chapter four

Process design


Source: Joe Schwarz, www.joyrides.com.

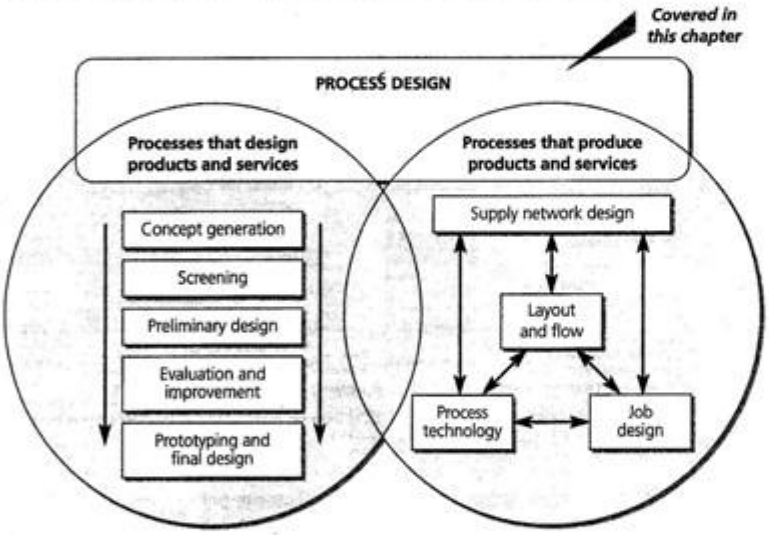
key questions

- What is design in operations management?
- What objectives should the design activity have?
- How are processes designed?
- What are 'process types'?

Introduction

Say you are a 'designer' and most people will assume that you are someone who is concerned with how a product looks – a fashion designer or a motor car designer, for example. But the design activity is much broader than that and while there is no universally recognized definition of 'design', we take it to mean 'the process by which some functional requirement of people is satisfied through the shaping or configuration of the resources and/or activities that comprise a product, or a service, or the transformation process that produces them'. All operations managers are designers. When they purchase or rearrange the position of a machine or piece of equipment, or when they change the way of working within an operations process, it is a design decision because it affects the physical shape and nature of their processes. Likewise, the products or services which are the outputs from operations processes are designed using a process, so operations managers cannot afford to be ignorant of the basic principles of product and service design. This chapter starts by examining design in general, but then focuses particularly on the design of processes. Figure 4.1 shows the issues covered in Part Two and how they relate to each other.

Figure 4.1 **The design activities in operations management covered in Part Two**



'Even faster food'[1]

example

No one really knows who opened the very first drive-through quick service restaurant (QSR), but many in the industry reckon it dates back to 1928 when Royce Hailey first promoted the drive-through service at his Pig Stand restaurant in Los Angeles. It was, however, a primitive process by today's standards. Customers would simply drive by the back door of the restaurant where the chef would come out and deliver the restaurant's famous 'Barbequed Pig' sandwiches. Today, drive-through services have become slicker, faster and a lot more common, especially in the last 25 years. In 1975, McDonald's did not have any drive-throughs, now more than 90 per cent of its US restaurants incorporate a drive-through process. In fact 80 per cent of recent fastfood growth has come through the growing number of drive-throughs. That is why almost all QSR chains, such as KFC pictured alongside, are expanding their drive-through services. Says one industry specialist, *'There are a growing number of customers for whom fastfood is not fast enough. They want to cut waiting time to the very minimum without even getting out of their car. Meeting their needs depends on how smooth we can get the process.'* The trade magazine for fastfood operators (also called *QSR*) publishes an annual survey of how well the different fastfood giants are doing with their drive-throughs in terms of quality, accuracy and, above all, speed. Every year the results of the survey are eagerly awaited by fastfood executives who make sure that considerable

time and effort is devoted to minimizing customer waiting time without reducing the quality of the food.

