2

Logistics in Manufacturing Organisations

Strategically managing the procurement, movement and storage of materials, production of *parts and* despatch of *finished products and the related information flows*, into and *through the organisation and its marketing channels* to meet customer needs for goods and service and *to achieve sustained profitability by cost-effective order fulfilment*.[1]

Objectives

- To analyse the functions required in a manufacturing link of a supply chain and design them as a sub-system which transforms materials into goods and relates effectively to immediate supply chain companies, for a specific industry
- To plan effective link structures and trade-offs between functions which would achieve the customer service and profit aims of logistics in a chosen supply network for products using the tools provided
- To consider the parts played by provision, inventory, transport and purchasing in the logistics of a manufacturing organisation
- To examine the more effective use of people to manage and improve the logistics performance of the link, hence satisfying end customers

INTRODUCTION AND ASSUMPTIONS

This chapter describes the supply chain tasks of achieving production flow within a plant so that the materials received are effectively converted into finished products. It includes delivery of parts and material from suppliers and shipment of goods to the plant's immediate customers, commonly referred to as *door to door**. Four sub-sections examine the operations of logistics in one link of the supply chain: order-taking, provision, transport and inventory. Information communication systems are described where they occur, within functions, rather than separately.

A number of tools for analysing supply chains are introduced. These tools include arrangement of functions, inventory management and performance measurement. The majority of the tools are qualitative, such as the effective arrangement of logistics functions, rather than quantitative techniques. We consider many of the quantitative techniques proposed to be less useful in real situations than in gathering strategic information for a management team to make a qualitative business decision. Further analysis tools are introduced in later chapters.

While this chapter mainly considers manufacturing organisations in which input materials are *transformed** into finished products, much of the material can be applied, with a little thought, to many service businesses. Chapter 3 develops the material specifically for service organisations.

In the first half of this chapter, we make some simplifying assumptions about the link studied because it is only part of the supply chain system. Generally the link will comprise one plant owned by one company at a single location. This company link intends to continue its present range of products while making sufficient profit and increasing turnover. Its marketing objectives are to serve current customers excellently while increasing the range of products and market share. The people working for this company are content to make familiar products and services which compete successfully rather than being intent on transforming the company. Similar logistics processes and tasks will be required in other links which supply materials and services or which receive goods and services from this plant. Connecting all the links into a chain is addressed in Chapter 6.

From section 2.6 onwards, we move from existing products to examine the effect of new products and services on this central link of the supply chain. The section on 'Supply development' delves into the new logistics systems which the manufacture of innovative products by new processes will require. Next, a section on 'Departmental links and business strategy' considers the connections of the logistics link with other functions and with the company's overall business strategy. 'Lean management and leadership' looks at the critical human dimensions of managing product flow in a plant involving decisions, tasks, training and steering. Since changes are happening all the time, the last two sections introduce 'Performance measurement and improvement' and the boundaries of a link in a logistics network.

2.1 BRIEF HISTORY OF INTEGRATED LOGISTICS

Logistics was originally used in a military context, meaning all the support actions necessary to keep an army in the field, fighting a war. Fifty years ago manufacturing and service companies did not have a logistics function. Generally, customer service was handled by the sales department. Inventory was managed by manufacturing or sales according to location. Suppliers arranged inbound transport and outbound transport was booked by someone in the sales department.

In the intervening period, many companies have created a logistics function to look after an increasing proportion of movement and storage functions. Typically, logistics manages, or is strongly involved in:

- order-processing,
- purchases,
- inbound transport,

- production plans and schedules,
- inventory management,
- distribution and delivery transport,
- warehouse management, and
- several information systems such as customer response management, materials requirements planning and distribution requirements planning.

For example, an Australian company, which we will call Innovation Plastics (IP), has a Manufacturing Resources Planning system which deals with many of the above functions. IP supplies a range of moulded plastic parts to Ford Australia to assemble into cars. The General Manager Logistics of IP uses this information system to manage all of the above functions except distribution and finished goods inventory. These two functions are not required at IP because Ford only ‘pulls’, or sends immediate delivery requests for the required car components.

Since logistics is a relatively new function, some companies have moved only part way along this change in organisation structure. It follows that directors and chief executive officers are unlikely to be logisticians. In many cases they lack an appreciation of the potential contribution of the logistics function. Instead they tend to treat link logistics as an area of cost and ‘menial’ operations which is more often controlled than consulted.

Paradoxically, this move to have a separate logistics function comes at a time when management is moving towards processes, away from functional departments. We favour a company which emphasises processes, such as order fulfilment and new product development, over functional departments looking after production, marketing or logistics.

2.2 LOGISTICS OPERATIONS FUNCTIONS

The general relationship between four key logistics functions in one link, of one company or plant, is shown in Figure 2.1. Some functions, such as order-taking, occur at one position in the plant while others, such as transport, occur in various areas. We can use this simple diagram to review the health of each function and the existence of other functions which may not be necessary. The functions must be examined in each link of the supply chain: if there are five links, there are twenty basic functions. The next four sections describe each of the key logistics functions.

2.3 ORDER-TAKING AND FORECASTING DEMAND

Order-taking comprises the receipt of orders in the supply chain product range from customers, their checking to ensure that they fall within the manufacturing capability and financial guidelines, and the response to customers that goods are available, or can be made, plus a delivery promise and price.

Transmission of an order from the customer is frequently made by facsimile or electronic message and it is often preceded by an order forecast. Checks carried out by the manufacturing company include ensuring that the customer is able to pay, and they

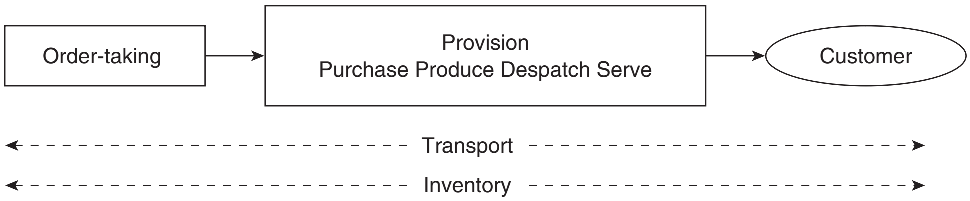

Figure 2.1 **Logistics operations functions**

are frequently carried out by computer program. Once the order has been received, a number of steps are needed to provide the products to customers, that is the adjacent customers in the next downstream part of the supply chain. This is called *provision.*

A tremendous variety of orders exist, according to the type of sale, whether the customer is a company or an individual and whether the product is a commodity or a customised item. Orders typically comprise a number of line items, perhaps 10 to 20 *stock-keeping units** (skus) which the customer requires as one delivery. Even though *forecasting** *demand** is not one of the operations functions, it is convenient to include it at this point because it is an early estimate of likely orders.

Although a fast response is the key to good provision of goods, forecasts are important to give the producing firm some information when it cannot make goods in an acceptable period after the order is received. Many companies operate on a mixture of actual and forecast orders. Under current practices, companies which are more distant from the end consumer have to rely on a greater proportion of forecasts and order amendments. A forecast of demand is therefore a critical management tool. The better this forecast is, the better an organisation can prepare for orders, avoiding the costs of over or under provision of goods. So a forecast is calculated, based on previous ordering patterns, and the accuracy of the forecast is *also* calculated. Preferably the forecast is varied according to current commercial knowledge, such as one-off changes due to disasters or industrial action.

Several matters should be considered in deciding the approach to forecasting:

- A single forecasting process should be used for the whole supply chain. This process should be applied at the link adjacent to the customer and the information should be shared with all chain partners.
- A time-series forecast of sales units at an aggregate level is calculated by a forecasting package. The package stores a time-series of sales over the previous 20 time periods. An equation is used to estimate the most likely level of sales in the next period. Equations frequently used are moving average (in which the forecast is the average of a number of previous periods) and exponential smoothing (a weighted average of previous periods in which more recent periods receive more weight). Often allowances for seasonality are also made.
- Management judgement by a number of internal experts from relevant company functions to improve upon the time-series forecast.
- Forecast accountability can be improved by reviewing their accuracy. Otherwise there is a danger that staff responsible for sales will prepare low forecasts, so that they are easier to achieve.

Significant improvement in forecasting requires close collaboration between supplier and buyer. A promising process is Collaborative Planning Forecasting and Replenishment (CPFR).[2] In CPFR both parties enter into an agreement to align their plans. When one party creates the sales forecast, exceptions due to new product introductions, etc. are agreed. This process of forecast and exceptions is followed through into order forecasts and firm orders. CPFR moves away from excessive reliance on past sales data but it has been found to be very labour-intensive.

2.4 PROVISION

*Provision** comprises the *processes** of purchase, produce, despatch and serve. Provision aims to achieve perfect flow by encompassing all the activities required to source *materials** from upstream links, to make products and to deliver them to the premises of the next link in the supply chain. It also includes the services, which each link company requires to carry out these processes, and the concomitant services needed by customers as part of their products, such as training in their use and after-sales service.

First process, purchasing

In the first process, purchasing is the whole relationship with numerous suppliers to effectively obtain all the inputs required to produce the link's output of goods and services. The purchasing process requires:

- appointing a number of companies capable of providing raw materials and component parts,
- placing purchase orders on the appointed companies to deliver quantities of materials sufficient for the manufacturing process. A typical order specifies the materials by a reference number, gives the quantity required and delivery date, and states the place of delivery,
- receiving materials and components on time, and
- evaluating suppliers to ensure that they are achieving promised deliveries.

Many companies negotiate 'blanket' orders with a supplier for a year and then operators tell the supplier the actual quantities and types of materials each day.

The above is the 'running' relationship with suppliers. This 'running' relationship depends upon a supplier discovery process which involves specifying the product needed, finding potential supply companies, working out which are capable of supply and then negotiating a commercial relationship. This discovery process is considered in section 2.6.

Supply has become a very intricate process because of the manufacturer's requirement for very low defect rates, just-in-time supply of components, and the ability for working groups of employees (or purchasing departments) to inform the supplier of the precise types and quantities of materials required.[3] Mass production manufacturers require suppliers to deliver the exact quantities requested, with defect rates in a low number of parts per million, so that the manufacturer is not required to inspect the components before using them. Just-in-time supply entails the manufacturer informing the supplier of the number and types of requirement very shortly (usually hours) before they are to be delivered to the factory.

There is a current emphasis on reducing the number of suppliers with whom a manufacturer deals from hundreds to tens. This can be achieved by the preferred suppliers increasing their range or by their assembling a *module** which incorporates both their own components and those from displaced suppliers. This reduction assists the manufacturer to deal more closely with the limited number of surviving direct suppliers. Manufacturers can now use electronic links, such as EDI or the Internet, to send messages instantaneously and automatically from their factories to suppliers. Planning systems typically provide a module which enables this electronic transfer.

Second process, production

The second process, production, or manufacturing, comprises all the steps required to convert raw materials and purchased components into required forms and to assemble them into a finished product and, by design and quality assurance, to ensure that those products achieve the customer-mandated specification. Production is carried out in a factory where machines convert the materials into the desired product. Quality assurance is achieved by:

- design which provides the necessary product capabilities,
- design for manufacture,
- quality trained operators,
- quality achievement in production by 'zero-defect' practices such as machine capability measurement, quality control charts, quality improvement tools (pareto curves, fishbone diagrams, etc.), and
- total quality management (TQM) philosophy.

