and pest control practices during distribution can reduce the need for packaging to protect against pest infestation.

4.2.2 Utility/productivity

The second packaging function, utility, is defined as value to a user. In the case of logistical packaging, the user is the logistical system and the value is productivity. Productivity in logistics is a very important concern because distribution is labour and capital intensive. Productivity is measured simply as the ratio of real output to real input:

$$\text{Productivity} = \frac{\text{number of packages output}}{\text{logistics input}}$$

Logistical productivity is the ratio of the output of an activity, e.g. the number of packages loaded into a truck, to the input activity, e.g. the labour and forklift time required. Most logistical productivity studies centre around better utilisation of inputs, particularly labour.

On the other hand, packaging initiatives like unitisation and size reduction can easily increase the output of logistical activities. A good example is palletisation, which dramatically improves the productivity of most material handling operations compared to break-bulk handling. Unitisation enables a single person and a forklift to handle thousands of kilograms in an hour.

Almost all logistical productivity measures are described in terms of number of packages, evidence that packaging affects the cost of every activity. Some examples include the number of cartons loaded per hour into a trailer, the number of packages picked per hour at a distribution centre, the number of packages that fit into a cubic metre (cube utilisation) of vehicle or warehouse space, the time to stock retail shelves and the cost of waste disposal. Packaging configuration directly affects the number that can be handled per hour or the number that fits into a vehicle.

Ergonomics is also a utility issue because healthy workers are more productive than employees engaged in personal injury lawsuits. Most injuries in physical distribution activities involve shipping containers. There are two types: accidents, usually involving an unstable package falling on a person, and chronic stress injuries due to manual handling of goods. Routine manual handling of packages has always been taken for granted, but it has a reputation for causing chronic back injuries. Many retail and warehouse workers are hurt by packages that are heavy, bulky, or must be lifted to a top shelf.

In order to protect workers, the US Occupational Safety and Health Administration (OSHA) has issued guidelines for maximum weight of manually handled packages and appropriate handholds, and the EU has set ergonomic standards in Directive 90/269/EEC. The recommended package weight is related to how far and how often a package is lifted, how far the worker's hands are extended, how far he/she must twist and the adequacy of the hand grip. For most routine material handling jobs, the recommended weight limit is between 20 and 30 lb (9–14 kg).

4.2.3 Communication

The third packaging function, communication, is becoming more important as logistical information systems become more comprehensive. Electronic data interchange (EDI) and control has been key to the development of effective and integrated management of material flow, inventory, transportation and warehousing. For EDI to succeed, accurate timely information on the status of the packaged product is required.

For all practical purposes, the package symbolises the product throughout the distribution. Every time that a product changes status, for example when it is picked for a warehouse order, information about the status change is registered in various logistics records by means of 'reading' the package identification and recording/changing its status in an information system.

The information systems that record a status change include inventory records, shipping records, bills-of-lading, order picking lists, order receiving verification, accounting payables and receivables, manufacturing and logistics system tracking, and retail pricing. Packaging codes are also sometimes used for sorting products to various destinations in a factory, warehouse or transport terminal. International shipments additionally require the language of shipping origin, destination and intermediate stops, as well as international markings for handling instructions. Furthermore, there is an increasing demand for tracking specific stock-keeping units throughout a supply chain.

Correct identification of stock-keeping units (SKU) including SKU number, name, brand, size, colour, lot, code dates, weight and number in the package are critical for good information management. Accuracy is essential. SKU information must be clearly legible. Workers must be able to quickly recognise a package from its label.

The most popular trend for reducing errors and increasing the efficiency of the information movement is to use automatic identification. Barcodes and radio frequency identification (RFID) enable a systems approach to managing information where every input is standardised, thus reducing errors. Whereas bar codes require a line of sight to be read by a scanner, RFID enables packages to call home from a distance when prompted via radio frequency. Furthermore, new information can be added to RFID tags as they move through the supply chain, accelerating their use for applications to track and trace where a product has been.

RFID promises to revolutionise package identification, since in theory the packages could be linked directly to a supply chain's information management system. The readability of these automatic identification forms depends on technological and symbolic compatibility of the package's label with every reader in the system. If automatic identification is intended to be used throughout a logistical system, it is necessary to use a common symbology. A number of standards organisations exist for this purpose.

4.3 LOGISTICS' ACTIVITY-SPECIFIC AND INTEGRATION ISSUES

Although they have been discussed separately, the three packaging functions of protection, utility and communication directly influence each other. The importance of each function varies between logistical operations. Sometimes there are trade-offs between these functions. For example, unitisation increases handling protection and productivity, but may decrease in-transit cube utilisation and require different markings from packages shipped break-bulk.

From the packages' point of view, there are many variations in logistical systems. In typical food and consumer product supply chains, unit loads are shipped by full truckload (TL) to the wholesale level. Here orders are picked, in one of several common methods, and then distributed in mixed loads on various types of pallets, carts or platforms to a variety of retail store types. On the other hand, some food products are floor loaded in trailers and delivered directly to a retail store without the use of pallets. Food service supply chains likewise include both direct and wholesale channels. And in e-commerce, each package may travel alone, or at least with strangers, using a small parcel transport system.

In each type of system, packaging must not only provide protection, utility and communication for specific operations, but it must also facilitate transitions between operations. In logistical systems, products change ownership and location, and packaging must be designed to satisfy a number of functional needs and users. For example, a slipsheet packaging system should not be implemented to improve trailer cube utilisation without considering how it will increase the consignee's unloading time if he/she does not have the appropriate handling equipment. The more complex the system, the greater the need to study its handling methods, transport modes, facility dimensions, damage sources and communication needs, in order to design packages that will optimise the system. The next sections review the general functional requirements for packaging during each link in the supply chain: food processor, transport, warehousing and customer service.

4.3.1 Packaging issues in food processing

Food processors are concerned primarily with the packing operation. Their emphasis is on the cost and quality of incoming packaging materials, controlling the quality and productivity of the packing/filling process, hygiene and mechanisation. In instances where food safety is threatened, packaging can be a critical control point in a product manufacturer's hazard analysis critical control (HACCP) plan. These are such important packaging issues that many food processors never find the time to look beyond their receiving and shipping docks. But there are other opportunities for packaging to improve a food processor's inbound and outbound logistics. Outbound opportunities focus on the customer's needs, and are described in subsequent sections of this chapter.

Inbound raw materials and ingredients being delivered to a factory need to be protected, and made easy to handle and identify. Their packages need to be easily emptied and inexpensively discarded. The high cost of land filling has been an incentive for producers to seek less expensive disposal means.

