1 Introduction to manufacturing

1.1 Introduction

The prosperity of human kind has been inextricably linked with the ability to use and work with the available materials and tools throughout history. Indeed, there is archaeological evidence of man's toolmaking ability dating as far back as 2–3 million years (Mair, 1993). However, the basis for manufacturing as we know it today can be traced as far back as 5000–4000 BC, with the manufacture of artefacts from materials such as wood, stone, metal and ceramics (Kalpakjian, 1995). The modern manufacturing organization, based on the factory system and the division of labour, was borne of the Industrial Revolution of the eighteenth century. The roots of modern manufacturing processes can also be traced to the late eighteenth century with the development of the cotton gin by Eli Whitney in the United States (Amstead *et al*., 1987) and the first all metal lathe by Henry Maudsley in the United Kingdom in 1794 (DeGarmo *et al*., 1988). The development of manufacturing processes continued in the early part of the nineteenth century with the introduction of a loom automatically controlled by punched cards in France in 1804, the development of the milling machine by Whitney and the use of mass manufacturing techniques by Marc Isambard Brunel in 1803 in the United Kingdom (Mair, 1993).

The development of manufacturing industries to this day still relies heavily on research into manufacturing processes and materials and the development of new products. Those countries that have been at the forefront of the development of manufacturing have come to be known as the *developed countries*, while those that have very little manufacturing are considered *underdeveloped* (el Wakil, 1989). This ability to manufacture products has a huge bearing on the wealth and prosperity of a country. In theory, the greater the ability of a country to manufacture, the wealthier that country should be (how this is achieved is discussed later in this chapter). Prime examples of this type of countries are the United Kingdom and the United States. For example, in the United Kingdom, manufacturing still makes a significant contribution to the wealth and prosperity of the nation, despite the decline of manufacturing in the 1980s. A recent government report estimated that there are 4.3 million people directly involved in manufacturing and account for 20 per cent of the *Gross Domestic Profit* or GDP (DTI, 1999). Similarly, figures for the United States estimate that approximately 17.8 million people are employed in manufacturing (van Ark and Monnikhof, 1996) and again account for around 20 per cent of GDP (BEA, 1998). However, for the likes of the United Kingdom and the United States to remain competitive in the global market, the resources employed in manufacturing must be used in the most cost effective manner. This means that the manufacturing of the products must be planned to make best use of these resources, which is the very essence of process planning.

1.2 Aims and objectives

The aims of this chapter are to define manufacturing and present the main types of manufacturing systems employed and their operational characteristics.

On completion of this chapter, you should be able to:

- define the manufacturing activity;
- state the main goals of a manufacturing organization;
- define the Principle of Added Value;
- define a manufacturing system;
- identify and describe the common manufacturing systems and their operational characteristics;
- identify and describe the main processing strategies and relate them to the common manufacturing systems;
- identify and describe the main roles and responsibilities of a manufacturing engineer.

1.3 What is manufacturing?

In the introduction to this chapter the importance of manufacturing to the wealth and prosperity of a country was explained. However, before proceeding, the question 'What is manufacturing?' has to be answered.

Although the basis of manufacturing can be traced back as far as 5000–4000 BC, the word *manufacture* did not appear until 1567, with *manufacturing* appearing over 100 years later in 1683 (Kalpakjian, 1995). The word was derived from the Latin words *manus* (meaning 'hand') and *facere* (meaning 'to make'). In Late Latin, these were combined to form the word *manufactus* meaning 'made by hand' or 'hand-made'. Indeed, the word factory was derived from the now obsolete word *manufactory*. In its broadest and most general sense, manufacturing is defined as (DeGarmo *et al*., 1988):

> the conversion of stuff into things.

However, in more concise terms, it is defined in the Collins English Dictionary (1998) as:

> processing or making (a product) from raw materials, especially as a large scale operation using machinery.

In a modern context, this definition can be expanded further to:

> the making of products from raw materials using various processes, equipment, operations and manpower according to a detailed plan.

During processing, the raw material undergoes changes to allow it to become a part of a product or products. Once processed, it should have worth in the market or a value. Therefore, manufacturing is 'adding value' to the material. The value added to the material through processing must be greater than the cost of processing to allow the organization to make money or a profit. Therefore, added value can be defined as (ICMA, 1974):

> the increase in market value resulting from an alteration of the form, location or availability of a product, excluding the cost of materials and services.

Finally, the income of an organization, calculated by deducting the total costs from the sales revenue, is also sometimes referred to as the added value or value added (Gilchrist, 1971). In fact, in the past organizations have used bonus or incentive schemes for employees based on this definition of value added. However, in the context of this book, the ICMA (1974) definition will be used when referring to added value. Therefore, using this definition, a manufacturing organization will only be successful if it not only makes products, but also sells them. This allows manufacturing to be further defined as:

> the making of products from raw materials using various processes, equipment, operations and manpower according to a detailed plan that is cost-effective and generates income through sales.

This definition adds the dimension of the processing being cost-effective.

1.4 What is a manufacturing system?

In general terms, based on the above definition, a manufacturing system can be defined as:

> a system in which raw materials are processed from one form into another, known as a product, gaining a higher or added value in the process and thus creating wealth in the form of a profit.

This is illustrated in Fig. 1.1. There is no one concept that will cover all industries in detail. Therefore, the concept defined above is generic. However, there are numerous detailed definitions of what represents a manufacturing system. One such definition that is particularly appropriate is that of Lucas Engineering and Systems. This defines a manufacturing system as (Lucas Engineering and Systems, 1992):

> an integrated combination of processes, machine systems, people, organizational structures, information flows, control systems and computers whose purpose is to achieve economic product manufacture and internationally competitive performance.

Figure 1.1 *Basic model of manufacturing system adding value*

The definition goes on to state that the system has defined, but progressively changing objectives to meet. Some of these objectives can be quantified, such as *production output, inventory levels, manning levels* and *costs*. However, other objectives for the manufacturing system may be more difficult to quantify such as *responsiveness, flexibility* and *quality of service*. Nevertheless, the system must have integrated controls, which systematically operate to ensure the objectives are met and can adapt to change when required. Some of the aspects of this definition will be explored further in this chapter, namely the organization of processes, people and structures.

1.5 Inputs and outputs of a manufacturing system

Generally, the input/output analysis of a manufacturing system will be as shown in Fig. 1.2. It can be seen from this that the system does not have an influence or control over all the inputs, for example, social pressures. This means that the system must be flexible enough to deal with input variations. It must also be able to cope with the rapid changes in technology and the market, particularly as product life cycles become increasingly shorter (Evans, 1996).

The main output of the manufacturing system is obviously the product or manufactured goods. These can be classified as either *consumer products* or *producer products*. Consumer products are those that are sold to the general public. However, producer products are those which are manufactured for other organizations to use in the manufacture of their products, which in turn could be either of the above categories of product. Therefore, in some instances, the output of one manufacturing system is the input of another. Thus, there may be considerable interaction between systems. Finally, it should also be noted that not all the outputs are tangible or measurable. For example, how is reputation measured although it can have a marked effect on the manufacturing system?

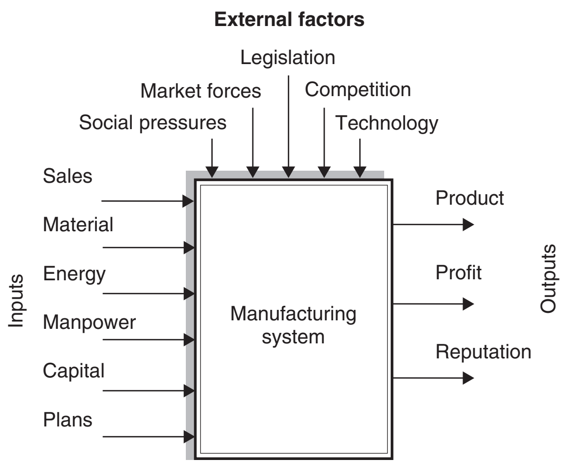


Figure 1.2 *Inputs and outputs of a manufacturing system*

1.6 Common characteristics of a manufacturing system

Regardless of the nature of the manufacturing organization or the product being manufactured, all manufacturing systems have a number of common characteristics, which are:

1. All systems will have specific business objectives to meet in the most cost-effective manner.
2. All systems consist of an integrated set of sub-systems, usually based on functions, which have to be linked according to the material processing.
3. All systems must have some means of controlling the sub-systems and the overall system.
4. To operate properly, all systems need a flow of information and a decision-making process.