From a logistics perspective, important differences in manufacture are whether the product has been made previously or whether it requires engineering design before it can be manufactured. This, and the preparedness of the customer to wait for a product, such as a car, rather than require it to be immediately available, such as food, leads to three different timings of manufacture relative to customer requirements:

- engineer to order,
- manufacture to order, and
- manufacture to stock.

Assume that the product is already designed and it is being manufactured to an order or to stock. Design and engineer-to-order situations are examined later in this chapter. Typically production requires a number of steps which gradually change the materials into all the required components. The components are then assembled into the finished products. This is illustrated in Figure 2.2 in which boxes labelled 'P' are manufacturing processes, ellipses labelled 'A' are assembly steps and a triangle represents an inventory location.

In this stylised production process, there are three manufacturing steps and two assembly steps. The arrows show materials handling between steps. Such handling may comprise movement by a person, a vehicle (such as a forklift truck) or a conveyor.

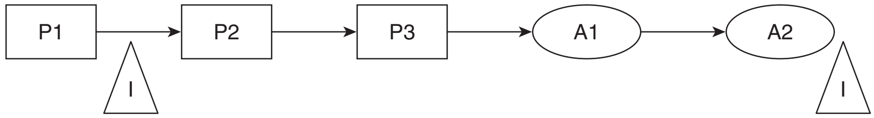

Figure 2.2 Elements in the production process

(P = production, I = inventory, A = assembly)

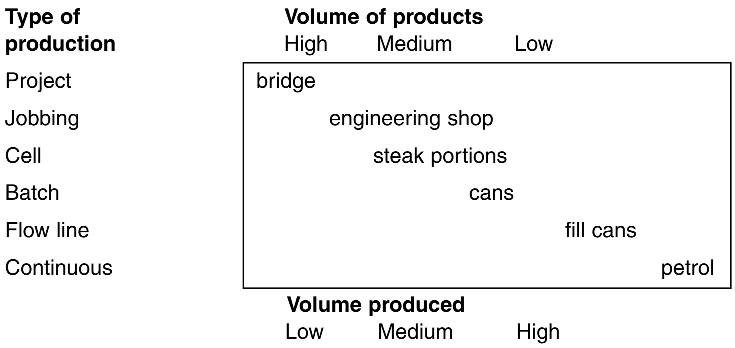

Figure 2.3 Production responses to variety of products wanted

The triangles show inventory, or work-in-progress, which can occur between any of the manufacturing and assembly steps. Practical production processes are usually more complex than Figure 2.2 indicates because different steps are used for different products, so there is a network of production steps, rather than the linear situation indicated. Also there are several different types of manufacturing process, ranging from jobbing (in which materials move between separate machines according to the precise work required for an individual product) to flow line (in which materials are moved by conveyors in a fixed route between all the machines required). Production can take many different forms, as illustrated by the case about making sausages (at the end of this chapter pp. 62–8) on a flow line compared to the batch manufacture of sweaters by Benetton (Chapter 1, Box 1.1, pp. 3–4).

Important considerations in production are the batch size passing from one step to the next, the quality attained at each step and the number of different products. Different types of process are needed to make high versus low varieties of product. The results of research by Hayes and Wheelwright[4] are illustrated in Figure 2.3. Ignoring the extremities, this figure shows how a jobbing shop can make small runs of a high variety of products, such as vintage car parts. At the low end of the left-hand scale, a flow line can fill soft drinks into cans in very high volumes.

Whereas manufacture makes or transforms parts, assembly requires a variety of parts to be fitted together. Typically 10 to 100 parts are assembled down a flow line by people and automatic machines. Then the assembled product is packed for protection on its journey to the customer. Packing entails wrapping the product for protection and to keep it in good condition until it reaches the customer, and to identify the product on its journey. Frequently, the product is built into a stack, in a case or on a pallet. This is known as unitising and it helps to reduce handling and errors during transport. *Unitisation** develops sufficient volume of products to be economically transported to the customer or an intermediate warehouse. With increasing frequency, provision includes after-sales service to the product. This was noted above in the automotive manufacturing case.

Manufacturing can take place at one factory or it can be broken into a number of stages at different factories. An example of this is the disassembly process of meat (refer the sausage case at the end of the chapter) which is shared between boning and small goods manufacturing 'factories'. Movements between processes in the factory, called *materials handling**, form an important part of production. Materials handling is described in section 2.5.

Provision information

In this section we examine the key functions of *Manufacturing Resources Planning (MRP)** information systems and the management purposes that they perform. Figure 2.4 outlines the main types of data and information used in provision. A full description of MRP function is given in section 5.4. MRP systems store the product structures and product routes through the plant and quantities required to produce a finished product. The systems also store and collect related data such as costs, inventory, yield and quality.

Key management decision and information recording functions are as follows:

- Driven by a business plan or budget, a resource plan is made for the production processes, the operators and the supply of materials.
- Order forecasts are made and displaced by actual orders as they arrive.
- Sales and operations planning is a procedure by which production, logistics, sales and other responsible managers use the extant data to decide the provision levels for the next month, as a compromise between their varied preferences.
- A *master production schedule (MPS)**, which states the quantities of finished goods required to satisfy orders held or anticipated over 10–15 future weeks, is derived and stored. A production schedule is a list of the end products and quantities to be manufactured over a period of time, such as a week (see Table 2.1). The items are given in the sequence of manufacture. This schedule indicates that, in week one, operators are to produce 17 pallets of sausages beginning with one pallet each of Bratwurst, pork, and honey and soy, and half a pallet of Halal.
- The correct product structure, by which materials and components can be made and assembled into a product, is stored.
- The routes which products must take between various machines are stored.
- *Materials requirements planning (mrp)** is a complicated calculation which converts the MPS into a time-phased list of the quantities of materials, components and subassemblies required to make the required products. It draws on product structures, inventory status, manufacturing lead times and routes and checks the availability of capacity to do this.
- Work orders are a document output by the mrp which tells the machine operators what to do. They go ahead and produce components and assemble them into products according to these orders.

Table 2.1 **Production schedule for sausages at Bradley**

Sausage type	**Week 1**						**Week 2**	**Week 3**	**Week 4**
	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Total**			
Bratwurst	1	1	2		1	5	5	3	2
Pork	1	1		2	1	5	5	2	3
Honey & soy	1		1		1	3	2	1	2
Hungarian		1		1		2	3	2	1
Halal	0.5		0.5			1	1	0.5	
Chicken		0.5			0.5	1	1		0.5
TOTAL	3.5	3.5	3.5	3	3.5	17	17	8.5	8.5
CAPACITY	5	5	5	5	5	25	25	25	25

- Purchase orders, generated by the mrp, tell vendors the quantities of materials and components required to make the products.
- Production activity control to measure and summarise events for managers to review and take corrective action as necessary.

Third process, despatch

The third process, despatch, covers activities of assembling an order of finished goods at the manufacturing plant and movement to the customer's premises. The first physical activity is order assembly, which requires an operator to bring together each line item from areas of the plant and package them on to pallets or into containers for despatch. The operator checks that all the items that the customer requires are included. The complete order is then loaded on to vehicles and transported by a truck driver to the customer. These transport terms are general: vehicles could be rail trucks or aircraft and truck drivers could be train drivers or pilots. The various vehicles may be operated by the manufacturer, the customer or a transport company. In many cases despatch is bulk transport of large quantities of goods, which will require breaking down in the distribution process into consumer quantities. The key piece of despatch information is the despatch advice which informs the customer exactly which goods are being sent in a delivery at a particular time. Other information flows are invoices, and the list of finished goods inventory at the plant.

Despatch is part of the wider process of *distribution*, which follows products from the manufacturer through various journeys and middlemen until they reach the end consumer. Distribution comprises these components, many of which are described in the next sub-section:

- bulk transport from factory to *distribution centre**,
- distribution centres (DC) are product warehouses serving a customer region by receiving, breaking bulk, storing, picking and assembling products to customer order,
- despatch from DC to customer premises, known as *delivery,*
- DC transport covers cross-docking, where goods enter a DC, are repacked and despatched without being stored, and time-slotting, where the truck coming to the

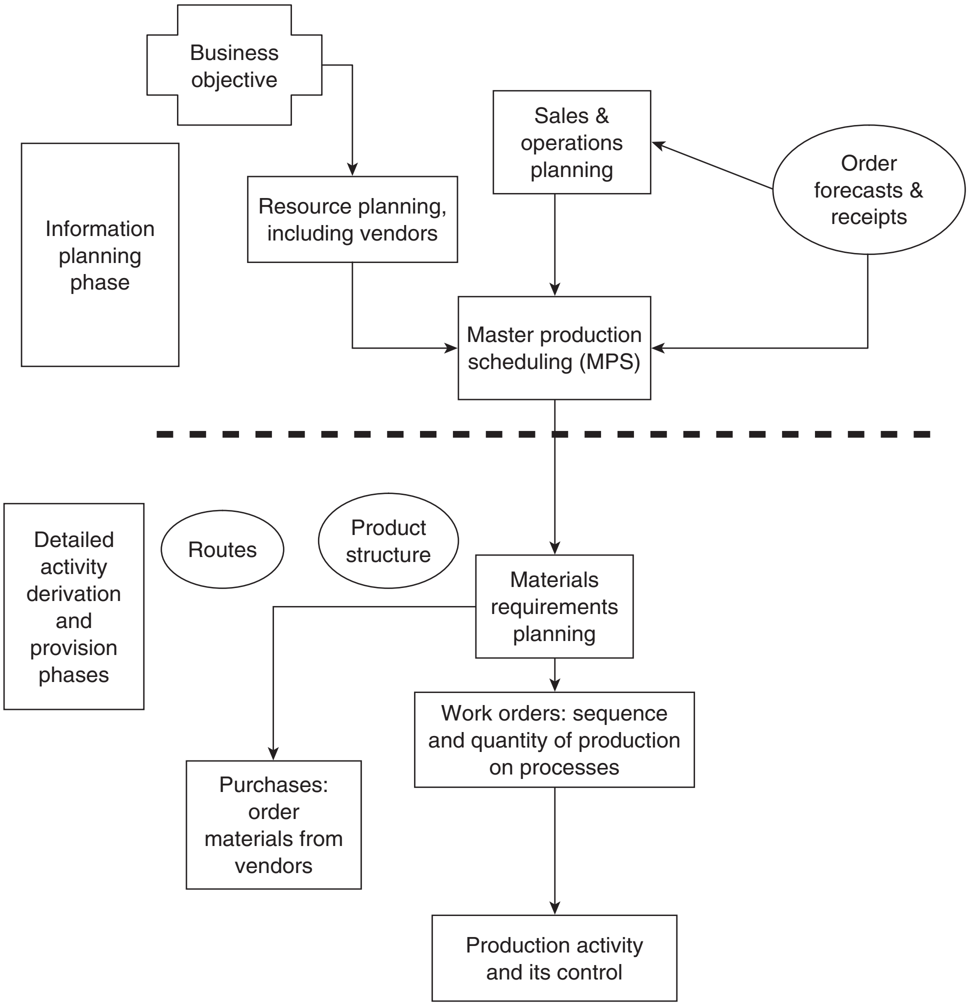

Figure 2.4 Main components of MRP systems in outline (after Vollmann et al.[5])

Source: *Manufacturing Planning and Control systems for Supply Chain Management*, 2005 by Vollmann TE, Berry WL, Whybark DC and Jacobs FR reprinted with permission of The Mc Graw-Hill Companies

DC is given only a short window of time (say 11 to 11.15 am) when his goods will be accepted,
- semi-trailers, or articulated vehicles, loading several destinations,
- transport routing problems (see section 2.5),
- coordinating with 'second tier' customers: product tracking, and
- inventory control and information in distribution, especially *warehouse management systems (WMS)* and *distribution requirements planning* (see section 5.4).