There is a financial incentive for manufacturers to recycle or reuse the shipping containers and pallets that they receive. Reuse has been an especially popular strategy when hygiene can be assured, because a food processor generally has a close relationship to its suppliers with a quick turn-around cycle. Both of these factors are necessary for an efficient reusable packaging system. The quick cycle is necessary in order to minimise the number of containers in the system. A close relationship is needed in order to negotiate responsibilities for return or rental.

4.3.2 Transport issues

Packaging protection during transportation is so important that shock and vibration testing is often called 'transit testing'. Damage that occurs during transit is particularly noticeable and well documented because of the relationship of carriers to the logistical system. Under common law, transportation carriers do not own the goods that they carry, but are bailees (contractors) entrusted to carry goods that are in their temporary possession without causing damage. When carriers damage products, they are liable for the items' full or partial value as stipulated in a contract or the bill of lading. The carrier is liable unless it can plead a common law defence and blame it on the shipper (e.g. inadequate labelling or packaging) or the perishability of the product (so-called inherent vice).

As a result of the importance of packaging issues to transport carriers, there is an history of carriers providing packaging guidance to shippers. Carriers reserve the right to refuse freight that they think is improperly packaged, and tests may be required before packaging can be approved. Some shippers develop partnerships with their carriers with the aim of reducing costs and preventing damage.

Dynamic forces vary by mode of transport. The technical principle of each mode affects service, economics, and dynamic forces as well as the packaging requirements for protection, utility and communication.

The technical principle of truck transport – pneumatic wheels rolling over bumpy pavement – combined with the springs that fasten the wheels to the truck bed, are the major contributors to in-transit vibration, generally below 25 Hz. This is the force that vertical vibration testing aims to simulate. In addition, potholes and other surface discontinuities cause transient impacts that can disorganise a load. This is the reason why packages should be loaded to a level height in the trailer. Stopping, starting and turning forces are generally moderate, but do necessitate minimal restraints or void fillers when there are voids in the load.

The fact that roads are ubiquitous, and that every truck has its own driver, makes truck transport relatively fast compared to rail transport. Door-to-store service for a full truckload (TL) minimises the need for packaging to add much shelf life. Perishable products are usually shipped in refrigerated trailers. In TL shipments, the load remains intact for the whole journey. The trailer can be loaded by the shipper in such a way as to minimise damage. Products shipped in TLs can be minimally packaged to protect from impacts because they are handled under relatively controllable conditions by the shipper and consignee.

In less-than-truckload (LTL) shipments, such as those used for e-commerce, a package is relayed from the origin through a number of the carrier's terminals until it is placed on the local delivery truck. The relay process results in handling under temperatures and dynamic conditions that cannot be controlled by the shipper, and an occasional package is dropped, frozen or thawed. Therefore, LTL packaging needs more protection. In each successive trailerload, packages are consolidated jigsaw style, which results in an assortment of product and package stacking patterns, and so LTL packaging needs more protection. Packaging can improve the productivity of an LTL truck terminal if it is designed to be unitised or has ergonomic features. Small parcel carriers expect packaging to be conveyable and very protective, since packages can be repeatedly dropped, kicked or tossed. Packages may need to fit within specified dimensions or pass performance tests. Products shipped LTL are always marked with the shipper's and consignee's addresses, and for security reasons they should not identify the contents.

Truck transport is expensive, compared to rail and ocean transport. There is a decided advantage to optimising the cubic and/or weight capacity of the trailer, and there is a trend towards making packages as small and lightweight as possible. Improving cube utilisation is packaging's greatest opportunity to provide logistics value. If package size can be reduced by 50%, transportation efficiency doubles. There are many ways to reduce package size, such as concentrating products like orange juice, or by eliminating space inside packages by shipping items nested, with minimal head space and dunnage.

Cube minimisation is most important for lightweight products like breakfast cereal that cube out a trailer below its weight limit. Trailer sizes vary; a typical size in the United States is 48 ft long × 102″ × 102″ (14.4 × 2.5 × 2.5 m), and payload weight limits are generally about 40 000 lb (18 000 kg). On the other hand, heavy products (like liquid in glass bottles) can weigh out a trailer before it is filled. For such products, the value-adding strategy is to reduce the package weight; for instance, substituting plastic bottles for glass significantly increases the number of bottles that can be legally transported in a trailer.

The technical principle of rail transport – steel wheels on steel rails – restricts rail movement to fixed routes. The hard wheels and rails restrict the vertical vibration but there are very severe dynamic impacts involved in train coupling operations. As trains are assembled and disassembled ('switching') in their relay across country, railcars are often slammed together to engage couplers. To avoid damage from switching, cargo must be securely blocked and braced, or voids must be filled within the railcar. Various national railroad organisations have researched rail damage and have developed tests and restraint recommendations.

The fixed routes, switching process, and train schedules make rail transportation slower than by truck. Packaging may need to provide a longer shelf life, more protection from climate changes, or products may need to be shipped in insulated or refrigerated cars. Railcars are generally larger than trailers and have no weight limit restrictions. Rail transport is less expensive than truck transport, and so there is less value in package cube or weight reduction when shipping by rail. Because of the long time, damaging conditions, and lack of weight restrictions, US railroads tend to carry more of the bulk and durable cargo, having lost the higher value consumer product cargo to trucking.

Air transportation's technical challenge is to overcome gravity. This makes it the most expensive form of transportation. The size and density of packages dramatically affect the cost of air transport, and so every weight and volume reduction adds value. Air shipment is fast, and many products, including perishables, can be shipped with minimal shelf life protection. Air transport itself has very little dynamic input, except for some vertical vibration during take-off and touchdown, and a little high frequency vibration in transit. Decompression is a potential problem since some cargo holds are not pressurised. Temperature abuse and exposure to adverse weather are common.

Packages shipped by air are always picked up and delivered by truck, and so they also need to withstand truck dynamics. They are handled repeatedly, sometimes outdoors in the rain or other extreme weather conditions, and therefore, packaging needs to protect from impacts, moisture, temperature extremes and being stacked with other cargo. Many small parcel carriers ship by air, and the packaging requirements are similar to those for LTL shipments. When quantities shipped are sufficient, unitisation can reduce damage and handling costs. Packages shipped by air need to be marked with addresses, but in order to deter theft, should not be marked to identify the contents.