All of the above must be incorporated into the manufacturing system to allow stable operation in the rapidly changing global market in which most organizations compete. Each organization has its own unique manufacturing system, developed to support its specific objectives and deal with its own unique problems. However, the sub-systems within each can be represented as shown in Fig. 1.3. It is clear from the figure that the sub-systems are built

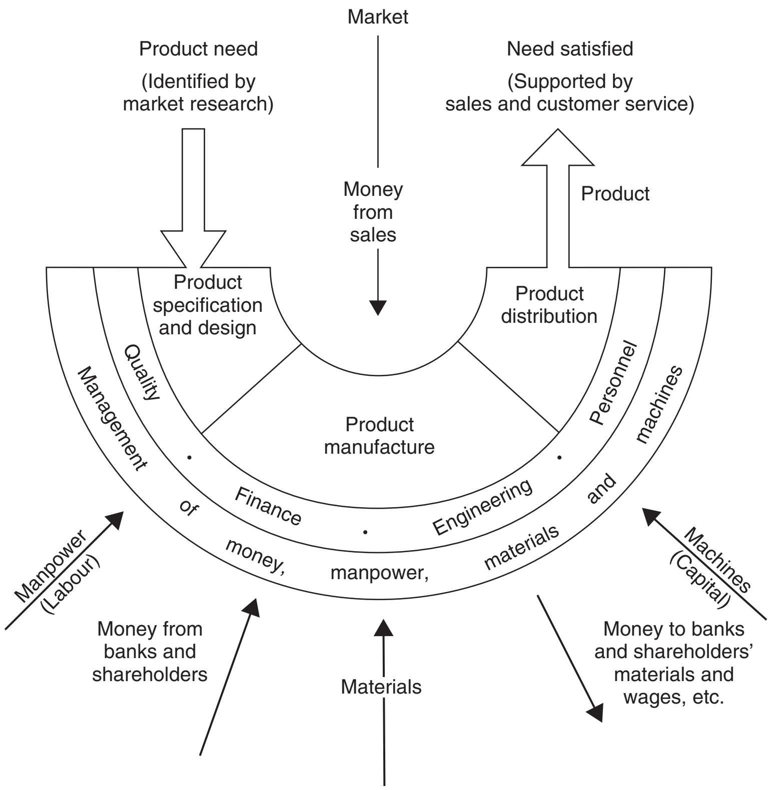


Figure 1.3 *The manufacturing system (Mair, 1993)*

around the main functions or departments of the organization and these can be further broken down. This aspect of manufacturing organization will be considered further in Section 1.8.

1.7 Developing a manufacturing strategy

As stated previously, all manufacturing systems have specific business objectives to be achieved, which are driven by the organizational mission statement. These business objectives are then used to generate the business strategy. The business strategy should be developed to allow the organization to meet its business objectives but be flexible enough to accommodate change. The business strategy in turn is used to formulate both the *marketing strategy* and the *manufacturing strategy*. Finally, the implementation of these strategies will require people and processes as illustrated in Fig. 1.4.

The manufacturing strategy can be defined as a long range plan to use the resources of the manufacturing system to support the business strategy and in turn meet the business objectives (Cimorelli and Chandler, 1996). This in turn requires a number of decisions to be made to allow the formulation of the manufacturing strategy. Six basic decision categories have been identified and these are (Hayes and Wheelright, 1984):

Capacity decisions – these deal with how customer demand is met in terms of the resources available and those required. In effect the questions being asked are, what has to be made, what will be used to make it and when and how will this be achieved?

Process decisions – this is basically about deciding which type of system should be employed. This is complicated by the fact that most companies employ hybrid systems. This decision is linked to four distinct processing strategies that are discussed in Section 1.10.

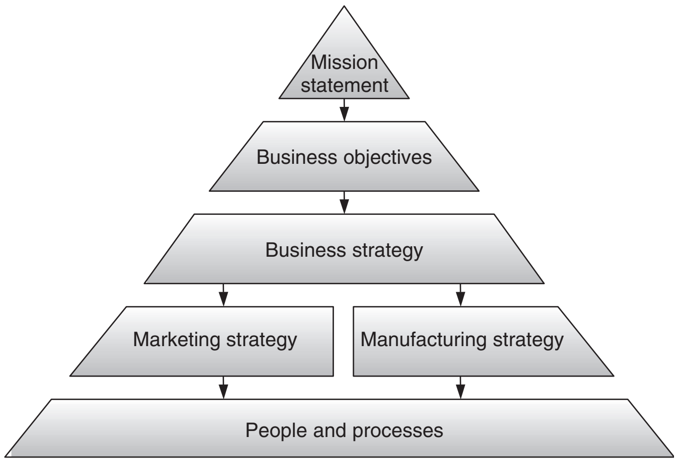


Figure 1.4 *Developing a manufacturing strategy*

Facility decisions – the main focus of this decision is the layout of plant at a factory level, and the assigning of specific products to specific plants at an organizational level. The types of plant layout that can be used will be considered further in Section 1.11.

Make or buy decisions – the essence of this decision is identifying what is to be made inhouse and what is to be sub-contracted. This is particularly important as it will influence the capacity, facilities and process decisions. This will be discussed further in Chapter 9.

Infrastructure decisions – this decision considers the policies and organization required to meet the business objectives. Specifically it will consider the production planning and control system, the quality assurance system (considered further in Chapter 8) and the organizational structure.

Human resource decision – obviously other decision categories can have a huge influence on this decision. The two main decisions are identifying the functions and organizational structure required (both of which are considered further in Section 1.8) and the reward system, that is, pay, bonuses, etc.

All of the above will be considered further to some extent in this book. In the remainder of this chapter the facilities decisions, process decision, infrastructure decision and, in part, the human resource decision, will be discussed further.

1.8 Manufacturing organizational structures

In Section 1.4, it was explained that the sub-systems of the manufacturing system are based on the functions or departments within the organization. The organization of these functions plays an important role in the achievement of the system objectives. Therefore, once the functions required have been identified, the most appropriate organizational structure must be employed to help achieve the system objectives.

1.8.1 Typical functions in a manufacturing organization

Although every manufacturing organization is unique in some respect, there are six broad functions that can be identified in almost any manufacturing organization. These are sales and marketing, engineering, manufacturing, human resources, finance and accounts and purchasing. The general responsibilities of these functions are as follows:

Sales and marketing – this part of the organization provides the interface with the market. The main responsibilities of this function are to ensure a steady flow of orders and consolidate and expand the organizations share of the market. Typical sub-functions might include sales forecasting, order processing, market research, servicing and distribution.

Engineering – typically under this functional heading the sub-functions would include product design, research and development (R&D) and the setting of specifications and standards. The level to which R&D is carried out will depend on the product. For example, in high-tech products, R&D will play a major role in determining the use of materials and processes and future product design.

Manufacturing – the diversification of the manufacturing function will depend very much on the size of the organization. Typical sub-functions might include:

- *Production planning* with responsibility for producing manufacturing plans such as the *master production schedule* (MPS) and the *materials requirements plan* (MRP).
- *Quality assurance* whose job it is to ensure that products are being made to the required specification.
- *Plant maintenance* with the responsibility of ensuring that all equipment and machinery is maintained at an appropriate level for its use.
- *Industrial engineering* whose responsibilities include the determination of work methods and standards, plant layouts and cost estimates.
- *Manufacturing engineering* whose responsibilities includes manufacturing systems development, process development, process evaluation and process planning.
- *Production/materials control* who coordinate the flow of materials and work through the manufacturing plant (work-in-progress). Stores will usually be included in this function.
- *Production* whose responsibility it is to physically make the product.

Human resources – this is again a broad heading that typically will include sub-functions such as recruitment, training and development, labour relations, job evaluations and wages.

Finance and accounts – the main responsibilities of finance include capital financing, budget setting and investment analysis. Accounts generally deal with the keeping of financial records including cost accounting, financial reporting and data processing.

Purchasing – this primarily involves the acquisition of materials, equipment and services. They must ensure that the above support the manufacturing capabilities by satisfying their supply need. They must also ensure the quality and quantity of supplies through vendor rating.

1.8.2 Types of organizational structure

How the above functions are represented within an organization will depend mainly on the size of the organization. For example, in a small organization some of these functions may be combined such as purchasing and finance and accounts. However in a large organization there may be further diversification of functions, creating more departments such as sales and marketing being large separate departments. How these are organized will also depend on a number of factors. These will include, among others, the size of the organization, how many facilities/locations there are within the organization, the complexity of the products being manufactured and the variety of products manufactured. Finally, the 'style' of management employed, that is, centralized or decentralized, will be a major factor in the type of structure employed. In an organization with a centralized structure, management responsibility and authority is held within the upper levels of the organization. However, in a decentralized structure, some of the responsibility and authority is pushed down to the lower levels. This allows decisions to be made at the levels most affected by them. It also frees senior management from the day-to-day decision-making. Taking all of the above into account, there are three basic organizational structures employed in manufacturing (Coward, 1998):

- a functional structure;
- a product structure;
- a matrix structure.

Functional structure

The most common structure employed is that which organizes the departments around the functions within the organization, that is, a functional structure. This type of structure also tends to be hierarchical in nature as shown in Fig. 1.5. The main advantage of this type of structure is that the knowledge and expertise of each function is concentrated in one part of the organization. However, in larger organizations with a functional structure, there tend to be conflicts of interest between departments, based on conflicting departmental objectives. For example, while marketing and production might want high inventories to ensure availability of product and continued production, finance will want to minimize inventories to minimize costs. Finally, a functional structure usually employs a centralized style of management.