Distribution centres

An important facility for despatch of many retail products is a distribution centre (DC), a type of warehouse, which plays a very important part in the outbound distribution of goods. A DC receives a wide variety of products from manufacturers in bulk and performs these tasks:

- breaking down bulk product quantities into customer-order quantities,
- storage,
- picking to assemble a 'shopping-list' of required goods, and
- fast response to customer order.

A distribution centre typically stores hundreds or thousands of different items in pallet locations arranged in bins along parallel aisles and vertical columns in each aisle. The tasks are achieved by forklift trucks moving pallets around and storemen picking goods from bins with the help of trolleys. In large volume situations, conveyor belts replace trucks to move goods around in cartons.

Distribution centres are frequently linked to factory warehouses and other DCs by distribution requirements planning (DRP) systems. These systems show the stock at each point and the actual or anticipated demand by customers for 8–10 forward periods of, say, a week. The visibility from any point of the whole current picture, and its estimated future situations, enables a high level of customer service to be obtained without excessive inventories being maintained or too many transport movements.

The situation within each distribution centre is managed by a warehouse management system (WMS) which shows the exact current status of each location, the receivals, picking and despatch planned for the current shift and the work status of each storeman or vehicle as they carry out the movement of goods required. The WMS is fed by storemen reading the *barcodes** of each pallet or carton of goods which they move. The overall effect is a very powerful measure of the performance obtained which, if used in a non-threatening manner, can enable the operators to improve their practices.

Fourth process, logistics customer service

The fourth process is service, which refers to all the functions of provision where there is no physical part or product involved. Logistics customer service refers specifically to the service parameters of product delivery and to concomitant services, such as warranty and after-sales service. Many services are necessary to purchase materials, produce goods and despatch them. Consider the training of operators, maintenance of machines, quality advice, cleaning services and technical services provided by engineers or scientists. These are examples of less visible functions, just as important to the provision of the finished goods as the physical components. Information is an important service which is fully developed in Chapter 5. Management itself can be viewed as a service, rather than a control in the modern view of empowered operators (see section 2.8).

Service also refers to a range of intangible 'services' which the customers want to enjoy for their own sake or to complement a physical product which they buy. A customer who has ordered a dining table from a furniture manufacturer wants to know whether it will be delivered on the day promised; a sales manager in Ireland needs to check whether the samples despatched from his parent company in Europe have been delayed on the way; a woman who bought a Ford car three months ago wants it to be checked and serviced.

A useful current view is that almost all manufactured products comprise physical and service parts. A meal in a restaurant comprises both the food and drink and the service of having all the tasks associated with cooking, taking the food to the table and cleaning cutlery and crockery carried out for the diners. Whereas ten years ago car manufacturers sold a car with a restricted repair warranty, now they provide the expected services for a number of years.

Provision dynamics

Provision also has a number of dynamic and performance-enhancing effects. Such effects must be included to get a proper representation of the way in which provision works in practice. Important dynamic effects are queuing, learning curves, and the use of simulation and iteration to get the system of machines, operators, external suppliers and information working well.

Queuing refers to the existence of work-in-progress or unit loads of parts waiting for the next process, or an operator or permission to be completed. In old-style purchasing, manufacturing and distribution managers frequently protected their operational efficiency by inventory or safety stock in warehouses and between processes. Figure 2.2 shows an example with inventory being held between production processes 1 and 2 to lessen the chance that process 2 is delayed. While there are a few situations in which queues are necessary, such as if your raw material comes from overseas, inventory is generally seen as waste, an extra cost which extends lead-times and gets in the way of effective provision. Under lean principles (see section 2.9), providers are exhorted to restrict work-in-progress between machines to a few hours of production. The same applies to deliveries of raw materials and 'bulk' stocks in warehouses and distribution centres except where rapid customer response overrides other concerns.

Learning curves are an important factor in new or modified processes. Especially where people are involved, manufacturing and distribution tasks tend to take considerably longer when first carried out. Research[6] has shown that most processes can be done, say, 12% faster as the number of replications is doubled. This exponential improvement can continue until a change occurs, when a regression followed by further learning improvement is likely to occur. An example of this is building a new ferry for short sea trips. The fourth ferry takes 40 days to build, the eighth takes 35 days, the sixteenth takes 31.5 days and so on.

*Simulation** and iteration are important improvement techniques. Discrete stochastic simulation[5] is a technique for studying the interaction of machines, operators and movement and for training operators and supervisors in effective operating decisions. Basically simulation builds a working, hand or computer, model of a process or processes and operates it in 'pretend' time to familiarise operators with the workings of the systems and allow them to try different methods of operation without taking time and money in the real world. The 'stochastic' or variable part comes from the use of sampling distributions rather than average values for important variable-value parameters. Iteration refers to replication of process improvement through simulation or other techniques until a preferred status is reached.

2.5 TRANSPORT AND MATERIALS HANDLING

Next we consider *transport*, the service operation which moves materials and goods between each process in the link and between links in the supply chain. Transport is examined from the point of view of managers operating the provision link in the supply chain. Many transport companies think that the movements they provide are strategically important to the delivery of goods to customers. Such companies are busy integrating between the various movements so that transport efficiency is optimised. We believe that the importance of this efficiency is limited to a range of resource materials such as grain, coal and timber. For other, more customised, parts and products, transport is simple (e.g. shift a container of toasters from Europe to USA) and many competing carriers are available. For this kind of product, transport is not strategically important to the supply chain. Transport decisions can be taken at an operating level.

The objective is to use information about the task to choose the most appropriate *modes** and types of *transport** for various movements of materials, components and goods in a number of industries. The aim is to obtain cost-efficient transport routes from supplier to factory and from factory to customer. First, we look at external transport modes and types, then materials handling between processes in the factory is examined.

External transport components of the link have changed considerably, with outsourced providers of transport and warehousing services frequently replacing the traditional in-house approach. This is caused by the transport company developing a greater skill in the movement of goods than that which the manufacturer of the products has. The producing company does not see transport as a core activity and therefore uses the transport firm to respond rapidly and effectively to an order.

Movements outside the factory include inbound transport of materials and parts and outbound distribution, or delivery, of goods. We will first focus on distribution, the delivery of finished goods and service from the factory to its customers. Secondly, we examine inbound transport of materials and parts to the factory. Materials handling, the movements between processes in the factory, is discussed in a separate paragraph.

The transport industry is, itself, a complicated set of services. It comprises many modes, many types, which provide different degrees of responsibility, many travel times which affect the price per cubic metre and inter-modal assemblage to achieve economies over long distances. In this section, we examine the types and costs of transport available before addressing the choice of these elements to carry out a particular transport task. Modes of transport, inter-modal assemblage and international transport are covered in sections 3.8 (Freight forwarders) and 4.1, respectively.

Types of transport

We now examine the various types of transport within the modes, and particularly, within the road mode. Types of transport vary according to the regularity and quantity to be moved and the relationship between the producer and the transport company.

Transport can be hired for an individual journey in quantities ranging from a taxi-truck to a semi-trailer. A taxi-truck carries quantities ranging from a few boxes up to a cubic metre. Larger quantities of pallet loads or loose cargo require a truck or a pantechnicon ('pan') towed by a prime mover making up a semi-trailer. In this case the transport company usually charges per pallet or per box.

More permanent arrangements require a contract carrier in which a transport company agrees to move a certain number of loads per week or to provide a truck and driver for several days per week. For example, the movement of meat (see Table 2.2) six miles (10 km) across Melbourne from the meat packer (boning room) to the sausage manufacturer is carried out by a refrigerated vehicle.

Table 2.2 Examples of journeys by materials and products

Product/material	Journey		Mode	Type of carrier
	From	To		
Confectionery	Melbourne suburb	Distribution centre in Perth	Road	Contract truck
Pig meat	Outer suburb	Inner Melbourne suburb	Road	Hired truck
Pallet of sausages	Inner suburb	Supermarket cold stores	Road	Refrigerated semi-trailer
Steel sheet	Near Tokyo, Japan	Melbourne suburb	Sea plus road	Container ship
Car carburettors	Detroit, USA	Adelaide suburb	Sea and air	Container ship, air freighter
Nissan cars	Durham, UK	Various European companies	Road, rail	Car carrier
Lobster tails	Tasmania, Australia	Los Angeles & London	Air	Passenger aircraft or freighter
Iron ore	Pilbara, West Australia	Japanese steelworks	Ship	Bulk carrier
Wheat	North Victoria, Australia	Port of Geelong, Victoria	Rail	Dedicated train
Beef steak	Meat processor, Hampshire	Various chain restaurants	Road	Refrigerated semi-trailer
Oil and gas	North Sea oil field	Refinery in Scotland	Pipe	Dedicated pipelines

Moving up the scale, a large proportion of product transport is done by *contract distribution** (see *outsourcing**) in which the carrier undertakes to provide all the movement of finished goods from the factory to customer stores. In contract distribution, the contractor quotes its price to provide a stated level of service for all the transport required for a year. When this quote is accepted, the carrier organises the whole goods distribution function. The carrier usually provides a supervisor at the factory who schedules the arrival of trucks and the loading of goods on to them, throughout the working week. He or she also looks after drivers and industrial relations. The journey to the various customers' premises and unloading are also arranged by the carrier. The factory gets a complete service for a known price without any detailed involvement. An example of contract distribution is the delivery of confectionery from a factory in Melbourne to destinations in the city of Melbourne (in contrast Table 2.2 shows that interstate confectionery destinations are handled by contract truck). In some cases, the contract distributor provides warehousing for the products at its site. The more complicated arrangements in which a transport company takes responsibility for an even wider range of logistics tasks is described in Chapter 7.

Historically, most manufacturing companies handled their own transport by their own trucks. This 'in-house' transport is now unusual, but may be retained where a company wants the drivers to carry out an extra task, such as collecting orders or placing the goods on shelves at the destination.

Transport task and decision

It is now possible to decide on the transport required for a particular logistics task. First, define in full the job to be done. This specification must include the quantity, cubic volume, type of goods and any special requirements, such as temperature control, for example moving a pallet of confectionery from Cadbury in a Melbourne suburb to a distribution centre in Perth. Then the choice is:

- which mode?
- which type of carrier?
- what frequency?
- which assembly?
- what price?

Box 2.1 gives an example of this transport decision.