The technical principle of ocean or river carrier transport – gliding through the water – creates dynamic forces and wet conditions. Waves, swells and storms cause a ship to move in every direction. Cargo must be well-secured inside its packages, and within the vessel or intermodal container. The air aboard ship is high in humidity. Ordinary day/night cycles and climate changes in temperature can cause condensation, rust and rot. Packaging solutions to resist moisture damage include using desiccant sachets or treated films, ensuring efficiently sealed packs that prevent moisture ingress, and controlling the moisture content during packing. Since waterborne transport meets land-based transport modes at port, packages also need to be suitable for rail or truck transport.

Ocean transport is the slowest of all modes, and cargo can be held in port areas awaiting further shipment. As a result, packaging is required to add more shelf life to food products. Cube optimisation can yield savings, but the most significant ocean transport cost affected by packaging is the cost of ship-loading. An idle ship in port costs almost as much per day as it costs when it is underway. Furthermore, break-bulk loading operations are costly and longshoremen's handling practices can be a great source of product damage and injury. Therefore, there is a great incentive to unitise or containerise cargo.

Maintaining a cold chain for international shipments of perishable food requires more than the use of transport vehicles and warehouses that can maintain refrigerated or frozen conditions – it also requires careful control of conditions during cargo transfer from one vehicle or warehouse to another. For example, a refrigerated break-bulk ship ('reefer') controls the temperature in the hold during the journey, but the conditions during loading can expose cargo to temperature abuse as it sits on docks awaiting lifting into a break-bulk hold. Some intermodal containers are capable of refrigeration and/or controlled atmosphere, but there must likewise be provision for powering the refrigeration during waiting periods at port.

Intermodal containers combine the best and worst of ocean, rail, air and truck modes, since the container can travel on any or all of these modes in succession. Trailer-on-flatcar shipping combines railroad economies with door-to-door service, and has packaging requirements similar to those for truck, but with the added dynamics of a double set of springs while the trailer is on the flatcar. Container-on-flatcar shipping generally involves ocean transport, reducing the time to load ships, but with the same dynamics and shelf life problems as rail and ocean transport. Other combinations, such as air-surface containers, road-railers, roll-on-roll-off ships, and lash barges, have their own unique operating characteristics and packaging opportunities. All intermodal transportations have a common advantage; individual packages are not handled. This reduces handling costs, impacts and the trip time.

It should be remembered that intermodal containers are often opened overseas, and individual packages are usually shipped further in a break-bulk situation, and so the demands of this journey also need to be considered. International transportation ranges from flatbeds to bike carts. Whether transportation is by one mode, multi-modes, or is intermodal, the rule for packaging protection is to package for the roughest leg of the journey.

4.3.3 Warehousing issues

Traditional warehouse order picking can be considered as a packaging operation. In a typical warehouse for consumer goods, large packages, e.g. full TLs or full palletloads are received. These are dismantled into smaller units, e.g. shipping containers or consumer packages as orders are picked. The orders are then repacked into mixed loads for delivery to logistical customers, such as retailers. Sometimes the orders are so small that individual items are picked from shipping containers and re-boxed into a delivery package. Sometimes the delivery package is simply an original box or pallet repacked with a mixed load. In other cases, reusable pallets or totes are used to deliver to the retailer.

Modern warehouses are called distribution centres (DCs), to emphasise that they only profit by moving goods. To a DC, storage represents unproductive assets. The productivity of warehousing is very important because order picking and materials handling are generally very labour-intensive. There is a great deal of emphasis on tracking and managing productivity. Cases or orders picked per hour, trucks loaded or unloaded per hour, and pallets received and put away per hour are examples of warehousing productivity measures.

Packaging can add productivity to order picking operations when products are packed in order quantities and cases that do not require additional labour to open or split. For example, if five is the standard order quantity, then products should be bundled into fives, rather than the traditional case quantities of 12, 24 or 48. The persistence of packing old-fashioned dozens is curious, given more rational reasons to specify other counts.

The trend in distribution is to speed up the order filling process, and many DCs are now no more than cross-dock operations. They quickly assemble the mixed load orders as shipments are received, or simply transfer already mixed loads from a single manufacturer to delivery trailers. In cross-dock situations, there is an increased demand for packaging to be modular and automatically identifiable to facilitate mechanised sorting.

On the other hand, some warehouses still serve a significant storage function. Packaging can improve storage efficiency when packages are dense and maximise the use of cube space. Most warehouses store in, and pick from, racks. Shipping containers and palletloads should be sized to fit the racks (and/or vice versa).

The stacking height, and, therefore, the required compression strength, is determined by the warehouse configuration. The stack height is only one palletload if racks are used, or it may be 3–4 palletloads high on the floor. Compression strength is affected by the strength of the shipping container and whether the contents help to support the load and the stacking pattern. Corrugated fibreboard box walls alone can rarely provide sufficient compression strength for long-term storage, because the corrugated fibreboard weakens in the presence of relative humidity and over time. Stack compression failure damages product and is also a safety hazard because a stack can fall over and injure or kill workers.

Two other protective factors are best controlled by the warehouse: pests and temperature. Although packages can be made to resist insects and mice, it is better to keep the warehouse clean to eliminate their presence. Effective hygiene and pest control procedures must be implemented. Spillage should be promptly cleaned up, and traps should be set in key pathways.

Most food DCs have at least three temperature zones: ambient storage for shelf-stable foods and general merchandise, a refrigerated area for fresh food, and a frozen storage area. With more varieties of fresh produce, freshly prepared meals, dairy products and bakery items, the demand for refrigerated storage has grown. Some refrigerated warehouses, especially those dealing with a wide variety of fresh produce, have several different-temperature rooms where each fruit or vegetable can be stored in its most advantageous climate. Most warehouse loading docks, however, are not refrigerated, and this can be a severe breach of the cold chain, especially if loads are staged on the dock for a long period of time. Although insulation can be added to packaging, it is usually more efficient to control the temperature of the facilities, especially in conventional supply chains for food.

Since packages are handled many times in warehouses, they must provide protection from impacts. And since they are often packed into mixed loads for shipment, they need to provide protection from stacking and puncture by other types of packages. They should be compatible, if not modular, to facilitate stacking and cube minimisation.

Packaging also needs to make it easy to find the right items when picking orders. Easy to read stock keeping unit (SKU) identification is essential, regardless of whether it is read automatically or in the old-fashioned way. The markings should be concise and legible, on all four sides if necessary. The name of the manufacturer, brand, size and count should not be obscured by advertising messages. Packages have to be read when they are received, put away in the correct location, picked, repacked and shipped. Good packaging communication can prevent shipping mistakes.

Food retail industry standards exist for bar code and RFID symbology, and these are increasingly being used to automatically sort and track shipping containers in a DC. Some DCs use in-house slave pallets or stickers that have a license plate bar code, magnetic strip, or RFID tag that is used to track and record the status of palletloads throughout the single facility.