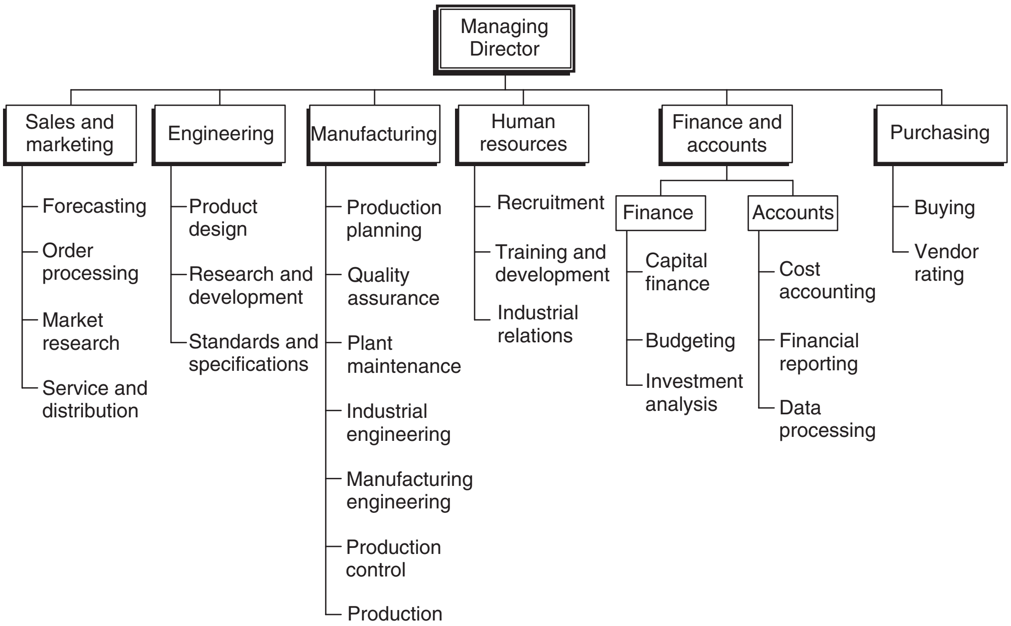


Figure 1.5 *A functional structure*

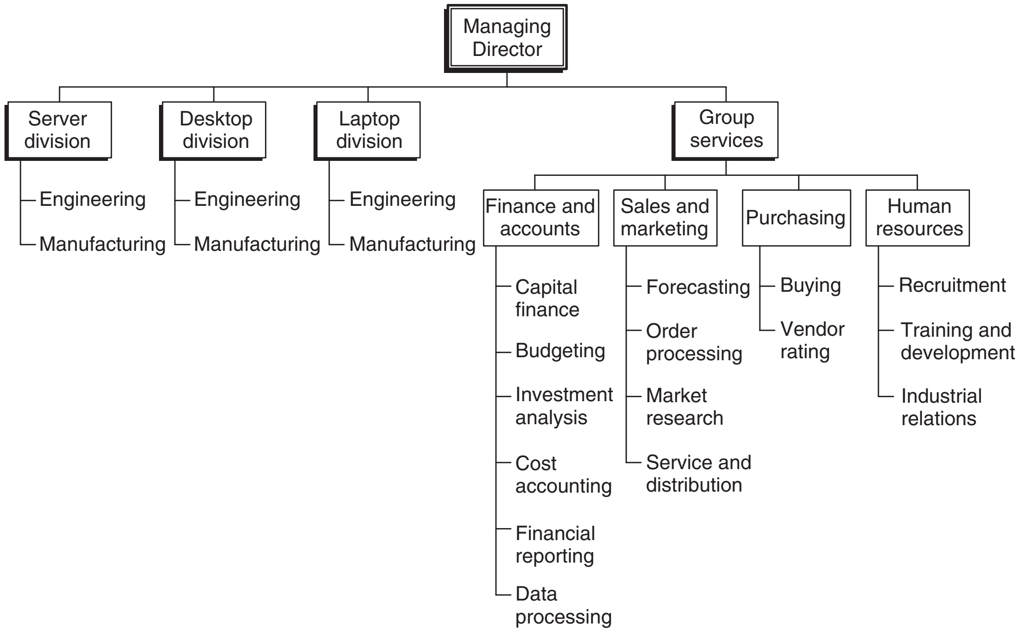


Figure 1.6 *A product structure*

Product structure

Many large manufacturing organizations produce a diverse range of products. In such organizations, it is common to employ a structure based on the products manufactured, that is, a product structure. This generally means splitting the organization into product divisions, all of which incorporate the functions required to manufacture the specified product. However, indirect functions such as sales and marketing, finance and accounts, human resources and purchasing will generally be shared across the group. Each division will also tend to act as an autonomous business unit. The main advantage of this approach is that the required product expertise is incorporated into a single part of the organization. However, the main disadvantage is the duplication of functions across divisions as illustrated in Fig. 1.6. Finally, product structures tend to employ a decentralized management style.

Matrix structure

In essence, a matrix structure is an attempt to obtain the benefits of both functional and product structures. This is based on one manager being responsible for functions and products in one area and is similar to the product structure in this respect. However, the main difference is that the matrix groupings are temporary. This is to allow the resources for each group to changed. This is based on a continuous review of resources carried out to ensure that the allocation of resources is appropriate for each group. Ultimately, this gives the

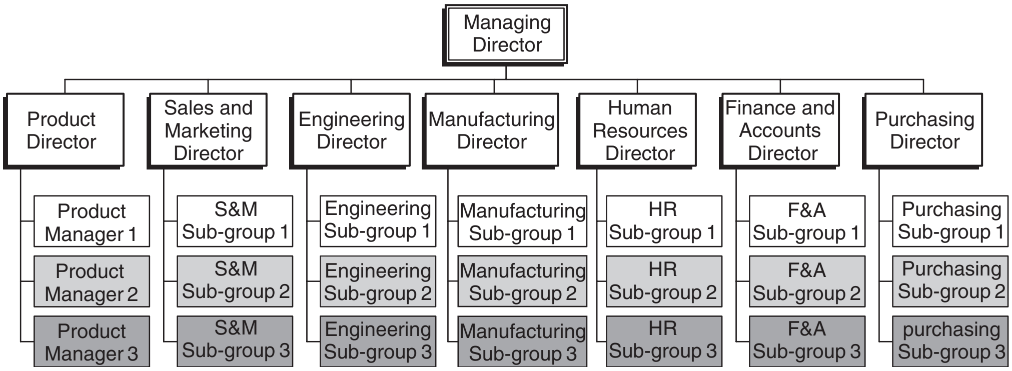


Figure 1.7 *A matrix structure*

matrix structure more flexibility than the product structure. Finally, the management style employed in a matrix structure is decentralized. An example of such a structure is illustrated in Fig. 1.7.

1.8.3 Organizational management levels

Within all manufacturing organizations there are usually three distinct levels of management. These are referred to as strategic, tactical and operational management.

Strategic level – this level is usually associated with senior management. This involves the setting of short- and long-term business objectives that will give the organization a competitive advantage over other similar organizations.

Tactical level – this level is associated with middle management. The main function of this level is to develop the plans by which the business objectives can be met using the organization resources.

Operational level – this level is the frontline management and the main function of this level is to ensure the everyday operations are planned and monitored.

1.9 Categories of manufacturing system

There are two basic categories of manufacturing system:

- discrete parts manufacturing;
- continuous process manufacturing.

Discrete parts manufacturing involves the manufacture of individual items and can be further classified into:

- project manufacture;
- jobbing shop manufacture;

- batch manufacture;
- mass/flow manufacture.

However, in recent times another system of manufacture has been developed called *cellular manufacture*. In cellular manufacture, processes are grouped according to the sequence and operations required to make a particular product. In effect, this is another discrete parts manufacturing system.

1.9.1 Project manufacture

The defining feature of project manufacture is the type of layout employed and the fact that there is a very low production rate, that is, not many units produced. The layout is known as a *fixed position layout*. In the fixed position layout, the product remains at the same location, that is, a fixed position, usually due to the size/weight of the product. The workers and all tools and equipment are then brought to the product to carry out work. It should be noted that component parts, sub-assemblies and assemblies might be manufactured elsewhere and then brought to the product location. The workers are usually highly skilled and material handling is high. It is also common for products manufactured using this layout to be one-of-a-kind, for example, ships, aircraft, space vehicles, bridges, buildings, etc. This approach to manufacture offers a number of advantages:

- there is reduced material movement;
- used with a teamwork approach it can improve continuity of operations;
- it is flexible in terms of coping with changes in product design, changeovers and volume.

There are also a number of disadvantages:

- increased movement of personnel and processing equipment;
- may require duplication of processing equipment;
- increased work-in-progress;
- increased space requirements.