Box 2.1 **Specifying a distribution transport task and choosing the type of transport**

A confectionery manufacturer, Cadbury-Schweppes in Melbourne, Australia wishes to distribute pallet loads of chocolates, bars and related products to a distribution centre (DC) in Perth, some 2,500 km away in West Australia. How should it move these perishable goods? How much is there and how often? Should Cadbury-Schweppes use road, rail or air? Should it go straight to some customers?

Cadbury-Schweppes chose a chilled contract truck direct to the DC because that ensured that the confectionery reached its destination intact, quickly and for an acceptable cost. So, in this case:

- mode is road,
- type of carrier is long-term contract,
- frequency is probably once a week,
- assembly is simple: one refrigerated truck from door to door, and
- price would be a rate per pallet negotiated between the shipper and the transport company.

Information in transport includes time slots and despatch advice and current location. In addition to the distribution of finished goods, described above, manufacturing companies require numerous raw materials and parts to be delivered to the factory. Modes and types of transport are the same as for goods distribution, but inbound transport has some differences. Historically, the main difference was that responsibility for materials transport lay with the supplier of the materials. This is still generally the case but some industries, notably the car industry, have changed to having the manufacturer arrange transport of parts. Factory-supplied transport is called a 'milk run' because the vehicle tours a number of suppliers, very frequently, picking up the exact number of parts required. The change took place because the factory wants a delivery every six hours, say, but does not want to pay for a complete journey each time. In a milk run, the factory only pays for one journey but gets the parts needed from half a dozen suppliers. In many cases inbound parts are delivered according to a *kanban** system of signalling the exact type and quantity of parts required.

Effective use of transport

Manufacturers aim to get the most economical use of transport by improving the utilisation of vehicles. The basic aim is to fill both the weight and cubic capability of the vehicle on every journey without unduly delaying materials or goods. One refinement is back-loading so that a truck, which has delivered product from A to B, is used to bring some goods from B to A, so that it does not return empty. The return goods could be from the same company or from another. An aim of centralised logistics for a company is to use one fleet of vehicles to carry out as many transport tasks as possible. This applies irrespective of whether the fleet is in-house or contractor-operated. Another method to increase vehicle utilisation is to use an in-house fleet to carry a base load of deliveries which are required weekly, throughout the year. Deliveries above the base are then contracted out to a transport firm.

Wider implications of movement between factories and companies throughout the supply chain are investigated in Chapter 7.

Materials handling

Movements between processes in the factory, called materials handling, comprise a range from handling by forklift truck between discrete processes to the use of conveyors and production lines for higher volume transfer of materials. While the technical details of materials handling technology are beyond the scope of this book, this section discusses several methods to handle materials according to the volume of the movement. Refer to section 2.4 for materials handling in distribution centres. At the lowest volume of flow, the manufacturer wishes to get a few materials or parts from one work centre to another in a jobbing shop or a manufacturing cell. This can be done by hand or by a pallet jack, which takes the weight of the materials on its wheels so the operator can pull the materials between work centres. In batch production, the volume has increased sufficiently to require a forklift truck to move boxes full of parts between work centres. At high volumes with limited variety of parts, conveyors are generally used to convey the huge numbers along the flow line between each machine. In some cases, where the handling has to be more precise, an automatic device, such as a robot, is used to move the parts into the exact position required for the next operation.

2.6 INVENTORY MANAGEMENT

Scope of independent demand stock

The final operations function (see Figure 2.1) is *inventory**: stocks of materials, components and products on the way to customers. Inventory in the link, made in advance of customer orders, serves the purpose of disconnecting the link production facility from its suppliers and its customers. It also separates each process in the provision activity. But each increase in inventory increases the time required for a new order to be delivered to the customer. Consequently materials in inventory are now seen as a mixed blessing: most of the emphasis in *lean manufacture** is to reduce inventory at every point. This is very difficult because managers do not decide the levels of inventory. Levels of inventory result from order forecasts, scheduling and production batch-size decisions. Inventory also results from unforseen consequences, such as order changes and quality failures. They are a consequence, not a direct aim.

Our objectives are, first, to identify the different reasons which require inventory to be held at various stages in a logistics link and hence to explain the quantities of goods that should be held to meet customer requirements, and the implicit costs. Our second objective is to appreciate the role of inventory records and other information in inventory control and management. Thirdly, to identify the impact of modern techniques of inventory reduction on conventional stock holding, especially by lean thinking.[6] Fourthly, we consider the special methods of managing inventories of parts and materials. Inventory levels are strongly influenced by forecast demand, which has been covered in section 2.3.

An important division of inventory is between *dependent demand** and *independent demand inventory**. Where manufacture requires many components to complete a finished product, such as the many thousands of components needed to assemble a car, the inventory of components required can be calculated by dependent demand. In dependent demand, a decision has been made to make, say, 450 cars today. Since each car requires five tyres, an inventory (or multiple deliveries) of 2,250 tyres is needed. There is no room for forecasts or management decisions, 2,250 will be required. The demand for tyres is dependent on the decision to make 450 cars today.

The second type of inventory, independent demand, involves stocks, such as cartons of sausage at a meatworks which are sold to numerous customers from finished stock because the customers will not wait for a batch of sausages to be made. Demand from one customer is independent of demand from another. In this case it may be necessary to forecast the anticipated sales of individual sausage types and have managers decide on the stock levels they will aim to keep. Section 2.3 discusses forecasting demand. This section concentrates on independent demand inventory. Dependent demand inventory is discussed further in section 5.4. A later part of this section examines inventories of materials and parts purchased by the manufacturing link.

Why hold inventory?

Although we argue that inventory should be minimised, there are a number of tactical reasons which tend to require stocks to be held. These inventory purposes vary widely between types of business:

- Inventory is required to uncouple production from customer orders when it is not effective to produce individual products to orders taken.
- Inventory is used to *decouple* (disconnect) fast production processes from slower ones.
- Stocks are used to enable bulk transport from the factory to a distribution centre. Goods are transported by the pallet load and the pallet is broken into individual orders at the centre.

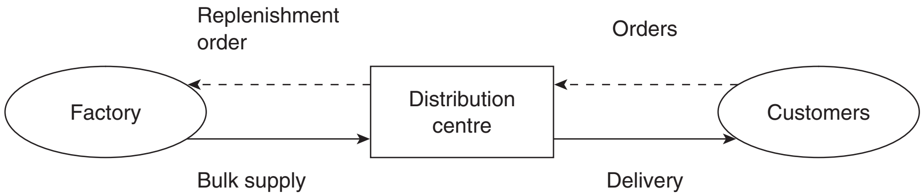

Figure 2.5 **Distribution inventory system**

- Low cost and low volume items, such as nuts and bolts, are held in inventory to save the cost of bringing in supplies frequently.
- Safety stock is a buffer against uncertain demand for products. Sales of products such as ice-cream and beer may vary because of the weather, so a stock is held. A retailer may hold stock because he or she is unsure when a delivery will arrive.
- 'Supermarket inventory' denotes stocks which are available for customers, of various kinds, to pick from without notice. This is a service to the customers. The higher the service level provided to customers, the greater level of stocks that must be held to ensure that level is attained.
- The geographical location of customers relative to producers may require local stock to be held because of the journey time.
- Seasonal inventory is necessary when a product, such as tomatoes, can only be produced for tinned tomatoes at one time of the year. The tinned tomatoes are produced over a period of several weeks and then sold over a year.
- Seasonal sales peaks usually require goods to be manufactured over several months prior to sale. So Easter eggs are produced many months before Easter.

Distribution inventory system via economic order quantity (EOQ)

For simplicity we examine the inventory required at a manufacturer's distribution centre which supplies a range of products to retailers (see Figure 2.5). The situation is *independent demand* in which customers are placing orders on the distribution centre which the centre delivers to them. The centre places replenishment orders on the factory which the factory delivers in bulk to the centre. Here we look at decisions of when to order and how many to order for one product. In the later section, ABC inventory groups and policies for a whole range of goods are examined.

The first step is to look at actual stock movements for the product, which we will assume to be cartons of tissues. Important insights can be gained from looking at daily movements of stock over an extended number of weeks (see Figure 2.6).

Although this step is rare in industry, it is vital to understand the inventory system that we are considering. Looking at the graph of actual stock, you can observe rate of sales, restocking and stock-outs.

*Economic order quantity (EOQ)** is a useful way to approach the inventory decisions of how much to order and when, although its answers must be used with care.[7] The 'saw-tooth' graph in Figure 2.7 shows a stylised version of the stock movements for the product illustrated in Figure 2.6. This chart shows how stock on hand starts at the quantity

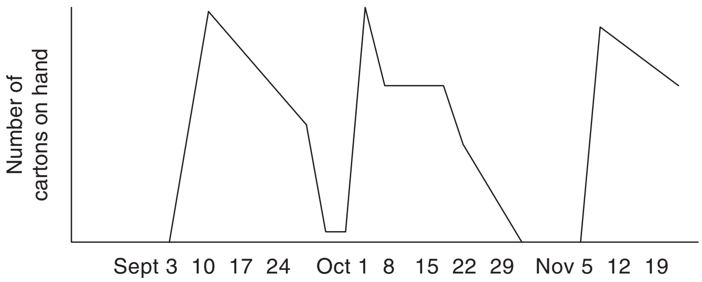

Figure 2.6 Tissue carton stock at distribution centre

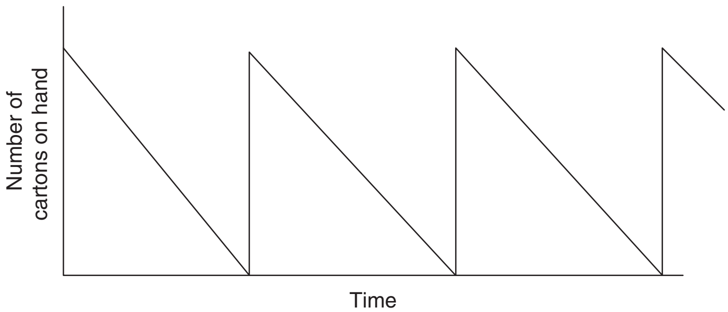

Figure 2.7 Underlying inventory cycles for working stock for one product

ordered, decreases as sales are made, increases as an order quantity is received just as stock runs out and then this cycle is repeated. The chart assumes that sales occur at a steady rate and that the reorder period is exactly known, so that the new order is received at the point of zero inventory. A further assumption is made that there are only two costs involved in having inventory, the carrying cost of having valuable product in stock and the cost of placing an order.

What causes these cycles? Assume that there are 200 cartons available at the left-hand side of Figure 2.8. Sales are made at 20 per day so the present stock will be exhausted in ten days. An order for stock will be delivered in two days so we must place an order when the stock falls to 40 cases. We examine the stock on hand and, when it falls to 40 cases, we place an order for 200. The order quantity, 200, is determined by the economic order quantity method, which is explained below, and an example calculation is given in Box 2.2.