4.3.4 Retail customer service issues

Once a supply chain customer, such as a retailer or restaurant, receives a shipment, logistical packaging has to perform a new set of functions. The package needs to be opened easily without damaging the contents. Handling and the unpackaging operation should be quick and efficient, and reclosure may be desired. The product should be easy to identify, and the package may be required to display or provide special instructions for installing and using the product. The package should minimise the customer's cost of disposal. Traditionally, retailers did not have much control over the packaging that they received. Most large manufacturers planned packaging to best suit their own operations, and small retail or restaurant customers had little power to request improvements.

Increasingly, however, food marketing channels are dominated by large retailers and food service chains who demand specific types of packaging. For example, grocery chains increasingly specify the durability of shipping containers and the information needed, prohibit some box styles, and demand that suppliers comply with sustainability or identification mandates. Some retailers even control the consumer packaging and sell their own brands. Discount chains often specify that fast-moving products are to be packaged on display-ready small pallets that generate minimum waste. Some retailers demand that produce suppliers use standardised reusable totes, described in Section 4.5.3. Restaurant chains may design their food processing area based around specific shipping container configurations.

Packaging affects the retailer's direct product profitability for every product, because a retailer's profit is directly related to the operational costs for opening packages, displaying and selling products, and inventory tracking. For example, bar codes that permit automatic scanning at a retail check-out counter reduce the cost of price marking, check-out, inventory control and reordering. Since packaging affects a retailer's productivity, cooperation between manufacturers and retailers can improve system-wide profitability.

Increasingly, manufacturers find that designing packages to add retail value can be a profitable strategy to increase sales. The most important customer service trends are point-of-purchase (POP) display-ready cases, intelligent labelling and PDQ (pretty darn quick) easy-open features like film wraps or reinforced strips that rip through corrugated fibreboard. Easy-open features also can help reduce customer-caused damage from razor blades. The graphics on most point-of-purchase display cases are of high quality and designed to attract attention. Some retailers are even requesting electronic security devices and RFID tags that could allow all of the cases on a mixed load to be scanned simultaneously.

Another retail trend is the efficient consumer response (ECR) strategy, in which products are packaged by suppliers in mixed cases or mixed palletloads to bypass the traditional warehouse order-picking operation. For this, suppliers need access to store-level order data, and packages contain a number of different SKUs packed to order. They are shipped through a cross-dock operation controlled by the retailer, where packages are sorted using bar codes into trailers to be delivered directly to retail stores. In such cases, the markings and package size need to facilitate efficient sorting and control.

4.3.5 Waste issues

The cost for discarding shipping containers is generally paid by logistical customers like retailers. Besides the environmental impact, disposal is costly and can severely reduce a customer's productivity. There is a clear incentive for firms to reduce, reuse and recycle logistical packaging waste in order to avoid or reduce disposal costs.

This economic incentive has caused logistical packaging to be less of a target for legislation than has been consumer packaging waste, where disposal is an external cost. In Europe, where there is packaging waste legislation, the provisions for logistical packaging are different from those for consumer packaging. They usually result in the packer-filler paying a tax that funds a recycling infrastructure and reduces the retailer's disposal costs.

Each strategy – reducing, reusing and recycling – has an economic impact beyond disposal costs. Reduction of packaging materials also reduces package purchase costs. Packaging reuse generally adds some costs for sorting and return transportation but may reduce package purchase costs in the long run. The growth of recycling is reducing collection and processing costs and improving the market for recycled materials. The trend towards recycling and reusable packaging also has sustainability benefits.

Recycling is an efficient disposal method for most logistical-packaging waste, since it naturally collects in large homogeneous piles at the facilities of manufacturers, warehouses and retailers. There are a limited number of materials: wooden pallets, corrugated fibreboard, polyethylene film, plastic foam and strapping. Recyclers welcome such concentrated and relatively clean sources (compared to sorting and cleaning consumers' curbside waste). As a result, logistical packaging has a very high recycling rate. Likewise, purchasing packages made from recycled material encourages the growth of a recycled-products market and infrastructure.

Recycling is sometimes erroneously called reverse logistics. Actually, the packaging materials are not taken back to the company that filled the packages, but rather the logistical system moves forward, through waste management companies, to reprocessors. In many cases, associations of packaging material manufacturers have set up their own networks for collecting and reprocessing.

4.3.6 Supply chain integration issues

Food can be prepared from commodities at any point in the channel, from the grower's facility to the consumer's kitchen. In this way, the supply chain concepts of postponement and speculation have always been applied to food production. Speculation strategies require the most packaging, since the food is prepared early in the channel and the package is expected to add a longer shelf life. On the other hand, postponement – waiting until the last minute to prepare the food – may not require the package to extend the shelf life beyond a few minutes. Likewise, the packages that supply these operations may also differ greatly in size because of economies of their large scale. Consumers buy flour in a very different package than does a food processing or food service business.

In more integrated supply chains, where the activities are coordinated and centrally planned, packaging can be better planned to reduce system-wide costs. When supply chains are controlled by a powerful customer, one is more likely to find store brands, reusable totes and systemic automatic identification systems. Integrated supply chains are more likely to consider postponement versus speculation as a way to reduce costs.

When there is less integration, there is a tendency to sub-optimise the system in favour of improving one operation. For example, the fresh produce industry has traditionally used a wide variety of box sizes, based on standard counts and/or the size of the fruit or vegetable. This works well for the grower because the fruit is sold by the standard count, and the box can be highly decorated to promote the identity of the grower. However, for an RDC that picks a mixed order, the variation in box sizes causes a number of problems because they cannot be automatically sorted and palletised and they do not fit securely in the mixed palletload. When they reach the retailer, the boxes may not fit together well in a display.

The recent trend to become larger and more powerful has led the retailers to better integrate their supply chain. It has also led many of them to demand that their produce suppliers use reusable modular totes, in order to minimise their sorting, stacking and stocking costs. Likewise, food service packaging for vertically integrated chain restaurants is often planned to improve operations and productivity in distribution centres and kitchens, in addition to fitting into the suppliers' operations.

For many food products, it is important to maintain a constant temperature throughout the supply chain. Any breach of the cold chain could exacerbate ripening, decay or the growth of bacteria. Temperature control is a responsibility of transport carriers, distribution centres and retailers, and many of these have a quality control process to ensure that the temperature is monitored and controlled. When food safety is threatened, the cold chain provides many critical control points in a good HACCP plan.