This is, in effect, a specialist job shop environment.

1.9.2 Jobbing shop manufacture

The jobbing shop's distinguishing feature is the production of a wide variety of products. Manufacture is very often specific to customer order and specification. This usually means very small lot sizes and very often the production of one of kind. However, some job shops manufacture to fill finished goods inventories. As a wide variety of products are produced, a wide variety of manufacturing processes is required. The product variety also means that the workforce must be highly skilled in order to fulfil a range of different work assignments. Typical products of job shops are special purpose machine tools, fabricated sub-assemblies and components for the aerospace industry.

Within job shops, production equipment is usually general purpose and generally arranged according to the general type of manufacturing process. For example, the lathes are in one department, milling machines in another and drill presses in still another and so forth. This is known as a *process-focused layout* and allows the job shop to make such a wide variety of products. Each different part requires it's own unique sequence of operations and therefore requires to be routed through the manufacturing system by means of a routing sheet. In general, forklifts and handcarts are used to move material from one process to another. It is estimated that as much as 75 per cent of discrete part manufacture is made in lots of 50 (DeGarmo *et al*., 1988) or less. Thus, the job shop system is an important method of manufacture.

1.9.3 Batch manufacture

The main feature of batch manufacture is the production of medium size lots of a product in either single runs or repeated runs at given times. The lot size range is approximately 5–1000 and even possibly more. Again, as the product variety can be high, the number of processes required is high and therefore the equipment is general purpose. Similar to job shop manufacture, the workforce must be skilled and flexible to cope with the high product variety. The process-focused organization of the job shop is also equally applicable for batch production. Therefore job and batch manufacture are often confused because they have the following common characteristics:

- the flow of manufacture will be intermittent;
- some parts will be for customer orders and others for stock;
- schedule control of orders will be required to ensure delivery times are met;
- there is a high product variety.

To differentiate between job and batch manufacture, it is not the number of components that is the deciding factor, but the organization of the manufacture itself. For example (Timmings, 1993), consider the manufacture of one lot of five components. These could be made by five operators with each making a component outright. This is what would normally happen in a job shop. However, each component could be passed from operator to operator with each specializing and completing a particular operation. In this case, the manufacture would be classified as batch production.

1.9.4 Flow/mass manufacture

The main characteristic of flow line manufacture is the high volume of products produced. It is usually referred to as mass manufacture due to the very large quantities of products manufactured. It is also common for mass manufacture systems to have high production rates.

With regards to the process equipment this tends be of a specialized nature, with processes being dedicated to a particular product. In fact, very often processes are designed exclusively to produce a particular product. This means that investment in specialized machines and tooling is high. The skill level of the workforce tends to be lower than that of both job and batch manufacture. This is due to the fact that the manufacturing skill is transferred from operator to machine through the specialist nature and design of equipment.

Products flow through a sequence of operations by material-handling devices such as conveyors and other transfer devices. They move through the operations one at a time with the time at each process fixed. In flow line manufacture, the organization of the process equipment is product focused. In this type of manufacturing system, the equipment is arranged in order of the product's sequence of operations. This means that equipment is arranged in a line with generally only one of each type of process. The exception to this is where duplicates are needed to balance the time taken for a particular product. The line is organized to make a single product or a regular mix of products.

1.9.5 Cellular manufacturing

A cellular manufacturing system is usually composed of a number of linked cells. The cells themselves usually compose of a number of grouped processes. These are normally grouped according to the sequence and operations needed to make a particular component part, sub-assembly or product. The arrangement within the cell is much like that of a flow system, but it is more flexible. Cells are normally laid out in a U-shape so that workers can move from machine to machine, loading and unloading parts. Usually there are high levels of automation within cells, including all machines being capable of running unattended and switching themselves off after the machining cycle is complete. This also allows the operators to carry out manual operations such as finishing and inspection or walk from machine to machine.

To implement a cellular manufacturing system, the current system must be converted in stages. This will entail taking parts of the current system and converting it into cells. The cells should be designed in such a way as to allow the manufacture of specific groups or families of parts, that is, parts which have the similar geometrical features and require the same manufacturing processes to make. One method used in converting traditional manufacturing, particularly the jobbing shop, to cellular manufacturing is *group technology*. This is a technique that helps group parts into compatible families.

Cells are generally linked directly to each other or to assembly points. They can also be indirectly linked by the pull inventory system known as *Kanban*. Finally, the cells can be linked in such a way as to allow the synchronous operation with sub-assembly and final assembly lines. With regards to the workforce, it may be the case that they move around the cells employing different processes. Therefore, workers are usually required to be multifunctional.

Cellular manufacturing has many features that make it different from the traditional manufacturing systems. Parts usually move one at a time from machine to machine instead of in batches. When a cell worker completes a journey round the cell a part should have been completed. Set-up times also tend to be shorter than for traditional systems. The lead times for parts and products also tend to be shorter. This is because the machines can run unattended and thus more than one operation at a time can be carried out. In general, cells are more flexible and more responsive, allow for shorter set-up and lead times and can provide higher productivity.

1.9.6 Continuous/process manufacture

Continuous/process manufacture involves the continuous production of a product and often uses chemical as well as physical and/or mechanical means, for example, sugar production, fertilizer production, etc. The main characteristic of continuous manufacture, sometimes referred to as process manufacture, is the fact that the equipment is in operation 24 h a day for weeks or even months without a halt. However, this rarely happens due to equipment breakdown and/or planned maintenance. There is no discrete product manufactured. Instead the product being made is manufactured in bulk and output is likely to be measured in physical volume or weight.

The process equipment will be highly specialized, probably automated, and thus very expensive and will be organized in a product-focused arrangement. However, the workforce is likely to be varied in skill level depending on their role, that is, semi-skilled plant operators, skilled maintenance technicians, etc. Continuous processes tend to be the most efficient but the least flexible of the manufacturing systems. Also, there tend to be by-products from this type of manufacture as illustrated in Fig. 1.8.

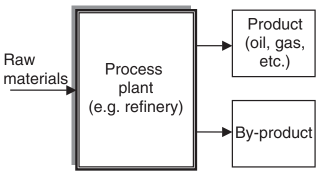


Figure 1.8 *Continuous manufacture*

Very often high-volume flow manufacturing is confused with continuous manufacture because of the following common characteristics:

- manufacture is usually continuous in both;
- manufacture is in anticipation of sales;
- the rate of flow of manufacture will be strictly controlled;
- there is a small product range.

The way to differentiate between the two is by the fact that in continuous manufacture the product physically flows, for example, oil, food processing, chemical processing, steel making, etc.

1.9.7 Summary

It can be seen from the above descriptions of the five traditional manufacturing systems that a trend emerges with regards to quantity and product variety. This is illustrated in Table 1.1. At one end of the spectrum is the project approach with one-offs and high product variety while at the opposing end is continuous manufacture with huge quantities of only a few similar products. This illustrated in Fig. 1.9. It should also be noted that cellular manufacturing attempts to apply flow-manufacturing principles to the manufacture of small lots and therefore cuts across both job and batch manufacturing in Fig. 1.9. All five traditional approaches are summarized in Table 1.2.

TABLE 1.1 *Summary table of traditional manufacturing systems*

Manufacturing system	*Description*	*Examples*
Project	The manufacture/construction of large one-off products over a lengthy period of time with very low production rates	Bridges, ships, aircraft, oil rigs, space vehicles, large special purpose machine tools
Jobbing shop	One-off or small quantity manufacture of products made or engineered to order employing a single operator or a group of operators	Special purpose machine tools, fabricated sub-assemblies and components for aerospace
Batch	Involves the manufacture of products from 5 to 1000 units to order or sometimes any quantity in anticipation of orders	Spares/components for aerospace and automotive products, general purpose machine tools, electronic assemblies
Mass/flow	The manufacture of very large quantities of products made for stock in anticipation of customer orders	Cars, domestic appliances such as televisions, fridges, cookers, etc.
Continuous/process	The plant is in effect one huge process with raw materials the input and finished goods inventory the output in anticipation of customer orders	Plastic, glass, petrochemical manufacture, steel

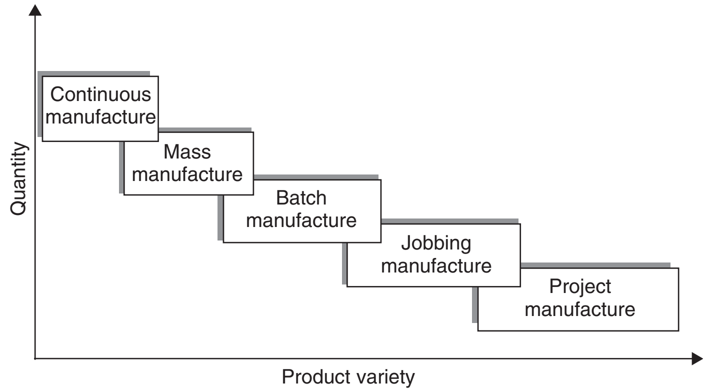


Figure 1.9 *Product variety versus quantity for traditional manufacturing systems*

1.10 Processing strategies

The process decision is further linked to four distinct strategies within manufacturing, which are:

- make to stock (MTS);
- assemble to order (ATO);
- make to order (MTO);
- engineer to order (ETO).