The first cost to consider in EOQ is the inventory carrying cost, the expense involved in maintaining inventory. The carrying cost is the interest forgone on the value of the average amount of product held in stock. The value of product in stock is its current (wholesale) price. The average stock on hand is half the maximum, since the quantity fluctuates steadily between the maximum and zero, at the bottom of the cycle. The interest forgone is usually taken as the annual interest rate paid on the company's

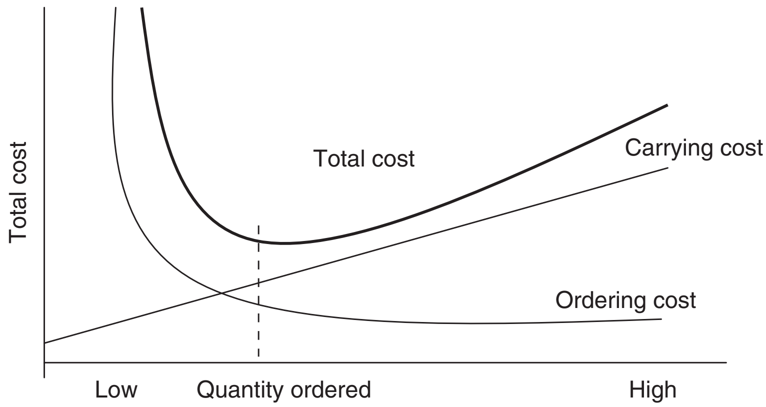

Figure 2.8 **Economic order quantity cost trade-off**

overdraft for the stock value, plus direct costs of storing the goods. Carrying cost increases as greater average inventory is held due to larger order quantities. The second cost is the annual expense of placing orders for that product. The ordering cost is the cost of placing orders a number of times through the year. Ordering costs decrease with larger order quantities because less frequent orders are required.

The economic order quantity is the amount ordered which will balance carrying cost against ordering cost. The minimum total cost occurs at the point at which the carrying cost is equal to the ordering cost, as illustrated by Figure 2.8. This EOQ cost trade-off is a plot of estimated cost incurred for a number of order quantities (x-axis). The straight carrying cost line represents the cost of holding inventory in stock at various order quantities. The curved order cost line is the cost of placing orders on the supplier. Adding these two cost curves together gives a total cost curve which is minimised at the EOQ order quantity. You must consider carefully which *real* costs are used in this calculation for your situation.

Box 2.2 Example of economic order quantity calculation

Kleenex Ltd holds cartons of facial tissues at a distribution centre (DC) to serve 20 convenience stores. On average each store sells one carton of these tissues per day. So the demand is 20 per day (d) or 7,000 per year (D), since the stores are open 350 days per year. How many cartons of tissues should the DC order from the manufacturer? Each carton has a cost (C) of $72 since it contains 32 kilograms at a wholesale cost of Aus$2.25 (£1) per kg. The cost of ordering (O_c) tissues is $4.30 per order and orders always arrive in two days (LT). The interest rate (i) paid by Kleenex on its overdraft is 8% (or .08) per year and other costs of holding inventory are deemed negligible.

(Continued)

Then, EOQ = square root of (2 × Ordering cost × Annual demand)
(Cost per carton x interest rate)

$$= \text{square root of } \frac{(2 \times O_c \times D)}{(C \times i)}$$

Inserting the above numbers,

$$EOQ = \text{square root of } \frac{(2 \times 4.30 \times 7000)}{(72 \times .08)}$$

$$= \text{square root of } \frac{60,200}{5.76} = \text{square root of } 10,451$$

So the order quantity, the EOQ, is 102.2 boxes

When should the DC reorder? It must order when it has only enough stock to last for two days, when the order will arrive.

Reorder point R = daily demand × lead time = d × LT

So R = 20 × 2 = 40 cartons

By reference to Figure 2.8, we start at a stock of 102 cartons. When we go down the line to 40 cartons, we place an order for 102 cartons, which arrives in two days, just as we clear the previous stock. Using this EOQ formula gives us the minimum point on the total cost curve in Figure 2.9 (see p. 53).

The distribution centre now knows how many cartons it should order but when should it place an order? An order should be placed when the quantity on hand drops to the amount that will be sold during the lead-time. This quantity was 40 cartons in the above example. This analysis ignores safety stock, which is held to reduce the chance that the centre will ever run out of stock for its customers.

The economic order quantity is widely used by companies to decide the quantities they should order. The answers should be scrutinised carefully, not just implemented automatically. Very many situations could invalidate the EOQ answer. Is another product or a special promotion about to take over from the first product? EOQ is based on a number of small, independent sales which approximate a steady sales rate. Is a customer about to make a one-off purchase of a great number for an event or a festival? Can we order this product by itself or do we prefer to coordinate with other products to reduce joint costs of purchase? Can we get a discount by buying a certain quantity? These very practical issues are considered in the next section, which moves from the ordering of one product to the management of many products in groups.

ABC inventory groups

We now move from the decisions on one product to management of the thousands of products that many manufacturers and distribution centres keep in stock. Good

Table 2.3 **Inventory items grouped by sales**

Product number	Annual number sold	Price per item	Annual Sales	% Total sales	% Cumulative sales	% Total products	Group
1	105	$431.40	$45,300	48	48	10	A
2	626	$51.30	$32,110	34	82	20	A
3	801	$8.99	$7,200	7.6	89	30	B
4	54	$89.80	$4,850	5.1	94	40	B
5	1,160	$1.47	$1,700	1.8	96	50	B
6	63	$15.32	$965	1.0	97.1	60	C
7	127	$6.50	$825	0.9	98.1	70	C
8	71	$9.72	$690	0.7	99	80	C
9	29	$18.62	$540	0.6	99.7	90	C
10	34	$7.95	$270	0.3	100	100	C
Total			$94,450	100			

management requires that these products are divided into groups which have common usage characteristics. This can be done by life cycle, degree of seasonality, usage rate or turnover (usage rate times value) according to the most appropriate measure for the business. Turnover is frequently the best measure. The '80/20 rule' is used to form groups of similar turnover items. Consider the ten items in Table 2.3.

If the product information for all the items held by a company is plotted in a graph of cumulative proportion of sales against cumulative proportion of products, Figure 2.9 results. The 20% of items which represent 82% of turnover are labelled 'A' items, or fast moving. The next 30% of items which represent 15% of turnover are 'B' items and the final 50%, representing only 5% of turnover, are 'C' items. Our analysis frequently turns up 'D' items, whose sales are so low that they should not be in stock at all! Once this inventory grouping has been done, it can be used to manage different groups in different ways. For example, the time spent reviewing the stock available on 'A' items can be much higher than the time spent on 'C' items. *This method is known as ABC inventory control**.

Inventory records and less stock

Companies keep computer records of the inventory that they have for all materials and products at each location. We have seen how this information can be used to decide how much inventory is required. But how good are these records? The majority of companies which we have examined have inaccurate inventory records. Computer records must be updated systematically every time there is a stock movement. Regular checking of physical versus computer records for a proportion of stock will throw light on differences. This regular checking is known as cycle counting because a small proportion of stock is checked each week until every item has been checked. Then the process cycles around again. It is not sufficient to correct the errors found. The reasons for the errors must be identified and the errors prevented from recurrence.

A major aim of logistics managers is to reduce the holdings of unordered stock because it gets in the way of delivering products to customer orders, as well as costing money to acquire and carry. So our third objective in this section is to identify the impact of modern techniques of inventory reduction on conventional stock holding,

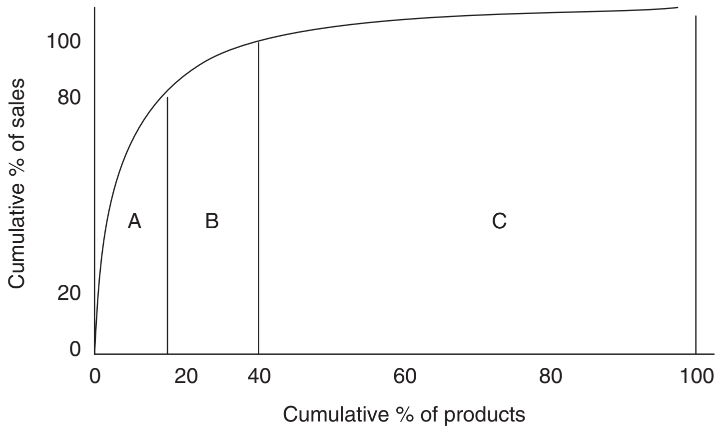

Figure 2.9 Pareto analysis of inventory items

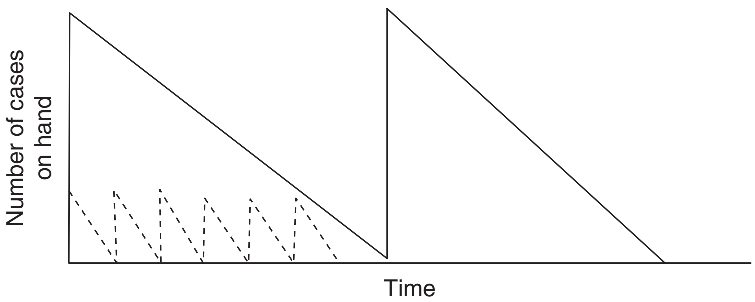

Figure 2.10 Inventory cycles for traditional and JIT/lean for one product

especially by the lean philosophy. Figure 2.10 shows how the saw-tooth model we used above for traditional inventory management can be modified to drastically reduce the amount of stock required. Under the *lean** philosophy,[6] derived from just-in-time, inventory is regarded as a type of waste. The large saw-tooth represents a monthly stock cycle, which was very prevalent in poorer industries in the 1990s. If this high stock cycle is replaced by the small 'dotted-line' quantity, then enormous savings in quantity of stock on hand can be made. But will this lead to higher ordering costs and stock-outs? It need not. The cost of ordering items is drastically reduced by automatic ordering and frequent review will prevent stock-outs. There is a consequent reduction in *safety stocks** which will be discussed next.

Safety stock can be used to increase customer service levels where resupply times are longer than customer delivery expectations at the cost of a larger inventory investment. Effectively there is an extra stock below the x-axis in Figure 2.10. When working stock runs out, the provider simply dips into the safety stock to continue supply to customers.

The amount of safety stock required in a given situation is related to the number of standard deviations of variation in sales, above the mean, for which stock cover will be provided.

Another important method of reducing inventory is to require suppliers to manage stock on behalf of a manufacturer or a retailer, known as *vendor-managed inventory (VMI)**. In VMI the supplier tracks product sales and inventory levels at their customers, sending products only when stocks run low. The decision to supply is taken by the supplier based on the ability of the stock available to satisfy market demand, allowing for the lead-time to resupply.

The success of VMI depends upon a close relationship between, for example, retailer and manufacturer. The overall aim is product availability at the retailer. Both parties need to use appropriate performance measures. The supplier needs to know real-time demand at the customer.[8]

Parts and materials inventory

Inventory of spare parts is very different from stocks of products being distributed because there is no order or forecastable demand for the spares. They are held as an insurance against a possible future breakdown which will require such a part. Some possible approaches are:

- estimate annual demand from that of a similar part which has been in use for some time on a car or an electrical appliance,
- if the part is inexpensive, buy a large number,
- if the part is important, say a drive shaft of a vehicle, and cannot be obtained in the future, buy a number related to the numbers of that vehicle sold in that area, and
- if the part is very expensive and not too bulky, hold a few at a central location and airfreight them to the location when required.