There are some ways that packaging can help to identify or bridge warm periods. Inexpensive temperature monitor tags can identify whether a package has exceeded a threshold temperature. Insulated packaging and/or frozen gel packs can be used when a gap in temperature control is expected. These play an important role for food packages in direct delivery and e-commerce, where the transport and delivery conditions cannot be assured.

Packages for extreme logistical systems, like those for the military and disaster relief food aid, are especially critical. Compared to commercial operations, these packages need to be stronger because distribution hazards are greater, shelf life requirements are longer, and the possibility of loss can be catastrophic. Optimisation of handling and transport productivity are vital. Accurate package identification can be a matter of life and death. The more complex the system, the greater the need to understand its packaging requirements.

4.4 DISTRIBUTION PERFORMANCE TESTING

The protection afforded by alternative packages can be evaluated and compared in laboratory and field tests. Performance testing is used to assess filled containers in situations that simulate distribution hazards and reproduce damage. It is important to distinguish distribution performance tests, which are used to aid packaging design, from material performance tests generally used for quality control. Quality control testing is not the subject of this chapter. Neither are shelf life testing and permeability, which are covered in other chapters.

The most common types of distribution performance tests are those that test the ability of packages to withstand the mechanical forces of shock, vibration and compression and those that test for the effects of temperature and humidity changes. There are a number of standardised tests available. The American Society of Testing and Materials (ASTM, 2009) has developed tests for packaging materials and containers since 1914. The International Standards Organization (ISO) has developed similar tests for international users. The International Safe Transit Association (ISTA, 2009) has developed a more limited set of standards, dealing solely with pre-shipment testing.

One of the most common standards is the test cycle, determined by distribution hazards and product vulnerability. ASTM D4169, ISO 4180, and ISTA's Projects include impact, vibration and stacking tests. There are similar French and Japanese standards. The Comité Européen de Normalisation (CEN) committee on packaging, TC/261, is developing a set of European standards. The test levels are determined by the product weight and the conditions expected in distribution. For example, a small air freight package is tested more severely than packages shipped on pallets in full TLs; packages to be shipped overseas are tested more severely than those in domestic shipments.

Another type of standardised test is for specific package types. Some examples include ISO 10531, a stability test for unit loads, tests for intermediate bulk containers and tests for wooden boxes for fresh produce.

Some industries have developed performance tests that are specific to their product and logistical system. Such tests are often a variation of a standard test. For example, the makers of paperboard beverage bottle carriers have developed specific jerk tests for the handles to ensure that they will not tear when they are wet.

4.4.1 Shock and vibration testing

Dynamic testing of filled packages can be performed on a variety of testing equipment. The purpose of the test generally guides the choice of equipment and test methods. Impact tests can be performed on free-fall drop equipment (e.g. ASTM D775, ISO 2248 and ISTA 1/1A, 2/2A), or shock machines. A shock machine, generally used for fragility testing (e.g. ASTM D3332), has a higher velocity change for the same drop height because of its rebound, but can be used to produce repeatable impacts. The velocity change produced by a shock machine is generally two to three times greater than that of a free fall drop for a given drop height, depending on the machine and the distance of its rebound.

Some vibration tests, e.g. those specified by ISTA and ISO 2247, are very basic, performed on synchronous equipment with a fixed low frequency (about 4 Hz) and high displacement, generally, 25 mm. Synchronous vibration tests are quite severe, and are sometimes called vibratory impact or repeated impact tests.

The ASTM standards specify electrohydraulic equipment, which is capable of varying the frequency and displacement. Some package/product tests (e.g. ASTM D3580) involve sweeping through a frequency range – usually, 3–100 Hz; if an item or stack resonates in the range to be expected during transport, additional testing is done at that frequency to determine the likelihood of damage. Such testing is linked to the natural frequency of the product, the stack of packages and the transportation vehicle, and is generally below 25 Hz. More sophisticated controls are capable of generating random vibration inputs, generating a spectrum of frequencies that have been statistically determined from measurements of transport conditions. ASTM standard D4728 gives examples of representative test profiles for various transport modes. As a result, product/package systems can be tested for their vulnerability to various truck suspension systems. Special fixtures may be used, for example, to simulate the vibration experienced by the bottom container in a stack.

Less used dynamic test methods are horizontal impact and revolving drum tests. Inclined plane tests (ASTM D880 and ISTA 1/1A, 2/2A) were originally developed to reproduce damage to appliances sliding down an inclined plane from the back of a truck. They have been generalised to simulate other kinds of horizontal impacts, including railcar switching impacts, conveyor jam-ups and pallet marshalling. A newer type of horizontal impact test has more controllable parameters, and includes programmable devices that can vary the shock duration, which will vary depending on the event to be simulated. The tumbling/revolving drum test is an old test, no longer favoured by the technical community because it is not repeatable and severely abuses a package, somewhat akin to throwing it down an endless flight of stairs.

Since most dynamic testing attempts to reproduce what is in reality a highly variable environment, an important question in shock and vibration testing concerns test levels and intensities. How much vibration time equals a transportation cycle, and what percentage of impacts (and from what height) does a package need to survive? There is no simple answer.

It is important to identify the objectives of the test before an appropriate method, intensity and time can be chosen. Specific information about damage is particularly useful when developing package tests. Tests to solve specific problems are often designed to reproduce the package's specific damage characteristics, e.g. the ends of bags burst in side drops and provide a measure of the difference between the performance of alternative packages, i.e. how much input energy is required to burst, rather than simply pass/fail. Dynamic testing addresses the forces that packages encounter during transportation and handling. Packages also need to withstand stacking forces during storage, reproduced by laboratory compression testing.

4.4.2 Compression testing

Most compression testing research has been conducted on corrugated fibreboard boxes, since the walls of boxes are often expected to carry the load of a stack. Factors that are known to influence corrugated fibreboard box compression strength include the material properties, the board combining method, the box dimensions, manufacturing defects, interior partitions, temperature, humidity, stacking/loading method, and time.

It should be noted, however, that in most cases the product inside the box helps to support the stacked load. For example, packages for products like canned goods, glass jars and plastic bottles may not need the shipping container to provide any compression strength at all, and, instead, use the strength of the product itself.

There are two types of tests. ASTM D642 and ISO 12048 apply an increasing load until failure in a test machine. ASTM D4577 and ISO 2234 use a constant load over a specified time period, and may use a test machine or a simple stationary apparatus.

Some food manufacturers have learned that a common source of damage is clamp-truck side-to-side compression damage. (A clamp truck squeezes a unit load in order to handle it.) In response, they have developed sideways compression tests.

Since corrugated fibreboard loses a great deal of its strength when it gets wet, compression tests are usually conducted at standard conditions of 23°C (73°F) and 50% relative humidity. But there may also be a need for testing boxes in high humidity conditions or preconditioning boxes before testing.