TABLE 1.2 *Summary table of characteristics of traditional manufacturing systems*

Characteristic	*Manufacturing system*				
	Project	*Jobbing*	*Batch*	*Mass/flow*	*Continuous*
Type of equipment	Mixture of general purpose/specialist equipment	General purpose, flexible equipment	General purpose, flexible equipment	Specialized, single purpose equipment	Specialized and generally high technology based
Process layout	Fixed position	Process-focused	Process-focused	Product-focused	Product-focused
Workforce	Highly skilled and flexible	Highly skilled and flexible	Highly skilled and flexible	Skilled but with only one function	Skill level varies according to function
Lot sizes	Mostly one-offs	Generally small, but can be medium	Generally medium, but can be small	Large	Very large
Product variety	Very high	Very high	High	Medium–low	Very low
Production rate	Very low	Low	Low–medium	Medium–high	High
Set-up time	Very long and variable	Long, but variable, and also frequent	Long, but variable, and also frequent	Long and complex	Long, complex expensive and infrequent
Manufacturing lead time	Very long and variable	Long and variable	Long and variable	Short and generally constant	Very short

1.10.1 Make to stock (MTS) strategy

Product-focused manufacturing companies tend to use an MTS strategy. The feasibility of this strategy relies on the fact that companies with product-focused manufacturing systems produce large quantities of a few standard products for which there is a predictable demand pattern. Further characteristics of this strategy are short customer delivery times, which is dependent on the finished goods inventory and high inventory costs. The MTS strategy also assumes reasonably long and predictable product life cycles. Finally, the interface with the customer tends to be distant and they are unable to express preferences with regards to the product design. All of the above are typical of company's who operate a mass manufacturing system.

1.10.2 Assemble to order (ATO) strategy

The ATO strategy is an approach to producing products with many options from relatively few major sub-assemblies and parts after having received customer orders. This entails manufacturing the above sub-assemblies and parts and holding them in stock until a customer order arrives. The specific product the customer requires is then assembled from the appropriate sub-assemblies and parts. The stocking of finished goods inventory is economically prohibitive because there are usually numerous options available and demand cannot be accurately forecast.

Companies employing an ATO strategy usually also employ a hybrid of process- and product-focused process layouts. This is because high-volume sub-assemblies and parts can be manufactured with a product-focused layout while low-volume sub-assemblies and parts can be manufactured with process-focused layouts. A manufacturing company operating with this strategy will primarily have contact with customers in a sales capacity only. Delivery time is low to medium and is based on the availability of the major sub-assemblies and parts.

1.10.3 Make to order (MTO) strategy

Many process-focused firms use an MTO strategy. This is because it allows the manufacture of products to customer specifications. To cater for customer specifications, this means that the product is not completely specified. This in turn means that manufacture does not commence until the customer order is received. Due to the fact that the customer is involved in the specification of the product, they will have extensive involvement not only with sales but also the engineering function of the manufacturing company. Delivery times range from medium to long and are based on the availability of capacity in both engineering and manufacture. This type of strategy is typically used in project, jobbing and batch manufacture in order to cope with the wide product variety required.

1.10.4 Engineer to order (ETO) strategy

ETO strategy is an extension of the MTO strategy with the engineering design of the product based on the customer requirements and specifications.

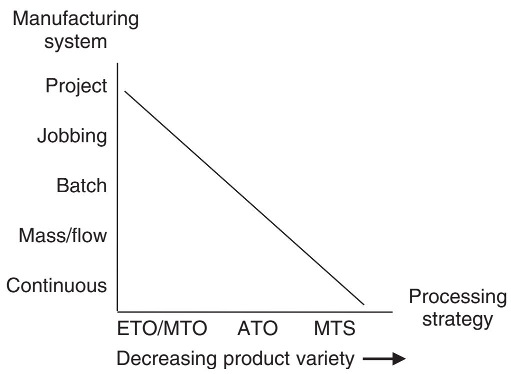


Figure 1.10 *Relationship between manufacturing system, product variety and processing strategy (© Addison Wesley Longman Limited 1998, reprinted by permission of Pearson Education Limited)*

This strategy exhibits the same characteristics as MTO. However, the level of customer contact with the manufacturing organization is even greater. This approach is typical of jobbing shops that specialize in one-off or one of a kind production.

1.10.5 Summary of strategies

Very few companies, with regards to both the manufacturing system and strategy employed, belong to one specific category. In fact most companies could be classified as hybrids. For example, a company may be a hybrid of MTS and MTO. This implies that it holds finished goods inventory for which there is a steady demand, but also has the ability to configure products to customer needs when required. It is clear is that in the progression from MTS to ETO, product variety and the degree of customization greatly increase as is illustrated in Fig. 1.10 (adapted from McMahon and Browne, 1993). It has been argued that in recent times manufacturing has actually moved along steadily from MTS to ETO as markets have become increasingly more competitive and customers demand more specialist, customized products. Table 1.3 compares the four strategies.

1.11 Plant layout

The focus of this part of the chapter is plant layout design. This will broadly consist of identifying the types of layout employed in manufacturing and the design of such layouts. In the previous sections, the process decision with regards to the type of systems and processing strategies that can be used have been considered. In this section, the facilities decision will be considered. When developing the manufacturing strategy this is, in essence, about plant design. This can be further broken down into three further subjects, namely plant facility system design, plant layout design and material handling system design (Tompkins *et al*., 1996) as illustrated in Fig. 1.11.

TABLE 1.3 *Comparison of MTS, ATO and MTO/ETO*

Characteristic	*MTS*	*ATO*	*MTO/ETO*
Customer relationship	Low/distant	Sales level	Engineering and sales level
Lead time	Normally short and dependent on finished goods inventory and availability	Short to medium and dependent on the availability of finished sub-assemblies and component parts	Normally long and dependent on the available capacity of both engineering and manufacturing
Manufacturing volume	High	Medium to high	Low
Product variety	Low	Medium to high due to availability of different arrangements of sub-assemblies and component parts	High
Product specification	No customer input	Based on customer orders for customized arrangements of sub-assemblies and component parts	Generally based on customer requirements and specifications

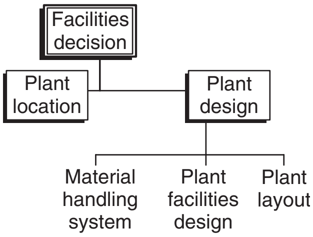


Figure 1.11 *Facilities decision (adapted from Tompkins, J.A., White, J.A., Bozer, Y.A., Frazelle, E.H., Tanchoco, J.M.A. and Trevino, J. Facilities Planning, 2 edn. © 1996. Reprinted by permission of John Wiley & Sons, Inc.)*

These can be further defined as follows:

Plant facility systems design considers the structural systems, heating, ventilation and air conditioning (HVAC) and general services, that is, water, electrics, lighting, etc.

Plant layout design considers equipment and machinery within the production area, all production related areas and often personnel areas within the facility.

Material handling systems design considers the materials, personnel and equipment handling systems required to support production.

From the above, it can be seen that the first element is clearly the remit of the Building Services Engineer and outside the scope of this book. However, the other two will be discussed briefly in this section.

1.11.1 What is plant layout?

As discussed above, plant layout focuses on the equipment and machinery within the production area and all related areas. However, this requires further definition. Plant layout is about the physical arrangements of departments, workgroups within departments, workstations, machines and stock-holding points within a manufacturing facility. These are also sometimes referred to as economic activity centres or work centres. The objective is to arrange the people and equipment to operate effectively and allow the smooth flow of work. In general, the inputs to the layout decision are as follows (Chase *et al*., 1998):

- specification of the objectives and criteria used to evaluate the layout design. Typical examples are the required space and the distance travelled between centres;
- estimates of product demand on the system;
- processing requirements in terms of the number of operations and amount of flow between the elements in the layout;
- space available within the facility, or if a new facility, the building configuration.

Not only does the plant layout affect the operational level of an organization, but can also have strategic implications. For example, layout can improve how an organization meets its objective by (Krajewski and Ritzman, 1996)

- facilitating the flow of materials and information;
- increasing the efficient utilization of labour and equipment;
- reducing hazards to employees;
- improving employee morale;
- improving communication.

1.11.2 Types of plant layout

In the earlier part of the chapter, a number of manufacturing systems were introduced. In discussing these systems, four types of layout were briefly mentioned namely fixed position layout, process layouts, product layouts and cellular layouts. The first three are the three basic types of layout. Cellular layouts, or group technology (GT) layouts as they are also known, are classified as hybrid type. All four will be defined in the following sections.