The competition to design the fastest and most reliable drive-through process is fierce. Starbuck's drive-throughs have strategically placed cameras at the order boards so that servers can recognize regular customers and start making their order even before it's placed. Burger King has experimented with sophisticated sound systems, simpler menu boards and see-through food bags to ensure greater accuracy. After all, there is no point in being fast if you don't deliver what the customer ordered. McDonald's drive-throughs in the Chicago area can accept payment by 'Speedpass', a mini-transponder, usually kept on the key ring and used in the US for payment at ExxonMobil gasoline stations. Passing the Speedpass over a sensor exchanges payment information and automatically debits a credit card. Some companies use computer simulation to evaluate the effect of process changes. For example, a simulation study found that avoiding misunderstandings at the order stage by improving the clarity of speakers would have a significant effect on average throughput time. These details matter. McDonald's reckon that their sales increase 1 per cent for every six seconds saved at a drive-through. While a single Burger King restaurant calculated that it took an extra 15,000 dollars a year each time it reduced queuing time by one second. It is particularly important that menu items are easy to read and understand. Designing 'combo meals' (for example burger, fries and a cola) saves time at the ordering stage. But not everyone is thrilled by the boom in drive-throughs. People living in the vicinity may complain of the extra traffic they attract and companies have to be increasingly careful where they site their new operations. Also, for some, a combination of fastfood (which does not always have a healthy image) and a process which does not even make customers get out of their car, is a step too far. *'The public are getting lazier and lazier,'* says one local official who tried to get drive-throughs banned in his area, *'It's far better for people to walk to lunch – not drive.'* ■

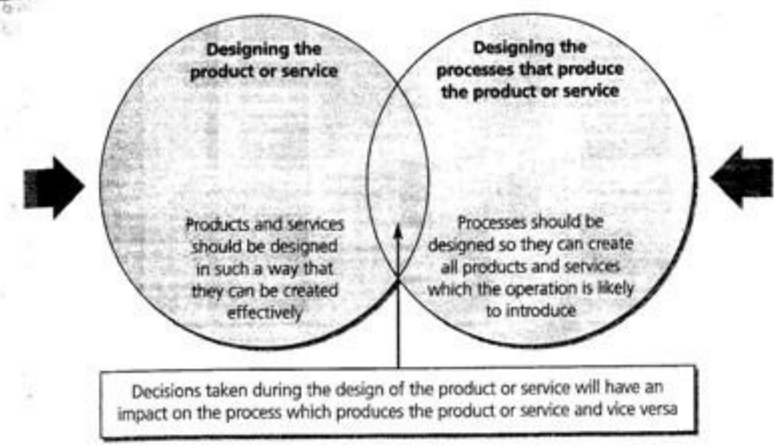
The developments in drive-through services highlight a number of process desig[n] issues. First, it is difficult to separate the design of the service from the design of th[e] process that produces it. Even the food itself (e.g. the 'combo meal') is designed wit[h] the constraints and capabilities of the drive-through process in mind. Second, the activ[ity] of designing the food, and the activity of designing the service experience are bot[h] themselves *processes*. QSRs devote time and effort to this design process, simulatin[g] alternative drive-through arrangements and evaluating the results of this design activit[y] in terms of quality, efficiency, and above all, speed. Third, the final design must take th[e] interests of the wider society into account, in this case in trying to eliminate avoidabl[e] nuisance to neighbours. Perhaps most significant though is the way the total proces[s] must be designed to fit the market it is attempting to serve. Drive-through processe[s] have been developed to offer relatively high volume, low variety (compared to mor[e] conventional restaurants) services with predictable quality, low cost and very fast service. Restaurants aimed at a different market, for example a full service restauran[t] would design their processes to operate in a very different way.

Process design and product/service design are interrelated

Often we will treat the design of products and services, on the one hand, and the desig[n] of the processes which make them, on the other, as though they were separate activities[.] Yet they are clearly interrelated. It would be foolish to commit an organization to th[e] detailed design of any product or service without some consideration of how it is to b[e] produced. Small changes in the design of products and services can have profoun[d] implications for the way the operation eventually has to produce them. Similarly, th[e] design of a process can constrain the freedom of product and service designers to operat[e] as they would wish (see Figure 4.2).