4.5 PACKAGING MATERIALS AND SYSTEMS

The common materials and systems used for logistical packaging are relatively simple. They include corrugated fibreboard boxes, shrink-film bundles, reusable totes and unitisation materials like pallets and stretch film. This section describes the properties and forms of each and illustrates when and where they are commonly used.

4.5.1 Corrugated fibreboard boxes

Corrugated fibreboard boxes are well known for their good stacking strength (when dry), easy availability and inexpensive cost. Corrugated fibreboard is the most common material used for shipping containers, and the regular slotted container (RSC) shown in Fig. 4.2 is the most common design.

In a well-designed box, the load bearing panels have their flutes parallel to the direction of the anticipated load: for stacking strength, the flutes should run vertically. When side-to-side strength is more important (in clamp handling, for example), it may be better for the flutes to run horizontally.

Corrugated fibreboard is easy to recycle, both from a technical and a logistical point of view. Used boxes are generally discarded in large, homogenous piles by factories, warehouses and retail stores – businesses that have an incentive to reduce their disposal cost by recycling.

As a result, corrugated board has a very high recycling rate. Corrugated fibreboard has been used to make shipping containers for almost 100 years. A series of standard grades have been adopted by most countries. It is categorised in three ways: by the thickness and spacing of the fluted medium, by the weight of the facings, and by the quality of paper used. The most widely used flute configurations are known simply as A, B, C and E. The first corrugated materials were either coarsely fluted A-flute or fine B-flute. The intermediate grade, C-flute has now become the most commonly used type, being a compromise of the best qualities of the other two. E-flute has very small flutes, and there are even finer grades called micro-flute, which are

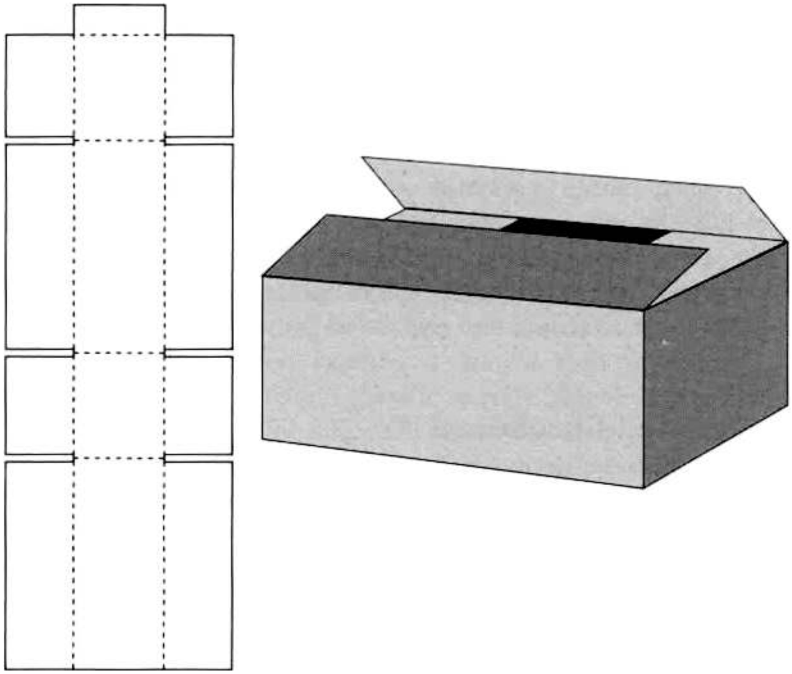

Fig. 4.2 Regular slotted container (RSC). (Packaging Materials (Twede & Goddard, 1998). Reproduced with permission from Pira International.)

used as alternatives to solid fibreboard. Dimensions given by the British Standards Institute and US Fibre Box Association (2005) are given in Table 4.1.

Kraft liners to face the board range from 125 to 400 g/m^2 with 150, 200, and 300 grades predominating in Europe. In the USA, where the materials are specified by basis weight, liners range from 26 to 90 lb (per 1000 ft^2) with 26 lb, 33 lb and 42 lb predominant. The corrugated medium is generally 127 g/m^2 (26 lb in the USA).

Single wall board (with two facings) is the most common form used for cases and trays. Double and triple wall boards are used for palletload-sized intermediate bulk containers, used for some dry ingredients in the food industry. At one extreme, single face board is soft and used for wrapping items like light bulbs and glass bottles. The other extreme is multi-wall laminated structures made into lightweight pallets.

Corrugated board has an important drawback: it can lose much of its strength (indeed, all of its compression strength) when it is wet. Further, the commonly used starch-based adhesives

Table 4.1 Common forms of corrugated fibreboard.

Flute	Flutes/metre	Flutes/feet	Flute height
A	105–125	36 ± 3	4.8 mm or 3/16
B	150–185	50 ± 3	2.4 mm or 3/32
C	120–145	42 ± 3	3.6 mm or 9/64
E	290–320	94 ± 4	1.2 mm or 3/64

Source: BS 1133, Section 7 and Fibre Box Association Handbook.

are also moisture sensitive. It makes good design sense, where possible, to design the box with minimal head space, allowing the inside products to help support the load. This will prevent the uneven collapsing of containers that can topple a pallet load. Wax dipping or coating has been used for particularly wet contents, like broccoli that is shipped with ice, but this practice is diminishing because the wax causes problems during recycling.

Corrugated fibreboard boxes are increasingly being used as advertising media in point-of-purchase displays, and so higher quality printing is demanded. There are three options: direct printing, pre-printed liners and litho lamination. The uneven surface of the board limits direct printing to relatively simple one or two colour flexography. Ink jets can also print directly on a box, and ink jet printing is particularly well suited for variable short-run information like lot codes. Pre-printed liners – high quality flexo printed facing materials – can be built in to the corrugated board at the point of manufacture. Litho lamination can produce the highest quality printing, including full colour halftones. It is made by laminating lithograph printed paper to the already converted board.

Corrugated fibreboard shipping containers have become a standard element of most logistical systems. In the USA, transport carriers required their use until transportation was deregulated in 1980. They remain popular because they are easy to purchase, perform well, and are recyclable. The technology of mechanical case packing is well developed. However, there is increasing competition from plastic alternatives, like shrink-wrap and reusable totes, which are lower cost in some situations.

4.5.2 Shrink bundles

Shrink bundle shipping containers are increasingly popular for products that do not require the compression strength of corrugated fibreboard. The products, like cans or bottles, are staged in a corrugated fibreboard tray (for stability), and the array is wrapped with a thin layer of film, such as linear low density polyethylene film (LLDPE) and then conveyed through a shrink tunnel that tightens the wrap.