1.11.3 Process layouts

A process layout is one where the processes, workstations or departments are organized according to function. This type of layout is typically used in low-volume, high-variety manufacturing where demand is too low or unpredictable for resources to be dedicated to a particular product or product groups, that is, a job shop. For example, in the metal-working job shop in Fig. 1.12, similar processes are grouped together such as drills and lathes. A part being manufactured then travels from area to area according to the route sheets and is processed in accordance with the operations lists, that is,

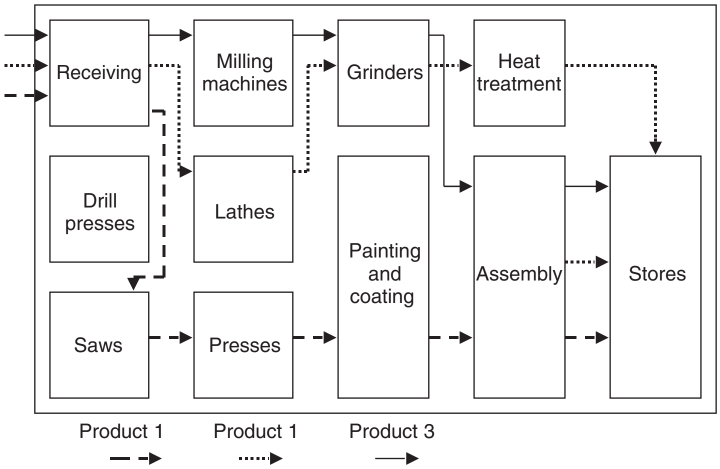


Figure 1.12 *Process-focused layout*

the process plans. Advantages of a process layout when compared to a product layout include:

- resources are general purpose and thus less expensive;
- it is more flexible as it is less vulnerable to changes in products;
- equipment utilization is higher as processes are used across a high variety of products;
- employee supervision can be more specialized which is important due to the high skill factor of personnel.

However, the process layout also has some distinct disadvantages including:

- processing rates tend to be slower;
- production time is lost due to set-up due to frequent product change over;
- high inventory required to keep workstations busy;
- lead times tend to be long and variable;
- too much material handling;
- the numerous routings and flows across the shop floor necessitate the use of simple carrying devices such as carts;
- production planning and control is more difficult;

Therefore, the major challenge of using a process layout is to locate centres in such a way to minimize the jumbled flow across the shop floor.

1.11.4 Product layout

In a product layout, processes, workstations and departments are arranged in a line as illustrated in Fig. 1.13. The arrangement of these is determined by what resources are required to manufacture the product, which will be detailed in the process plans. This makes the location of centres easy as the sequence of operations will also be as detailed in the process plans. Although product layouts may be in a straight line, this is not necessarily always the case, and they are often referred to as production lines. They typically employ equipment dedicated to a particular task and each line deals with only one product or product family. As such, they are employed for high-volume, low-variety manufacture. Product layouts have a number of distinct advantages over process layouts for high volume production. These include:

- high production rates;
- low work-in-progress inventory;
- minimizing material handling;
- minimizing lost production time due to changeovers;
- ease of production planning and control.

However, there are also a number of disadvantages to consider for product layouts. These are:

- as product designs change, so too must the product layout. This is a problem for organizations that manufacture products with short life cycles;
- as the layout is based on the product it is less flexible;
- process breakdowns can halt an entire production line;
- the capacity of the line is determined by the bottleneck work centre;
- poor use of resources for low-volume products.

The main objective of employing a product layout is to organize the workstations in such a manner as to achieve the required output with the minimum resources.

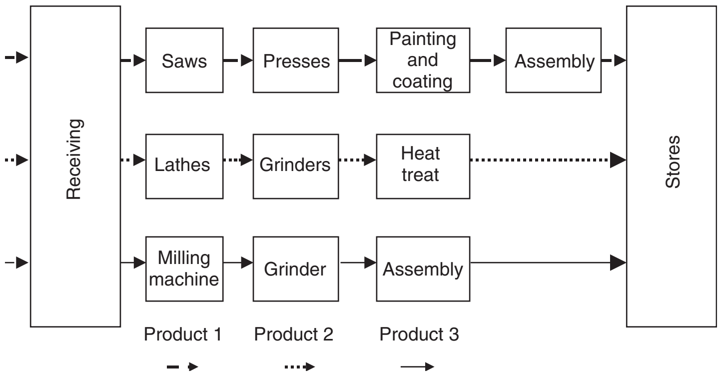


Figure 1.13 *Product-focused layout*

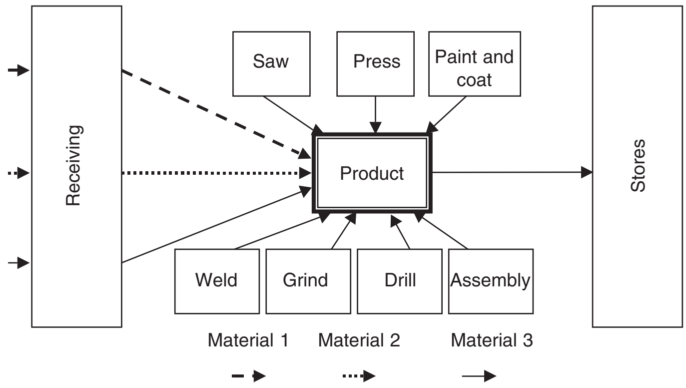


Figure 1.14 *Fixed position layout*

1.11.5 Fixed position layout

In the fixed position layout the product remains at the same location, that is, a fixed position, usually due to the size/weight of the product. The workers and all tools and equipment are then brought to the product to carry out work as illustrated in Fig. 1.14. It should be noted that component parts, sub-assemblies and assemblies might be manufactured elsewhere and then brought to the product location. The workers are usually highly skilled and material handling is high. It is also common for products manufactured using this layout to be one of a kind, for example, ships, aircraft, space vehicles, etc. The advantages and disadvantages of a fixed position layout are the same as those stated for project manufacture in Section 1.9.1.

1.11.6 Hybrid layouts

As was discussed in the earlier part of this chapter, in reality the majority of organizations employ hybrid layouts. For example, many organizations have process layouts to manufacture component parts that are unique to a single product and produced in low volumes, but employ a product layout to manufacture high-volume common parts and for assembly. Cellular/GT layouts are hybrid layouts as are flexible manufacturing systems (FMS). The use of group/cellular layouts can result in the following advantages:

- higher process equipment utilization;
- less material movement than process layouts;
- offers benefits from both process and product layouts.

As always, there are disadvantages and these are:

- often requires multi-skilling of cell members;
- dependent on balancing flow through cells to avoid high work-in-progress;
- has some of the disadvantages of both process and product layouts.

A typical layout is illustrated in Fig. 1.15.

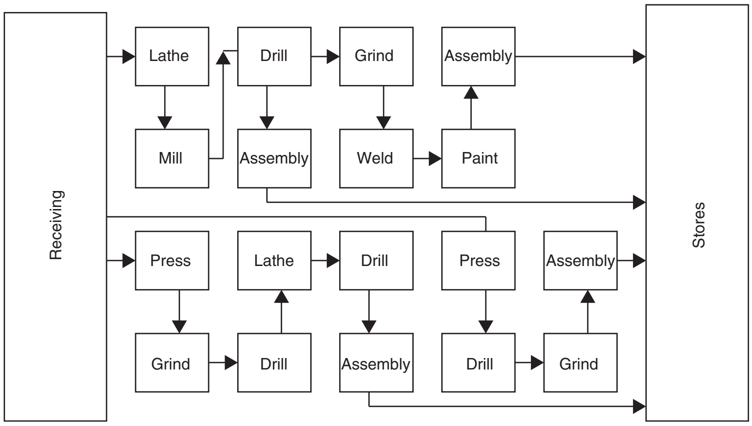


Figure 1.15 *Hybrid layout*

1.11.7 Summary

In determining the layout of a particular plant, there are basically four types of layout, namely process layouts, product layouts, fixed position layouts and hybrid layouts. The major influence in determining which is the most suitable will be the volume and variety of product to be manufactured. Other criteria that may be used will include the cost of the layout, the materials handling requirements, the flexibility of the layout, stock requirements and ease of maintenance.

1.12 Manufacturing engineering

There are two distinct engineering functions with direct responsibility for the manufacture of a product, namely industrial engineering and manufacturing engineering. Industrial engineering, whose main responsibility is usually to support manufacturing engineering, is considered as an indirect function in many manufacturing organizations and for costing purposes is included in the plant overheads (Tanner, 1996). The main focus of the industrial engineer is how the work is done and improving this if possible. Therefore, industrial engineering is involved in:

Methods analysis – studying how the work is performed and determining how this can be improved in terms of productivity and quality.

Work measurement – determining how long a job takes through carrying out time studies and developing standard times for every task.

Plant layout – determining the physical layout of the equipment and machinery on the shop floor and related areas, that is, influencing the facilities decision.