The last four sections covered the major operational functions in each link of the supply chain. An important piece of analysis is to check the sufficiency and sparing design of each function.

2.7 SUPPLY DEVELOPMENT

This section looks into the design of the focal company in a supply chain for new and existing products from a functional or tactical view point, filling in matters already in train. Figure 2.11 shows how product and supply chain development is best considered as a separate cycle. In the figure, provision is split, loosely, into market development and manufacturing components. It delves into the logistics changes required to operate effectively with the introduction of new products and new processes. A new product may have a different size of package, or outer, which requires negotiation with marketing or modification to pallet storage. A new process in manufacture could have a range of logistics impacts such as inventory or hours of service implications. The more proactive or strategic approach to design a whole supply chain, or one link therein, to cater for new products or novel processes, is covered in Chapter 8.

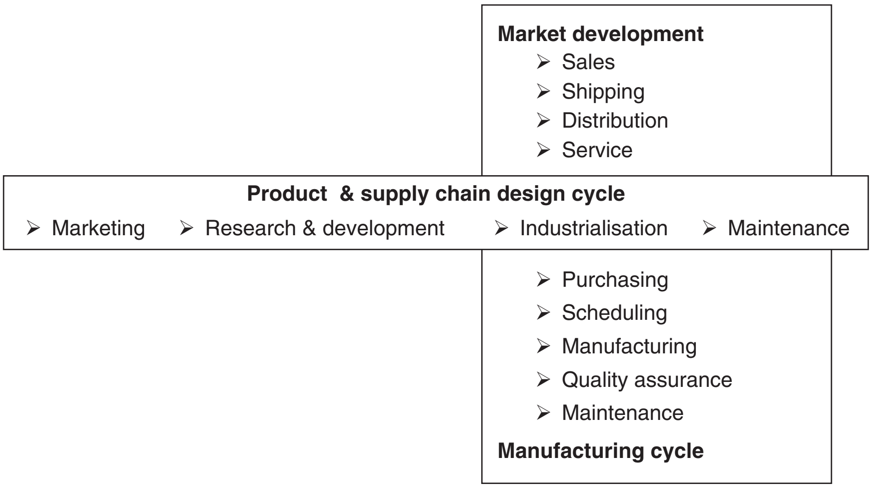

Figure 2.11 **Relationship between design and provision cycles (after Jouffrey and Tarondeau[9])**

Product design is an earlier step in the overall business than the order-taking and provision processes described above. It requires marketing to specify the general form of the new product. Then a team of product designers works with process and manufacturing engineers to identify how the new product will be manufactured and to purchase and commission the machinery required. Suppliers will be discovered and developed to deliver the exact materials and components required. Production managers and administrators join this team towards the end of its work until the new product is launched on to the market.

At the same time the whole supply chain must be designed, or altered, to fit the new product: to enable its effective provision and distribution to customers. The ‘start from scratch’ approach to this is considered in Chapter 8. Here we consider tactical changes to supply, provision and distribution which will do the best job without investing in new facilities and systems or the experienced people to operate and manage them.

The introduction of a new product may have a major or a minor effect on the logistics operations required in the company. If a manufacturer of hair shampoo changes the designs of its plastic containers, this is not likely to make a serious impact on the logistics of materials into the factory or distribution of shampoos. However, if a computer manufacturer decides that its new models will be delivered within 48 hours of receipt of a customer specification (as Dell did a few years ago), this will turn the supply chain inside out. So logistics managers need to keep close enough to the design of new products, and new manufacturing processes to make them, to respond with appropriate changes to the logistics system.

Consider the case at the end of this chapter, ‘Sausages made to order?’. The introduction of many new types of sausage has caused the inefficiencies in batch production which the operations manager seeks to remove. Each single introduction is a minor change but the move from ‘one type to nine varieties’ requires a major change to logistical operations. The managers concerned with logistics need to review production scheduling methods, and *make-to-order** rather than to stock and transport to the customer.

For a major change, consider the changes being made by the European automobile industry as a result of the '3-day Car Project'.[6] Studies in the mid-1990s showed that European car companies took, on average, 30 days to make and deliver a car against a new order placed. However, the manufacture of that car took only 25 hours. The difference is partly due to inventories of parts and finished cars, but mainly due to the time taken to pass the order between the various players and to get the car into a production schedule. This situation does not fit within the 'one link of the chain' emphasis of this chapter. But it does show a major redesign of the car manufacturing logistics as a result of the introduction of new methods of handling customer orders.

Each car company is aiming to receive orders quickly from the dealer, schedule them rapidly on to the production line and deliver the complete car to the dealer for the customer in five days instead of the previous 30 days.

In reality there is a continuum between manufacture to stock and new design of product and process. The continuum is the degree to which customers' requirements have to be taken into account before manufacturing and assembly can take place. Mass vehicle manufacturers which have engineering changes to product several times a day illustrate the deleterious effects of getting this wrong. This adversely affects training, product quality, reworks and productivity.

Midway in this continuum is 'engineer-to-order', in which customers want products to be varied to meet their needs. Because this variation is not part of the standard range, the order must be referred to a manufacturing engineer. He or she specifies a change to the production process for this individual order, which is then manufactured. This situation is unusual across the spectrum of manufactured products. It rarely occurs in food or consumer goods. It is more frequent in jobbing shops, producing small numbers of metal components. An example is the manufacture of varied buckets for a range of earthmovers.

The location of manufacturing processes relative to suppliers and markets is an important factor. This varies according to the value of products and their perishability.

Finding new suppliers

The purchasing process, (see section 2.4), first process, requires firms to discover suppliers of particular materials, components and services. Major steps are:

- specifying the material or service needed,
- finding potential supply companies,
- working out which companies are capable of supplying the material effectively, and
- negotiating a commercial supply relationship, including lead-time, price, quality and quantity.

2.8 DEPARTMENTAL LINKS AND BUSINESS STRATEGY

> Bureaucracy hates change…
> is terrified by speed
> and hates simplicity.[10]

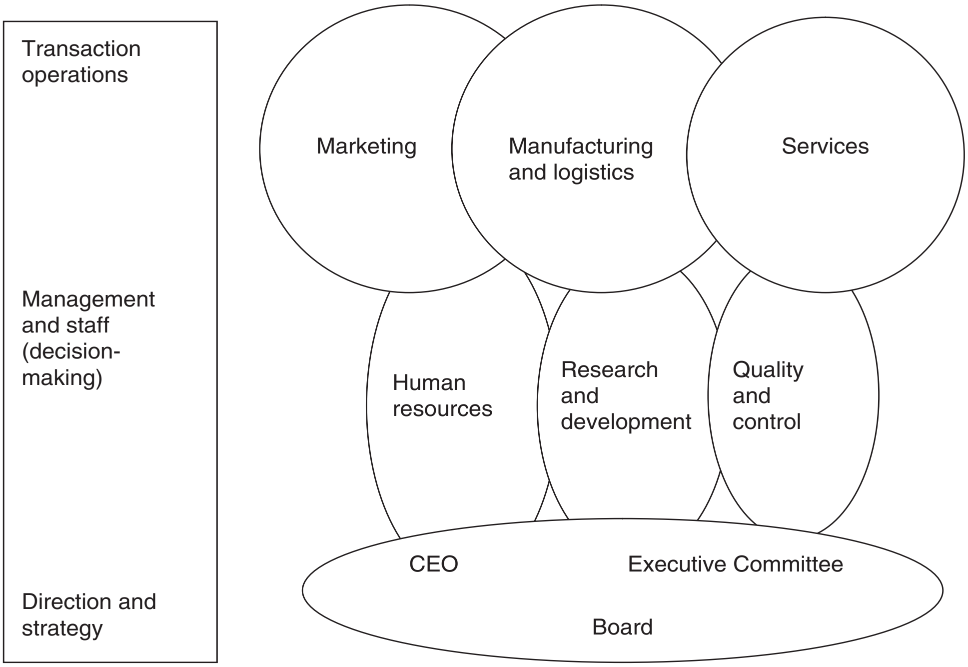

Figure 2.12 The structure of a company showing the main departments (after Mintzberg)[11]

(CEO Chief = Executive Officer or President)

How do supply chains fit within the overall organisation of one company? Supply networks are responsible for the majority of resources in the company but, for many reasons, the company is not organised as part of a family of chains. Rather it is arranged into a series of departments working under a business strategy developed by top executives and approved by the Board. Figure 2.12 is a simple model of a firm, based on Mintzberg's work.[11] This model shows three levels of activity from transaction operations at the top, through management and staff decisions in the middle to direction and strategy at the bottom. Direction is put at the bottom because, in more modern, effective firms, it supports management and technical staff, who in turn coach and enable supporting operations to provide goods to customers.

This model is equally applicable to distribution companies, such as supermarket chains and quasi-manufacturing service businesses, such as maintenance shops. The important topic of the type of organisation structure which the firm adopts is delayed until section 6.5 when it can be considered in the context of the whole *supply network** (i.e. a set of supply chains) of the businesses. Each circle contains a number of actual functions, depending upon the size and industry. For example, key services are accounting, engineering and information systems. Marketing includes sales, merchandising and market development.

The relationship between the management of logistics and the other departments within the overall organisation of one company (see Box 2.3) could be the subject of another book. In another sense there is no single answer: the answer is contingent upon the industry, the management style, the strategic direction, the geographical dispersement and the place of the business entity (firm) in its group. This area is covered in section 8.3.

Box 2.3 Innovative organisational structure at Becton Dickinson

Becton Dickinson, a global manufacturer of medical products, has created a new operating division called BD Supply Chain Services. The role of this unit is to integrate and more effectively manage all the company's supply chain processes and their interaction with Becton Dickinson's operating divisions. BD Supply Chain Services has forged a clear, competitive advantage for the company. Profitable growth, cost minimisation, and capital efficiency are influenced everyday by the best practices adhered to within this new division.

(Source: Tyndall and colleagues[12])

The most important point in tactical management of the whole firm is the requirement for its strategy and processes to have priority over department responsibilities, parochial preferences and executive power bases. The thesis that a company is a link in a business supply channel implies that all departments, not just purchasing, manufacturing, logistics and distribution, should work, predominantly, for the development and provision of new and existing products.

Link strategy

Recently, forward-thinking managers have realised that strategy is needed at a functional level as well as the overall business strategy of a complete *strategic business unit** Functional-level strategy is profoundly determined by the managers closer to the activities and can be viewed as emergent[13] rather than imposed from above.

A lot of energy has been expended on wide audits of the logistical activities of companies. The view taken, then synthesised from an all-encompassing audit, is less important than product-group strategy derived by a group of responsible managers. For example, when a smallgoods company sells bacon to another company for making preprepared meals, this is an entirely different distribution route from bacon sold to a supermarket chain for fresh retail consumption.

2.9 LEAN MANAGEMENT AND LEADERSHIP

> The final test of a leader is that he (or she) leaves behind him in other men the conviction and the will to carry on.[14]

We now consider the roles of the operators, managers and directors who steer and carry out activities in links in the supply chain. We argue that successful chains occur because trained, motivated, dedicated people ensure that a near-perfect flow of goods is delivered to the end customers. The managers of such chains aim to train, steer and guide the operators.