The advantages of a shrink bundle, over the comparable corrugated fibreboard shipping container, are that it uses less material and is less expensive. Whether there is more damage is a matter for debate. A shrink bundle is certainly less objectively protective. But many times less damage occurs because the people handling it can see the contents, and, therefore, handle the package more gently. Like fibreboard, LLDPE shrink-film can be easily recycled, along with the stretch film and plastic bags that are also discarded by warehouses, factories and retailers.

4.5.3 Reusable totes

As the cost of disposal grows, and as some countries have added incentives for waste reduction, the use of multi-trip packaging has also grown. The most common uses are for inter-plant shipments of ingredients, for retail warehouse to store totes, and for fresh produce from the farm to the retail shelf. Most reusable packages are plastic, although some firms reuse corrugated fibreboard boxes, wooden boxes and pallet boxes. Most of the growing reusable-packaging applications have one thing in common: a short, well-managed supply chain with steady predictable demand. The primary participants are either integrated by corporate ownership, contracts, partnership or administration under the control of one firm.

Good supply chain management is important because of the need to control the movement of reusable containers and the need to share the benefits. All partners in a reusable system must cooperate to maximise container use, and an explicit relationship is required for coordination and control. Otherwise, containers are easily lost or misplaced. The shipment cycle should be short, in time and space, in order to minimise the investment in the container pool and to minimise return transportation costs. The demand for products should be steady with little variation because the number of containers needed depends on the number of days in the cycle including during peak demand.

Deciding to invest in a reusable packaging system is a very different task from purchasing expendable containers. Many packers are tempted to justify the purchase only in terms of the savings in expendable container costs. The decision should consider all explicit relevant costs – the investment determined by the number of packages in the cycle, as well as the costs of handling, sorting, tracking, cleaning and managing the container pool – versus the purchase and disposal costs for expendables. Intangible benefits like improved factory housekeeping, ergonomics and cube utilisation, and decreased damage should be considered.

The grocery experience in the UK shows that the big savings accrue to the retailer. The standardised modular nature of their reusable totes (the standard footprint is 600 mm × 400 mm) allows containers to be automatically sorted in a distribution centre. Modularisation facilitates more tidy mixed-loads. They streamline in-store retail operations where the produce is displayed in the totes, and a full one can quickly be swapped for an empty one.

Given the difficulties of container management, there is increasing interest in outsourcing the management, logistics and/or ownership of reusable containers and pallets. This is an emerging industry of container pool agencies that organise the participants, assess costs, manage the exchange procedure and container inventory, clean and repair, assess fees and track containers. The containers may be owned by the participants or simply rented to them by the third party. Some pools have been successful in fresh produce and mixed grocery channels in Europe and the USA. Such third-party service providers can develop economies of scale to justify a network of depots and vehicles to be able to collect the empties at a reasonable cost.

4.5.4 Unitisation

Materials used for unitisation vary, but they usually include a pallet or other platform. Wooden pallets predominate, although plastic pallets are increasingly used. Pallets are ubiquitous in food marketing channels, where most handling is done by forklift.

Most pallets in the food industry are reused, to varying degrees of success based on their construction. The choice of wood species has a great impact on cost and durability. The denser and stiffer the wood, the greater its durability and cost. Hardwoods (like oak) are the most durable and costly, and they are used for pallets that are rented as part of pallet pools. Most plastic pallets are made from high-density polyethylene or polypropylene; they can be thermoformed or injection-moulded.

In the food industry, pallets are generally rented or purchased with the intent to sell them to recyclers after use. Pallet rental and recycling companies will repair or remanufacture them to return them to use. Some countries, like Canada and Sweden, have a common pallet pool that is jointly owned by the stakeholders in the grocery industry.

Pallets can be designed to be entered on two sides or all four. The vertical members can be blocks in the corners and centres, or stringers that extend from front to back, as shown in Fig. 4.3. They can have decking only on top or on both faces. Decking on both faces is recommended when palletloads are double-stacked, to spread the weight of the upper load more evenly over

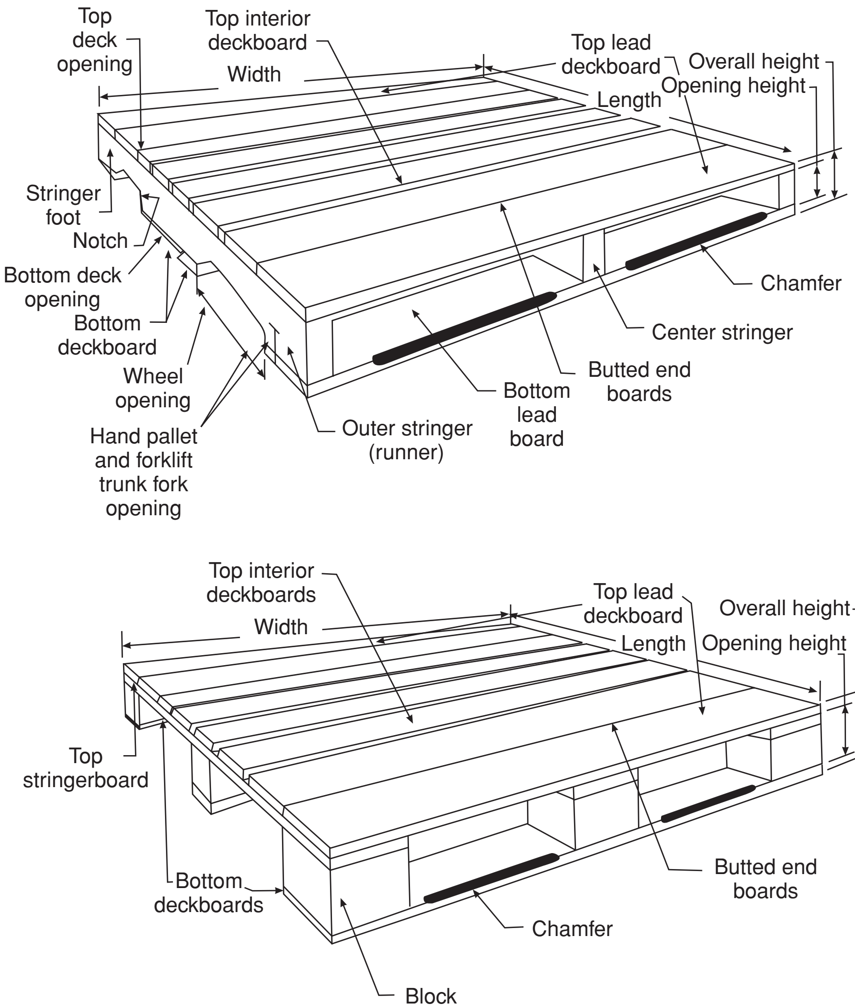

Fig. 4.3 Four-way entry pallets with stringers (top) or blocks. (National Wooden Pallet and Container Association (1998). Reprinted with permission.)

the lower one. The decks can have varying numbers of horizontal boards. Wide gaps can cause damage since boxes can deform into them.