Material handling – determining the design of the handling systems required to support the flow of material through the plant layout, that is, again influencing the facilities decision.

Plant maintenance – determining a suitable plan for the upkeep of equipment and machinery directly involved in manufacturing.

It should be noted that the last three tasks listed above sometimes come under the heading of plant engineering in manufacturing organizations.

Manufacturing engineering is generally responsible for all phases of product manufacture, with the exception of product design and production control. There are four specific areas of responsibility for manufacturing engineering:

Manufacturing systems development – this particular aspect of manufacturing engineering is often carried out in conjunction with industrial engineering. This is due to the fact that manufacturing systems development incorporates the likes of methods analysis, work measurement, plant layout and materials handling, which have already been defined as responsibilities of industrial engineering.

Process development – again this tends to be carried out in conjunction with industrial engineering and involves the evaluation, application and implementation of appropriate new technologies. Considering the rapidly changing technologies involved in manufacturing, this can often be a major undertaking.

Process evaluation – this involves determining the capabilities of the machines, tools and staff to allow appropriate types of work to be allocated to each work centre. This may be carried out in conjunction with quality engineering, particularly when if capability studies are required.

Process planning – this is traditionally considered to be the main role of manufacturing engineering and entails planning the manufacture of the product. Based on a thorough knowledge of machines, tools, methods, staff, materials and product specifications, manufacturing engineering will select and sequence the processes and operations required to transform the chosen raw material into the finished component. This particular task is the focus of this book and in the next chapter the activities involved in process planning will be discussed.

1.13 Summary

As has been illustrated in this chapter, manufacturing and its organization can be particularly complex. There are various decisions that have to be made that will influence how a manufacturing organization will operate. Most will include the functions outlined in this chapter to a greater or lesser extent and organize these according to one of three types of structure, that is, functional, product or matrix. Most will also employ a hybrid of particular approaches to manufacturing, that is, job and batch manufacture, batch and mass manufacture, etc. depending on the complexity of the product and the demand for that product.

However, regardless of the functions, structures and approaches employed, in a modern context manufacturing is about taking raw materials and processing them and adding value. In an efficient manufacturing organization, the cost of the processing will be less than the added value to allow a profit to be made. Therefore, to ensure this is the case, manufacturing engineering must develop plans for the manufacture of products that make the best use of the resources employed, such as machines, tools, materials and people, that is, cost-effective process plans.

Case study 1.1: Re-organization at Edward Marks Ltd*

Introduction

The performance of Edward Marks Ltd had been poor recently. A number of managers within the organization have identified the root cause of the problem as poor communication throughout the organization. This was based on the observation that many of the departments within the organization were pursuing their own objectives, regardless of the affects these had on other departments. Frequently, the detailed information and the decisions made, based on this detailed information, were not fully understood.

There had recently been a change in the position of the Managing Director (MD), and as part of an initiative to improve performance, he had decided that a management audit was required. This was to be carried out by a consultant provided by the Management Services of the parent group.

Problems as perceived by the MD

During his short spell at the company, the MD had observed the following:

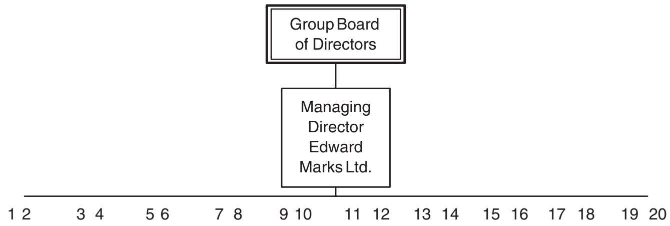
1. There was a flat organizational structure with 20 department heads, some called directors, but with no particular seniority (see Fig. 1.16).
2. Quality control and stores were split across two departments.
3. Power struggles occurred between department heads due to lack of definition of their roles and responsibilities.
4. Decision-making involved too many people.
5. Decisions made were left open for interpretation, and not all concerned or affected were always informed.
6. Corporate communications were not coordinated with at least five directors communicating with the same customers.
7. There was very little product innovation due to the fact that nobody had been allocated this responsibility.

The audit process

The Consultant formed an audit team consisting of the Marketing Director, Production and Operations Managers and the Director of Special Projects. The audit objectives were clear:

1. Identify the targets that have been set in the company strategy.
2. Check the targets are realistic.
3. Identify the problems preventing the target being achieved.
4. Identify the cost of failing to meet these targets.
5. Identify the changes required in order to meet the targets.
6. Identify the resources required to solve the problems.

* Adapted from Coward (1998).



1. Director: Desk Division
2. Director: Business Forms Division
3. Director: Office Decoration Division
4. Director: Office Equipment Division
5. Director: Office Furniture Division
6. Director: Production/Operations Management
7. Director: Management Information Systems
8. Director: Buildings and Sites
9. Director: Marketing
10. Director: Public Relations
11. Director: Plant Security
12. Director: Finance
13. Director: Special Projects
14. Director: Logistics
15. Director: Production Planning
16. Director: Human Resources
17. Director: Advertising and Promotion
18. Director: Research and Development
19. Company Secretary
20. Company Lawyer

Figure 1.16 *Organizational structure at Edward Marks Ltd (Coward, 1998)*

The audit will be carried out from the MD down to department heads and beyond, if required.

Problems identified

The problems listed below are not an exhaustive list of the problems identified during the audit. These are the major problems as perceived by the audit team.

1. The flat structure of the management organization was causing problems due to lack of defined roles and responsibilities at the director/department head level.
2. There was lack of ownership and communication. This manifested itself in people at lower levels of the organization being unhappy at the lack of information about the decisions being made.
3. There were major quality assurance problems that required urgent attention. This would require a cross-functional team to investigate and solve these problems.

Proposed solution

After considering a number of proposals, it was decided that radical restructuring could help all three major problems identified above. A product-based structure would be implemented as illustrated in Fig. 1.17. This would reduce the MD's involvement with so many department heads. This would identify clear roles and responsibilities for all managers and provide clear channels for communication. In addition, a Quality Department would be set up to deal with problems identified in the audit. The long-term objectives of the Quality Department would be to put in place an appropriate quality system incorporating quality assurance, quality control and testing for all divisions. The organization of the Quality Department would be as illustrated in Fig. 1.18.

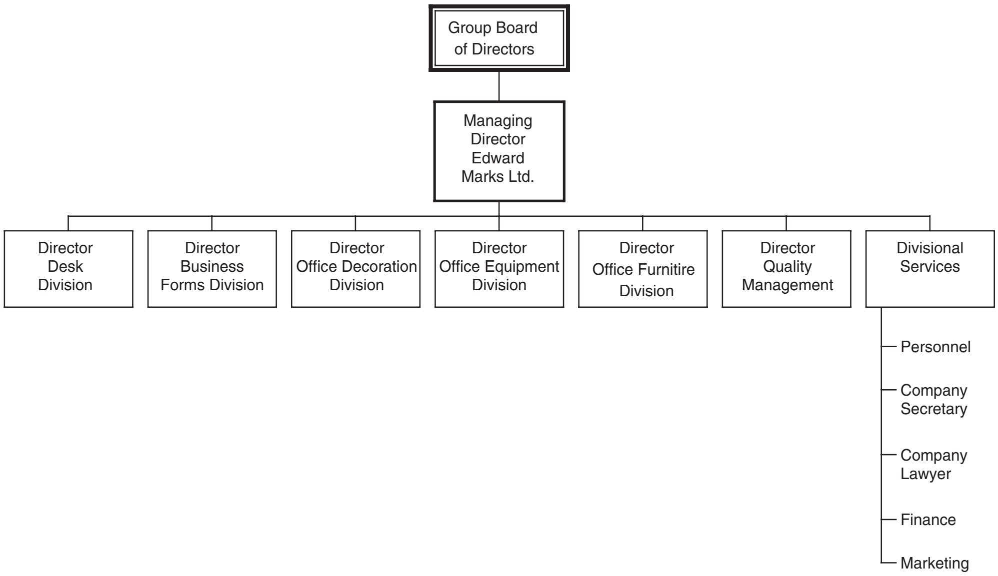


Figure 1.17 *Proposed structure at Edward Marks Ltd*

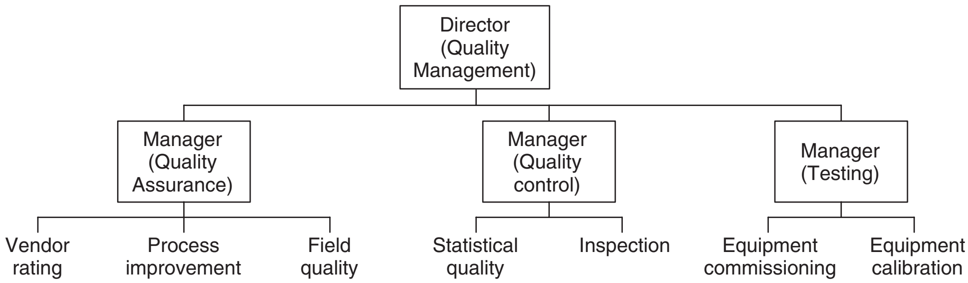


Figure 1.18 *Quality Management Department at Edward Marks Ltd*

Summary

Although implementing the above solution may go a long way in solving the problems identified by the audit, it will not be painless. The two major problems the restructuring will present are that of staff demotion and the possibility of redundancies. The final problem to be overcome now is how the change will be financed.