This holds good whether the operation is producing products or services. Howeve[r] the overlap between the two design activities is generally greater in operations whic[h] produce services. Because many services involve the customer in being part of th[e] transformation process, the service, as far as the customer sees it, cannot be separate[d] from the process to which the customer is subjected. The difficulties of overlappin[g] the two activities of product and process design have implications for the way i[n] which the design activity is organized, as will be discussed in Chapter 5. Certainly when product designers also have to make or use the things which they design, it ca[n] concentrate their minds on what is important. For example, in the early days of flight the engineers who designed the aircraft were also the test pilots who took them out o[n]

Figure 4.2 The design of products/services and processes are interrelated and should be treated together



their first flight. For this reason, if no other, safety was a significant objective in the design activity.

Process and product/service design must satisfy customers

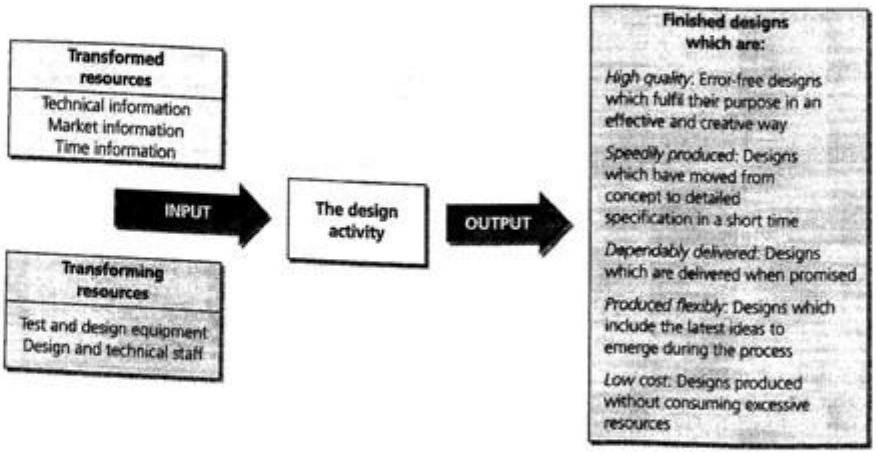
The design activity in operations has one overriding objective: to provide products, services and processes which will satisfy the operation's customers. *Product* designers try to achieve aesthetically pleasing designs which meet or exceed customers' expectations. They also try to design a product which performs well and is reliable during its lifetime. Further, they should design the product so that it can be manufactured easily and quickly. Similarly, *service* designers try to put together a service which meets, or even exceeds, customer expectations. Yet at the same time the service must be within the capabilities of the operation and be delivered at reasonable cost. The same is true for *process* designers. The way that the process which creates the product or service is designed will have a significant impact on the ability of the operation to meet its customers' needs. A process which has been located in the wrong place, which has insufficient capacity, which is arranged in a jumbled and confused layout, which is given inappropriate technology, or which is staffed with unskilled people cannot satisfy customers because it cannot perform efficiently or effectively.

The design activity is itself a process

Producing designs for products, services or the processes which create them is itself a process which conforms to the input–transformation–output model described in Chapter 1 and therefore has to be managed. Figure 4.3 illustrates the design activity as an input–transformation–output diagram. The transformed resource inputs will consist mainly of information in the form of market forecasts, market preferences, technical data, and so on. Transforming resource inputs includes operations managers and specialists technical staff, design equipment and software such as computer-aided design (CAD) systems (*see* Chapter 5) and simulation packages.