Management of logistics in a firm is an evolving process since this perspective on companies and their partners has only recently been developed. Consequently, many companies are arranged according to functions such as marketing, operations and finance. Supply chain management has responsibilities which cut across functional boundaries.

This situation can be addressed by forming logistics as another function comprising the parts best managed under a senior logistics manager. Alternatively, processes and committees can be put in place which enable coordination between the various functions to achieve the flow of planning information and goods.

The biggest body of work on the management of supply chains is that on lean thinking leading to a l*ean enterprise*.*

Lean management

Womack and Jones[6] developed the following five principles through which *lean thinking** can be applied to a value stream, the name they use for a single-product supply chain:

- specify value by a single product as seen by the end customer,
- identify the value stream for each product,
- make value flow without interruption,
- let the customer pull value from the producer, and
- pursue perfection.

*Lean management** requires a team of managers, representing all companies in the supply chain, to meet and be trained by consultants in lean value stream analysis. The team then maps each step in each process that the product goes through from source to consumer. They then consider a future supply chain, from which waste has been removed. Finally they implement an *action plan** to reach an agreed future state, in which waste has been removed, people reorganised and unnecessary processes have been dropped. In later work, more managers from the companies will analyse and improve the supply chains of further products, continually moving towards a perfect state.

Leadership

Here we quote from five lessons of FD Roosevelt's presidency of the USA, as reported by Axelrod.[15] We believe they apply equally to leadership of supply chains as to national and international policies:

- *Purpose and policies.* FD Roosevelt responded in actions so that a perfect social programme was one in which it was impossible to tell where theory stopped and practice started.
- *Contact.* 'All policy is human policy', so the leader must keep in contact with his/her people and inform them of the true state of the business.
- *Persistence*. Leaders never lose hope. They do something to survive. Things go wrong, but a committed leader never abandons the enterprise by allowing it to ride with the prevailing current. For each circumstance, plans are drawn up and policies determined.
- *Motivation.* An excellent way to motivate employees is to provide them with a choice. 'Either we go down this path with these consequences, or we choose a

better path with superior outcomes.' Leadership plans must be built from the bottom to the top. Any plan which focuses on one at the expense of the other must be rejected. To an individual, an effective leader comes across as one who is speaking directly to him or her while also addressing the collective enterprise.

- *Progress and prediction.* A leader is a guide. He/she tells not only how far we must travel but also how far we have come.

Teams and support

We believe that supply chain and logistics practices should be formed by teams of operators and advisers under the direction, coaching and 'listening' of managers. The key idea is that supply chains, and their parts, cannot be managed by individuals, however talented. Effective chains demand teamwork in design and in operation.

For a fuller development of people improving supply chains, see section 8.2.

2.10 PERFORMANCE MEASUREMENT AND IMPROVEMENT

Supply chains should be managed so that products and services flow from source to destination, where the customer receives her or his products. This management needs to be very effective to make a profit for all organisations concerned while meeting customers' needs on time. This requires reduced waste (rejects, time, extra efforts, etc.) and greater customer effectiveness. To improve the efficiency of our supply chain we need to measure how well we are doing and make chain-wide improvements. It does not matter how well we go at any point: it is the 'system' efficiency and effectiveness that count in meeting customers' needs.

Link goals

Each link in the supply chain has its own goals which should be consistent with the customer supply goal of the whole chain. There is a current emphasis on reducing the number of suppliers with whom a manufacturer had to deal from hundreds to tens. This assists the manufacturer to deal more closely with the limited number of surviving direct suppliers.

Performance measurement and profit control

An important part of management is performance measurement which must comprise physical and financial measures of business achievements.[16] The tendency of businesses to rely on purely financial measures is being addressed by the use of the Balanced Scorecard.[17] This is very important in logistics areas where customer service and delivery performance are more crucial than dollar turnover figures. Logistics must be seen as a function which can increase turnover and profit, rather than as a cost centre to be controlled.

It is also essential to view logistics in the firm as contributing to business profits. Logistics has a main objective of satisfying customers by excellent delivery of correct products but immediately behind this objective comes the need to operate profitably. Businesses have mainly viewed logistics as a cost centre. This approach is not conducive to allowing logistics to invest in new facilities and information systems. Consequently, logistics should be seen as a profit centre which can, in conjunction with other functions, increase turnover and hence justify an optimal level of expenditure.

2.11 LIMITS OF THE LINK NETWORK

The meat-processing case in this chapter describes a supply chain with three important suppliers, two transport service companies and six main customers. This is assumed to be the limit of the network of companies that must be considered to make decisions about the link. In practice there were 95 suppliers, 46 service companies and 220 customers which the meat processor, Bradley, had dealings with during a year. Students need to make a similar simplification in examining the main link in their supply chain. This is quite independent of the need to consider suppliers to your suppliers and customers of your customers. These and other wider aspects will be addressed in Chapter 7.

No analytical formula can be given to decide the limits of the supply chain network for study purposes. Students should consider which suppliers, distributors and service contractors make a significant difference to the chain they are studying from the perspectives of the end customer and the major partners in the chain, who are endeavouring to operate profitably.

Summary

This chapter describes the supply chain tasks of achieving production flow within a plant so that the materials received are effectively converted into finished products. It includes delivery of parts and material from suppliers and shipment of goods to the plant's customers. It introduces the great variation between the key logistics issues for clothing, sausages and cars while all fit within the same framework. The history of integrated logistics documents its rapid development over the last 30 years. We examine four main drivers of logistics in one link of the supply chain: order-taking, provision, transport and inventory. Information communication systems are an integral and enabling part of each of these drivers.

After looking at the *operations* of one link, the chapter reviews some wider link issues. 'Supply development' delves into the new logistics systems which the manufacture of innovative products by new processes will require. Next, 'Departmental links and business strategy' considers the connections of the logistics link with other functions and with the company's overall business strategy. 'Lean management and leadership' examines the critical human dimensions of managing product flow in a plant involving decisions, tasks, training and steering. Since changes are happening all the time, the last two sections introduce 'Performance measurement and improvement' and the boundaries, for planning purposes, of a link in a logistics network.

Analytical tools covered are the arrangement of operations functions, forecasting demand, transport selection, inventory management, supply development and performance measurement.

Questions

1. For your chosen organisation within its supply chain, revise the link structures and trade-offs between functions so that they better achieve the firm's customer service and profit aims for an existing product group.
2. Repeat question 1 for a new product.
3. Recommend the improved use of people to manage a production, or distribution, company to improve its logistics performance for end customers and stakeholders.
4. You have the task of managing inventory at a car spare parts warehouse. What principles would you use to buy inventory? How would you segment the 70,000 parts for more specific control?
5. For a product you know, explain how you would make the transport decision for its distribution: (a) in one country, and (b) world-wide.

Case: Sausages made to order?

Introduction

At 11am Paul Liddy, Operations Manager of Bradley Smallgoods, sat down at his desk. He has been at work since 6am, checking that all the meat-processing lines are operating to schedule. He has talked to his supervisors, his main meat supplier and his largest customer, Safeway supermarket chain. Paul's thoughts turn to possible improvements since Bradley's profit is too low.

Bradley, a meat-processing company in Melbourne, Australia, has employed a series of continuous improvement techniques over the last eight years in an attempt to change from being production-driven to having a strong customer orientation. While this has improved the industrial relations environment and working conditions, it did not improve the return on assets employed until last year, 1998. A loss was made in 1997 as a result of having to recall smallgoods after a food poisoning outbreak, although it was later proved that Bradley was not responsible for the food poisoning. The improvement in profit in 1998 was more due to a fall in pig meat prices than enhanced market or operations strategy.

Paul's main long-term objective is to streamline operations so that customer service levels will increase and costs will be reduced. At the top of his list of desirable improvements is: 'making sausages to order'. While studying last year, he was impressed by the concept of replacing inventory of perishable goods by manufacture to order. He knows that, typically, 22% of sausages are sold at a discount, because not enough orders are received for the many varieties in stock. It has been difficult to achieve change in the past but Paul believes that the necessary changes could be made at Bradley. How will his supplier, Apollo Meats, and his major customer, Safeway supermarkets, react to his proposal?

Background

Bradley purchases boned pig meats and processes them into a range of cured, preserved and fresh meat products known as smallgoods. Formed in 1947, it is the subsidiary of a large food-processing company. Bradley has an annual turnover of Aus$110 million from

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sales of 14,000 tonnes of product and employs 440 people. Although selling into national markets and having some exports, its sales are predominantly made in the state of Victoria. Bradley sells to three market segments, 60% of its output going to supermarkets, 20% to delicatessen shops and 20% to other food manufacturers.

Management at Bradley is in transition due to the appointment of a new General Manager at the end of 1996, and a new Operations Manager, Paul, in May 1997. The General Manager restructured Bradley's senior management and totally reorganised the operations group under Paul Liddy. In operations, this reorganisation comprised the appointment of six new managers to manufacturing and logistics positions and retrenchment of the majority of factory supervisors. Bradley is now progressing towards self-directed work groups, including shop-floor team leaders as part of the unionised workforce. Consequently, Paul's operations and logistics team at Bradley includes both new appointees and managers who had been there for many years. It comprises 11 managers, as shown in the partial organisation structure, see Figure C2.1.

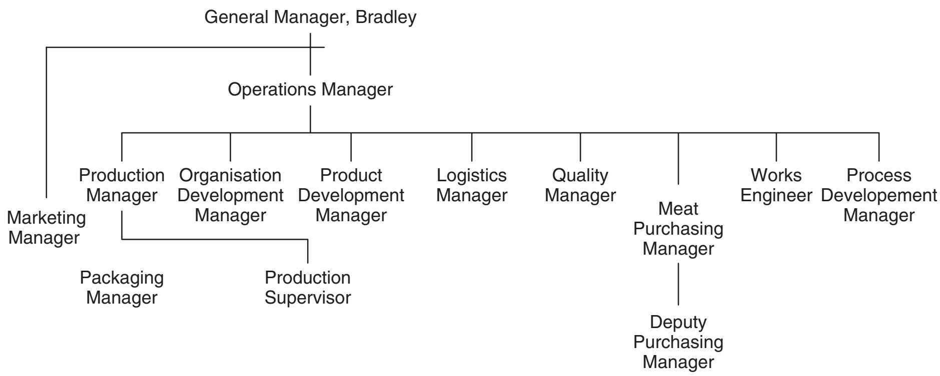

Figure C2.1 **Partial organisation chart**

Bradley has been making fresh sausages from meat trimmings, grain and seasonings filled into a casing for almost 50 years. Originally the company made only one kind of sausage. Pork sausages were primarily sold through corner shops and delicatessens, delivered in refrigerated vans. Total weekly sales were very regular – 20 tonnes per week. Given steady sales in one product, it made sense to make sausages in runs of five tonnes, loaded into 16-kilogram boxes for distribution.

More recently many other producers have started making sausages with very cheap ingredients, 'to throw on the BBQ'. These inferior sausages are sold in supermarket meat counters at $3.99 per kilogram. At the same time customers of the deli counter in a supermarket, where prices are up to $12.99 per kilo, want a variety of sausages such as bratwurst, pork, honey and soy, beef and tomato, and chicken. When Paul last counted there were 14 varieties on offer and Bradley make nine varieties themselves.