Discussion questions

1. What kind of organizational structure is in place originally?
2. What kind of problems does this structure create? Are these typical of this type of structure?
3. What, in theory, are the advantages of the original structure?

4. What surprising omission is there in the original structure?
5. How is the new structure going to solve the problems identified in the audit?
6. What are the main disadvantages of the new structure?
7. Can you suggest any other alternatives or improvements for the company structure?

Case study 1.2: Manufacturing at Stickley Furniture*

Introduction

L&J.G. Stickley is a furniture manufacturer that specialize in off-the-shelf and customized furniture made from fine cherry, white oak and mahogany. It sells this furniture through eight retail outlets throughout New York State where the company is based. In the rest of the United States, a network of 100 approved dealers is employed.

Manufacturing facility

The manufacturing facility is a large (see Fig. 1.19 for layout), rectangular building with a 10 m ceiling. There is a wide variety of equipment used. As would be expected in a plant primarily processing wood, there are a number of saws and sanders. One of the saws is a computer-controlled ‘optimizer’ saw used to reduce the raw lumber into production lengths. There are also a number of presses employed for holding the glued sub-assemblies. There is also a number of drilling machines. For special jobs, there is also a broaching machine. Finally, there are two manual routers and two computerized numeric control (CNC) routers used for producing grooves and specialist cuts respectively. There is also a custom shop that mainly consists of specialist hand tools. In addition to the production equipment, there is also a tool room area. This has a variety of equipment that is used for maintaining cutting tools and making replacements as and when required.

Furniture-making tends to be labour intensive regardless of the equipment being used. The skill level of the workers ranges from low skilled to highly skilled. For example, there are low skilled material handlers and highly skilled craftsman such as the three master cabinetmakers that handle customized orders. Finally, due to the nature of the processes being used, power costs are in the region of $40 000–50 000 a month.

Material processing

The manufacture of any piece of furniture commences with the processing of the raw lumber. This is carried out on the large ‘optimizer’ saw from improved productivity and reduced waste. The lumber is cut into standard lengths for use in production and approximately 3500 m in length are cut every day. The standard lengths are then cut for specific jobs using other saws. At this point, depending on the part being produced, the material takes one of two processing

*Adapted from Stevenson, W.J. (1996). *Production/Operations Management*, 5th edn, Irwin. Reproduced with the permission of the McGraw-Hill Companies.

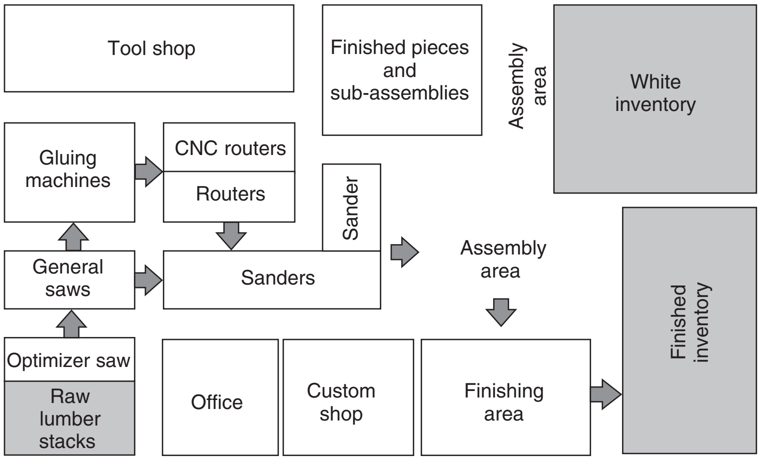


Figure 1.19 *Layout at Stickley*

routes. Pieces being used for the likes of tops of tables, desks and dressers will be glued together and then held 20–30 at a time in one of the presses. Pieces such as table or chair legs, chair backs and other such items will undergo further shaping on the routers. Regardless of whether the piece has been glued or shaped, they all go through sanding to remove any excess glue, where necessary, and to improve the surface finish. For particular jobs, holes may be required using either the drilling or broaching machines, depending on the shape. For jobs with specialist cutting requirements the CNC routers may be used or even finished by hand carving by the cabinetmakers.

Next, the various components are assembled, either into sub-assemblies, or sometimes directly to other parts to make a finished piece. Each item is stamped with the date of production and components such as dresser drawers, cabinet doors and expansion leaves of tables are also stamped to identify their location (e.g. top drawer, left door, etc.). Careful records are kept so that if a piece of furniture is ever returned for repairs, complete instructions are available (type of wood, finish, etc.) to enable the repair to closely match the original piece. The furniture items then usually move to the 'white' inventory section, and eventually to the finishing department where linseed oil or another finish is applied before the items are moved to the finished goods inventory to await shipment to stores and customers.

Production planning and control

Although the demand is seasonal, a level production plan is employed. This allows for both a steady output and workforce. Demand usually peaks in the first and third quarters of the year. Therefore, during the second and fourth quarters when demand drops off, the excess production goes into inventory to cope with the peak demand. Priorities for shopfloor scheduling are based on current inventory levels and processing times. In general, lot sizes are calculated using the economic order quantity (EOQ) method and typically are 25–60 units. There are usually a number of different jobs being processed at any one time.

Inventory

In addition to the 'white' inventory and a small finished goods inventory, the company maintains an inventory of furniture pieces (e.g. table and chair legs) and partially assembled items. This inventory serves two important functions. One is to reduce the amount of time needed to respond to customer orders rather than having to go through the entire production process to obtain required items, and secondly, it helps to smooth production and utilize both equipment and workers. Because of unequal job times on successive operations, some workstations invariably have slack time while others work at capacity. This is used to build up an inventory of commonly used pieces and subassemblies. Moreover, because pieces are being made for inventory, there is flexibility in sequencing. This permits jobs that have similar set-ups to be produced in sequence, thereby reducing set-up time and cost.

Summary

Although the company was on the verge of bankruptcy and had only 20 employees in the early 1970s, under new ownership the company has prospered in its current form. Due, in part, to the introduction of the customized products, the business has flourished and now employs 650 people and has annual sales of $65 million.

Discussion questions

1. Which type of manufacturing system is the primary mode of operation at Stickley and why?
2. What other types of manufacturing system are being used? Explain your answer.
3. Comment on the type of manufacturing layout.
4. Comment on the type of equipment utilized at Stickley.
5. Comment on the skills level of the staff at Stickley.
6. Comment on the variety of product produced.

Chapter review questions

1. Why is a healthy manufacturing industry important to the wealth of a country?
2. What is meant by 'adding value' and how does this relate to manufacturing?
3. In your own words, define what you think manufacturing is.
4. What is a manufacturing system and what are the main elements in its composition?
5. What are the main inputs and outputs of a manufacturing system?

6. What are consumer products and producer products and how do they relate to the inputs and outputs of a manufacturing system?
7. What are the common characteristics for all manufacturing systems?
8. What is a manufacturing strategy and how does it relate to the development of other organizational strategies?
9. What are the main decision categories within the development of a manufacturing strategy?
10. What are the main functions that are incorporated into a manufacturing organization? How do these vary for organizations of different sizes?
11. What are the main influences on how the functions of a manufacturing organization are arranged?
12. What are the main organizational structures employed in manufacturing? Describe these in terms of their similarities and differences.
13. What is meant by discrete parts manufacture and how does this differ from continuous manufacture?
14. What are the four traditional approaches to manufacturing systems? Briefly describe each one.
15. Job and batch manufacture are often confused. What are their similarities and differences and what is the distinction between them?
16. Flow and continuous manufacture are often confused. What are their similarities and differences and what is the distinction between them?
17. What is cellular manufacture and how does it relate to the four traditional approaches?
18. What advantages does cellular manufacture offer over the traditional approaches to discrete part manufacture?
19. The process decision within the development of a manufacturing strategy is linked to four distinct processing strategies. Identify and describe these strategies. How do they relate to the approaches to manufacture already described in questions 14 and 15?
20. How do the above processing strategies relate to manufacturing system characteristics such as production quantity and product variety?
21. Identify and briefly describe the four types of layout used in manufacturing. How do they relate to the manufacturing systems approaches already identified in questions 14 and 15?
22. What are the main advantages and disadvantages of a process layout when compared to a product layout?
23. What is the main disadvantage of a product layout?
24. What is meant by hybrid layout and how does it relate to both the process and product layouts?
25. Where is a fixed position layout likely to be used and why?

26. What is the difference between a manufacturing engineer and an industrial engineer? What kind of tasks are they likely to engage in together?

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