We can describe the objectives of the design activity in the same way as we do any transformation process. All operations satisfy customers by producing their services and

Figure 4.3 The design activity is itself a process



goods according to customers' desires for quality, speed, dependability, flexibility and ‹ In the same way, the design activity attempts to produce designs to the same objecti‹

Creativity in the design activity

Creativity is important in process design as well as product/service design

The final quality of any design of product, service or process will be influenced by **creativity** of the designers involved in the design activity. Increasingly, creativity is : as an essential ingredient not just in the design of products and services, but also in design of operations processes. Partly because of the fast-changing nature of m industries, a lack of creativity (and consequently of innovation) is seen as a major r

> *It has never been a better time to be an industry revolutionary. Conversely, it has never a more dangerous time to be complacent. . . . The dividing line between being a leader being a laggard is today measured in months or a few days, and not in decades.*[2]

Of course, creativity can be expensive. By its nature it involves exploring someti unlikely possibilities. Many of these will die as they are proved to be inappropriate. to some extent, the process of creativity depends on these many seemingly wasted in tigations. As Art Fry, the inventor of 3M's Post-it Note products, said:

> *You have to kiss a lot of frogs to find the prince. But remember, one prince can pay for . of frogs.*

Balancing creativity with evaluation

Creativity is a vital ingredient in effective design, but it must be balanced by the n systematic process of evaluation. Evaluation in design means assessing the wort value of each design option, so that a choice can be made between them. This invc assessing each option against a number of **design criteria.** While the criteria used in particular design exercise will depend on the nature and circumstances of the exer it is useful to think in terms of three broad categories of design criteria:

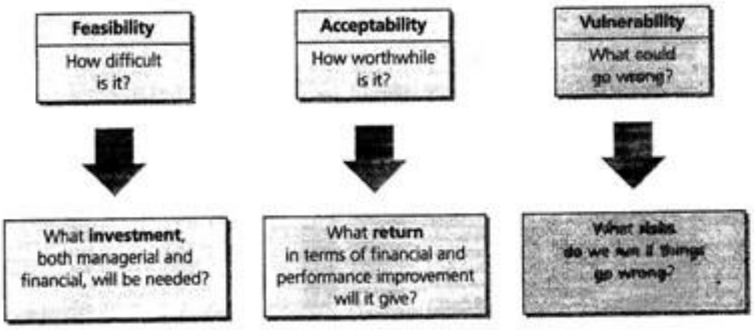
Design criteria

Feasibility

The **feasibility** of the design option – can we do it? That is,

- Do we have the skills (quality of resources) to cope with this option?
- Do we have the organizational capacity (quantity of resources) to cope with this opt
- Do we have the financial resources to cope with this option?

Figure 4.4 Broad categories of evaluation criteria for assessing design options



Acceptability

The **acceptability** of the design option – do we want to do it? That is,

- Does the option satisfy the performance criteria which the design is trying to achieve? (These will differ for different designs.)
- Will our customers want it?
- Does the option give a satisfactory financial return?

Vulnerability

The **vulnerability** of each design option – do we want to take the risk? That is,

- Do we understand the full consequences of adopting the option?
- Being pessimistic, what could go wrong if we adopt the option? What would be the consequences of everything going wrong? (This is called the 'downside risk' of an option.)

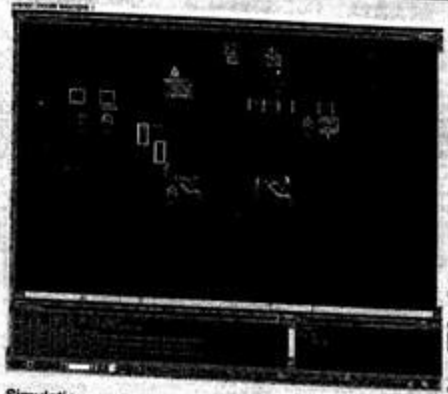
Figure 4.4 illustrates this classification of design criteria.