Other platforms include slipsheets, carts and racks. Carts, racks and plastic pallets are often used to deliver orders from a DC to a store. The choice of a platform system depends on the operational requirements. For example, plastic pallets are preferred by many retailers for store delivery because they are lightweight, and have a clean appearance, compared to wooden pallets.

A slipsheet is a flexible platform made from a sheet of heavy fibreboard or plastic. They are used because of their low cost and minimum cube usage. However, special handling equipment is required to be used by both the shipper and consignees. A special kind of lift truck attachment pulls the sheet onto a polished steel platform that carries it on the front of the lift truck. To set it down, the attachment pushes the load off the platform. Another special kind of equipment is a clamp truck. It grabs a load between platens and squeezes it with enough pressure to be able to lift it as a unit and carry it in its clamps. This is used for lightweight sturdy unit loads of products like toilet paper and breakfast cereal cartons.

It is important to note that slipsheet and clamp handling are often used for the benefit of the shipper who wants to eliminate the cost and cube of pallets. But many wholesalers and RDCs can only handle conventional pallets with their forklifts, because they do not have specialised equipment to receive the load. They use the forks of an ordinary forklift to scrape unit loads off the floor or to separate stacked units, and then place them on pallets. This causes damage and inefficiency. Such specialised types of unit loads are best used in a more integrated supply chain where all participants can be persuaded to use the same handling methods.

There are a number of materials that can be used to restrain a unit load. Polyethylene stretchwrap is the most common. Stretchwrap can be applied either manually or mechanically. The turntable type of stretch wrapper is the most common mechanical method: the load spins while a roll of film is played out in a spiral manner up and down the load. The manual applications are usually found in warehouses, where the order pickers wrap mixed loads as they stage them. Whichever method is used, the wrap should be as thin and tight as possible without crushing the load.

Other unit load restraint materials include polyethylene shrinkwrap, polypropylene strapping or quick release adhesives. Since shrinkwrapping requires more energy than stretchwrapping, it is less popular. It is used mostly as thick covering for unit loads intended to be stored outside. Strapping or tape, sometimes used around the top two layers of a load adds a minimum level of stability. Pallet stabiliser adhesives applied between layers of boxes provide sheer strength, but allow the boxes to easily pop apart when lifted. Tape and adhesives should be used in cases where they do not damage the outer surface of the shipping container, or where such damage is not considered a problem.

The pallet pattern is generally determined by the dimensions of the shipping containers. To maximise transport and handling efficiency, there should be no wasted space or under-hang; and over-hang is also to be avoided because it causes damage. Cubic efficiency can be improved by designing shipping containers to better fit the footprint: most grocery pallets in the USA are 48″ × 40″; in Europe, most conform to the ISO standard of 1200 mm × 1000 mm. There is less than an inch of difference between the two standards, and, for a given box dimensions, some of the same pallet patterns can be used.

A number of computer programs are available for optimising a pallet pattern, given the size of shipping containers. They can also be used to optimise the size of the shipping container itself as well as the primary packages inside, given the dimensions or volume of a product. Sometimes a very small dimensional change can result in dramatic transport savings. The pallet cube optimisation programmes have been found to be especially valuable for long distance shipments, exports and fast moving consumer goods, where transport savings add up quickly.

4.6 CONCLUSION

This chapter has shown the importance of logistical packaging to a supply chain's operations. Packaging should be considered at an early stage of product design. Ideally, the primary package, the shipping container and the unit load should be considered as an integrated design problem.

The size, shape, weight, and properties of the primary package and the nature of its contents will determine the requirements for the logistical packaging, given the characteristics of a particular distribution channel. Changes to the product or primary package for reasons of cost savings or marketing improvements will very likely have an impact on the performance required as well as dimensions and unit load efficiency.

The objective of logistical systems is to deliver food products and raw materials to the right place, at the right time, at the most effective total cost. Packaging adds value only when it serves these objectives.

REFERENCES

American Society for Testing and Materials (2009) *Standards and Other Documents Related to Performance Testing of Shipping Containers*. ASTM, Philadelphia.

Fibre Box Association (2005) *Fibre Box Handbook*. FBA, Rolling Meadows, IL.

International Safe Transit Association (2009) *ISTA Resource Book*. ISTA, Lansing, MI.

Twede & Goddard (1998) "Packaging Materials", published by Pira International.

FURTHER READING

Bowersox, D.J., Closs, D.J. and Cooper, M.B. (2009) *Supply Chain Logistics Management*. McGraw Hill Irwin, Burr Ridge, IL.

Fiedler, B.M. (ed.) (1995) *Distribution Packaging Technology*. Institute of Packaging Professionals, Herndon, VA.

Friedman, W.F. and Kipnees, J.J. (1977) *Distribution Packaging*, 2nd edn. John Wiley & Sons, New York.

Gustafsson, K., Jonson, G., Smith, D. and Sparks, L. (2009) *Retailing Logistics and Fresh Food Packaging: Managing Change in the Supply Chain*. Kogan Page, London.

Maltenfort, G.C. (1988) *Corrugated Shipping Containers: An Engineering Approach*. *Jelmar*, Plainview, New York.

Maltenfort, G.C. (ed.) (1989) *Performance and Evaluation of Shipping Containers*, *Jelmar*. Plainview, New York.

McKinlay, A.H. (1998) *Transport Packaging*. Institute of Packaging Professionals, Warrenton, VA.

National Motor Freight Traffic Association (annual) *National Motor Freight Classification*. NMFTA, Alexandria, VA.

National Wooden Pallet and Container Association (1998) *Uniform Standard for Wood Pallets*. Alexandria, VA.

Schaffner, D.J., Schroder, W.R. and Earle, M.D. (1998) *Food Marketing: An International Perspective*. McGraw-Hill, Boston.

Twede, D. and Parsons, B. (1997) *Distribution Packaging for Logistical Systems: A Literature Review*. Pira, UK.

Yam, K. (ed). (2009) *The Wiley Encyclopedia of Packaging Technology*, 3rd edn. John Wiley & Sons, New York.