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The present supply chain

The supply chain starts on a piggery in northern Victoria where the pigs are grown to the appropriate age. Bradley buys, say, 2,000 pigs which are slaughtered and dressed at an abattoir adjacent to the piggery. Their carcasses are delivered to western Melbourne where Bradley employs Apollo Meats to bone them. Apollo's butchers separate the various cuts of meat and trim all meat from the bones. This meat is refrigerated and delivered twice a week to Bradley, 10 kilometres away, in large plastic boxes. Bradley buys various spices and other additives. It obtains packing from a local branch of Sealed Air Corporation. This comprises sausage casings and packs to receive the links of sausage.

Figure C2.2 shows Bradley's sausage manufacturing process:

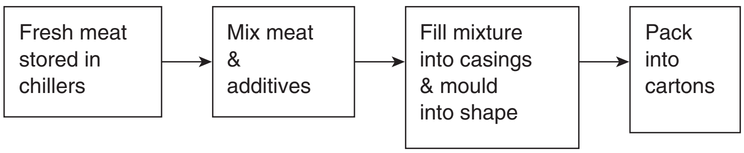

Figure C2.2 Processes in a smallgoods factory

Bradley distributes sausages from its chilled store at the end of the production line. Distribution to Safeway comprises mainly full pallets with some 16 kg boxes picked for the lower volume varieties, such as Halal sausage. Transport from Bradley to Safeway's cold store is achieved by 'pans' (pantechnicons) pulled by a prime mover, carrying a load of 28 pallets weighing about one tonne each. Bradley hires a transport company to deliver these pans to the cold store at the Safeway distribution centre in a narrow time slot.

Safeway is the largest supermarket chain in Australia, with 150 stores in Victoria. Its central meat buyers, working for Gwen Davies, the senior buyer, purchase sausages from Bradley by the truckload on a two-day lead-time. Bradley keeps pressing for a week's notice of requirements, but Safeway buyers prefer to order at 4pm on Monday for a Wednesday morning delivery. Faced by large swings in sales both through the week and according to the weather, their response is to postpone ordering until the last possible moment. Safeway's customers are the full range of people who use its many Victorian stores. Some of them buy sausages to keep in the freezer until needed. The majority buy sausages for a particular occasion, such as a barbeque.

The overall supply chain is depicted in Figure C2.3.

Information flow

Safeway places orders for sausage varieties twice a week. It estimates its requirements a month in advance but without any commitment, so these estimates are very little use to Bradley. Bradley has a weekly requirement that Apollo processes a number of carcasses for delivery every two working days. This number is changed without notice when Bradley so wishes, on the Friday before a working week.

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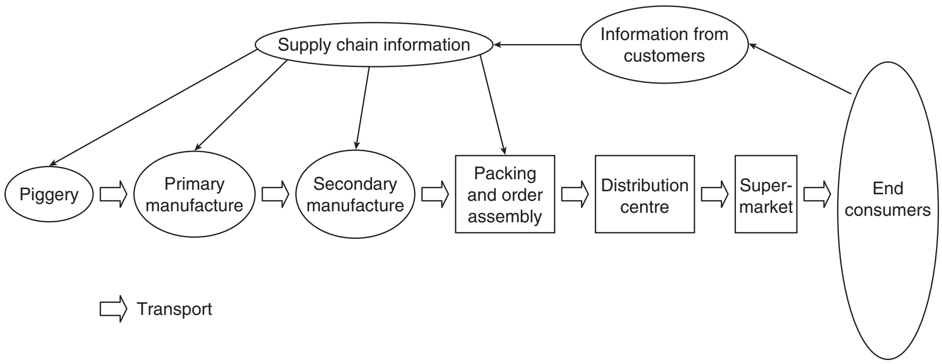

Figure C2.3 **Links in the integrated supply chain for smallgoods products**

Production scheduling is carried out at Bradley using a stand-alone spreadsheet. The scheduler uses this sheet to plan production four weeks ahead, but there are daily changes to the schedule as customers' exact needs are obtained.

The only computer information Bradley has on the stocks of sausages is the financial value of the pallet loads in its despatch store. To find out stocks of individual varieties, sales staff have to ask the store person. Safeway has detailed information about its sausage stocks at its cold store but does not share this with Bradley. Delivery information is compiled from the loads assembled in despatch.

Delivery performance and profit

Mikhail, Bradley's production supervisor, knows that getting meats in is not a problem, since the trimmings are a by-product of the thousands of carcasses processed each week. Schedules for production quantities of the nine varieties of sausage are drawn up by Chris, production scheduler, one month ahead and firmed up on the Friday before the week of manufacture. Typically, the two most popular sausages are made twice a week, three more varieties made every week, and the four others once every two weeks.

Table C2.1 shows a typical sausage production schedule. With use-by dates just eight days after manufacture, this requires some juggling and significant price reductions to clear stocks when orders do not match stock on hand.

Paul's improvement project

Paul knows from experience that Bradley management takes an autocratic view of changes. However, he felt that the recent reorganisation and the emphasis the General Manager was putting on increased profit would improve his chances. In the past matters would be investigated internally and then announced to suppliers by a phone call with a confirmatory fax. Safeway were apt to treat Bradley in the same way. Paul feels he would resolve this production problem more effectively if he consulted his supply chain partners at the outset. He arranges a meeting with Gwen of Safeway and Brian of Apollo Meats for 10am on Friday.

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Table C2.1 Scheduled production of sausage – produce to stock (tonnes)

Sausage type	Week One						Weeks		
	Mon	Tue	Wed	Thu	Fri	Total	Two	Three	Four
Bratwurst		5				5	5	5	
Pork				5		5	5		5
Honey & soy			3			3	3		3
Hungarian	3					3	3	3	
Halal			1			1	1		1
Chicken					1	1	1		1
TOTAL	3	5	4	5	1	18	18	8	10
CAPACITY	5	5	5	5	5	25	25	25	25

After discussing current performance, Paul introduces his ideas, saying: 'I have a proposal for a change in the production of sausages. I want to move from making sausages in large batches in advance, to making exactly the varieties and quantities you want when you order them.'

Gwen was interested. 'That sounds like a good proposition. We would get fresher sausage, provided you can react quickly to our afternoon order. We could not tolerate any drop in delivery performance. Already we have seen 8% of deliveries miss the required time this year.'

Brian had a problem. 'My boning room is not set up to deliver meat exactly when you want it. I only operate one crew of butchers, so I need to arrange my production schedule a week in advance.'

Paul acknowledged his concern. 'I see my proposal as a major change which we will have to think through to suit all our situations. If we could achieve this change, it would provide a major increase in margin for our company. Bradley intends to share any gains with you after paying for any extra costs you incur.'

Paul sought their agreement to a study that he would drive. He suggested they meet again in two weeks to examine the study and deal with any sticking points. After further discussion, Brian and Gwen agreed to this course of action.

Two weeks later

At the next meeting, Gwen brought her order clerk, Rachel, and Brian was accompanied by his boning room supervisor, Zoltan. Based on the studies Mikhail and Chris had done, Paul tabled a typical schedule (see Table C2.2) that would result from his proposed just-in-time production of sausage. To achieve this would require Safeway to order what they wanted more frequently from Bradley. Paul suggested an order every four hours would help him.

Result of study

In mid-April Paul, Mikhail and Chris summarised their investigation findings (see Table C2.3). For various performance measures at Safeway, Bradley and Apollo, the study

(Continued)

Table C2.2 Scheduled production of sausage – just-in-time production (tonnes)

Sausage type	Week One						Weeks		
	Mon	Tue	Wed	Thu	Fri	Total	Two	Three	Four
Bratwurst	1	1	2		1	5	5	3	2
Pork	1	1		2	1	5	5	2	3
Honey & soy	1		1		1	3	2	1	2
Hungarian		1		1		2	3	2	1
Halal	0.5		0.5			1	1	0.5	
Chicken		0.5			0.5	1	1		0.5
TOTAL	3.5	3.5	3.5	3	3.5	17	17	8.5	8.5
CAPACITY	5	5	5	5	5	25	25	25	25

Table C2.3 Study results

Item	Current	Proposed
Safeway		
Ordering pattern	Twice a week	2 times per day
Average order size	3 tonne	0.4 tonne
Delivery performance	92%	97%
Shelf life on receipt	8 days	14 days
Bradley		
Production process	Make-to-stock	Make-to-order
Ability to fulfil order	78%	98%
Loss on discounted sausages per week	£1200/$4400	£110/$400
Number of sausage batches per week	~4	~10
Apollo		
Shifts operated per week	5	5
Shifts boning for Bradley	2	5
Cost of 15 minute downtimes	0	£60/$165

findings show the current situation and the expected achievement if the recommendations are adopted. Notable changes are the increased frequency of Safeway ordering, the increased number of sausage batches and the extra shifts needed at Apollo. This would make considerable improvements to delivery performance into Safeway's distribution centre and order fulfilment while delivering significantly reduced losses on discounted sausages.

Reactions to the proposal

Gwen, the Safeway buyer, accepts the main results of the study. She agrees that orders could be placed every four hours during the working day, with the benefits of getting fresher sausage and fewer delivery failures. However, she says she cannot predict the size of individual orders. Her biggest problem will be to get her superior and store managers to accept Paul's proposals.

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Brian, from Apollo Meats, is quite negative about his ability to bone some carcasses for Bradley during every shift. Zoltan has told him that traceability and cleanliness would be compromised by changing from boning for a food service company, such as Best Cut, to Bradley products during every operating shift. He would probably have to stop the entire operation for 15 minutes and he could face an industrial dispute from the boners. They would lose earnings because of the piece-rate pay system.

Paul has explained the study's proposals to his General Manager. The General Manager is entirely in favour, and has promised his enthusiastic support. He will tell all staff what is happening at the weekly management meeting and at the next employee meeting in the canteen. Unfortunately, Bradley's shift supervisors were not convinced when Paul took them through his proposal. They could see problems in changing over, which they didn't want to do during the Easter period, in two weeks' time. More seriously, they could not envisage the real savings in their area to be obtained by make-to-order processing. A lot of their work is related to the batch of sausages made. So, they say, more batches equal more work.

Paul's next step

Paul feels disappointed that his initiative has met with such a mixed reception. He has the General Manager's permission. Should he push ahead with the move to make sausages to order when the Easter peak is past? Perhaps he should carry out a further study involving his supervisors so that they would feel part of the recommendation? Maybe Bradley needs the help of a change agent who has been through this before?

Paul resolves to think carefully about the effects of his plan on supply chain partners before proceeding. He is reliant on Apollo for his meat supplies at the moment, other suppliers could be obtained, but it would be better to try to negotiate a compromise acceptable to the boning plant. Will Gwen be able to get the other Safeway managers' support? And will the actual size of Safeway orders fit Bradley's capacity to make to order?

Case questions:

1. Can you identify Bradley's supply chain and justify the steps you include?
2. What are the three most important supply chain issues for Paul to address?
3. What should Paul do? Why?

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