Simulation in design

Design involves making decisions in advance of the final product, service or process being created, and so the designer is often not totally sure of the consequences of his or her decisions. For example, a running shoe designer might make a decision about the construction of the shoe, or an architect about the layout of a football stadium, based on previous experience and basic theories. To increase their own confidence in their design decision, however, they will probably try to *simulate* how the product and the layout would work in practice. In some ways simulation is one of the most fundamental approaches to decision making. Children play games and 'pretend' so as to extend their experience of novel situations; likewise, managers can gain insights and explore possibilities through the formalized 'pretending' involved in using simulation models. Simulation explores the consequences of decision making rather than directly advising on the decision itself – it is a *predictive* rather than an *optimizing* technique.

The simulation 'model' itself can take many forms. In the case of the running shoe design, the 'model' might be almost identical to the intended product, except that a 'one-off' prototype shoe would have been made rather than one produced on the actual manufacturing system which would be used for the eventual product. The prototype shoe would then be flexed many millions of times to simulate prolonged wear. In the case of the football stadium, the architect could devise a computer-based 'model' which would simulate the movement of people through the building according to the probability distribution which describes their random arrival and movement. This could then be used to predict where the layout might become overcrowded or where extra space might be reduced. The box 'Process simulation in retail banking' describes how one retail bank used simulation to help design its processes.

Process simulation in retail banking — example


Source: OEE Consulting

Simulation screen


Source: OEE Consulting

The actual process

Retail banking has become a much more competitive business in most markets. Basic banking products, such as current accounts and credit cards, are also now provided by many different financial service companies, insurers, and even supermarkets. This has led to a significant increase in competition between the providers of such services. Increasingly, these companies are having to design operations processes that provide a significantly enhanced service, preferably at lower cost. This is why simulation, once the preserve of expensive and high-tech operational research departments, is rapidly becoming a significant aid to process design in banking operations. It is particularly suited to use in environments where the operational design is complex and therefore expensive to 'try out' for real and also where there is a significant degree of randomness, such as the arrival patterns of customers or the varying length of time taken to serve them. Simulation allows process designers to ask 'what-if' questions for a new design. Alternative designs can be explored at relatively low-cost and low-risk.

The advantage of simulation became clear to Lloyds TSB, one of the UK's most prominent financial services groups, when they used it to help design a new Operational Service Centre. A new centralized operation was created by merging a number of smaller centres. Process design decisions included the number and skills of the people needed to staff the process, what hours they should work, how many terminals and servers to install, the sequence of process activities, how teams should be organized, and so on. The company knew that all these variables were important in determining how the new process would operate, but some variables were likely to have a much more dramatic impact than others. The key question was, which ones?

The computer simulation used by the bank exposed the likely impact of each of these variables in a way that was almost impossible to demonstrate by any other method. In addition, once the model of the new operation had been built, a whole range of processing scenarios could be tried out and their impact assessed in terms of cost, service level and utilization. *'Modelling our new operations, particularly with dynamic simulation, has helped us visualize and test a range of design choices, in a way that we never could before,'* says John Tyley of Lloyds TSB, *'In particular, it has helped us to deploy process design strategies that have significantly improved the level of service that we provide to our customers. It also gave us a degree of operational transparency before we actually built the new operation. Simulation has been very useful in allowing us to anticipate and reduce operational risk whilst improving our service level to customers.'* ■

Questions

1 **List the range of 'variables' that you might want to simulate in an operation that processes a car insurance business.**

2 **How would you justify spending large amount of money on building a computer simulation model for a new car assembly plant?**

Environmentally sensitive design

With the issues of environmental protection becoming more important, designers are increasingly having to take account of 'green' issues in their work. In many developed countries, legislation has already provided some basic standards which restrict the use of toxic materials, limit discharges to air and water, and protect employees and the public from immediate and long-term harm. Most of these constraints affect both the design (and operation) of *processes* and the design of the products and services themselves.

Interest has focused on some fundamental issues:

- *The sources of inputs* to a product or service. (Will they damage rainforests? Will they use up scarce minerals? Will they exploit the poor or use child labour?)
- *Quantities and sources of energy* consumed in the process. (Do plastic beverage bottles use more energy than glass ones? Should waste heat be recovered and used in fish farming?)
- *The amounts and type of waste material* that are created in the manufacturing processes. (Can this waste be recycled efficiently, or must it be burnt or buried in landfill sites? Will the waste have a long-term impact on the environment as it decomposes and escapes?)
- *The life of the product itself.* It is argued that if a product has a useful life of, say, 20 years, it will consume fewer resources than one that only lasts five years, which must therefore be replaced four times in the same period. However, the long-life product may require more initial inputs, and may prove to be inefficient in the latter part of its use, when the latest products use less energy or maintenance to run.
- *The end-of-life of the product.* (Will the redundant product be difficult to dispose of in an environmentally friendly way? Could it be recycled or used as a source of energy? Could it still be useful in third-world conditions? Could it be used to benefit the environment, such as old cars being used to make artificial reefs for sea life?)

Designers are faced with complex trade-offs between these factors, although it is not always easy to obtain all the information that is needed to make the 'best' choices. For example, it is relatively straightforward to design a long-life product, using strong material, over-designed components, ample corrosion protection, and so on. But its production might use more materials and energy and it could create more waste on disposal. To help make more rational decisions in the design activity, some industries are experimenting with **life cycle analysis.** This technique analyses all the production inputs, the life cycle use of the product and its final disposal, in terms of total energy used (and more recently, of all the emitted wastes such as carbon dioxide, sulphurous and nitrous gases, organic solvents, solid waste, etc.). The inputs and wastes are evaluated at *every* stage in its creation, beginning with the extraction or farming of the basic raw materials. The box 'Ecologically smart' demonstrates that it is possible to include ecological considerations in all aspects of product and process design.

Life cycle analysis

Designing processes

All operations managers manage processes, in fact almost *all* managers manage processes of some type. That is why process design is so important. It affects the day-to-day activities of everyone who is involved in a process. It is this realization that processes are everywhere in business that has led to **process design** and process redesign and improvement becoming a popular topic in the management press and in consultancy.

Process design

So what do we mean by a process? In fact we have already defined it in Chapter 1. It is '. . . any part of the organization which takes a set of input resources which are then used to transform something, or are transformed themselves into outputs of products or services which satisfy customers . . . ', and customers, of course, can be internal or external.

Ecologically smart[4]

example

When Daimler-Benz started to examine the feasibility of the Smart town car, the challenge was not just to examine the economic feasibility of the product but also to build in environmental sensitivity to the design of the product and the process that was to make it. This is why environmental protection is now a fundamental part of all production activities in its 'Smartville' plant at Hambach near France's border with Germany.

The product itself is designed on environmentally compatible principles. The company's engineers are required to design with the product's end of life in mind. Even before assembly starts, the product's disassembly must be considered. In fact the modular construction of the Smart car helped to guarantee economical dismantling at the end of its life. This also helps with the recycling of materials. Over 85 per cent of the Smart's components are recyclable and recycled material is used in its initial construction. For example, the Smart's instrument panel comprises 12 per cent recycled plastic material. Similarly, production processes are designed to be ecologically sustainable. For example, the plant uses an environmentally friendly painting technique using powder coating. This allows less paint to be used while maintaining a high quality of protection. It also involves no solvent emission and no hazardous waste, as well as the recycling of surplus material. But it is not only the use of new technology that contributes to the plant's ecological credentials.

Ensuring a smooth and efficient movement of materials within the plant also saves time, effort and, above all, energy. So, traffic flow outside and through the building has been optimized, buildings are made accessible to suppliers delivering to the plant, and conveyor systems are designed to be loaded equally in both directions so as to avoid empty runs. Also the plant was designed to be expanded without compromising its logistic efficiency. The company even claim that the buildings themselves are a model for ecological compatibility. No construction materials contain formaldehyde or CFCs and the outside of the buildings are lined with 'TRESPA', a raw material made from European timber that is quick to regenerate. ■

An alternative, but very similar definition is '. . . a group of resources and activities whi add value by turning specific inputs into outputs . . .'. At its simplest the design a process involves identifying all the individual activities that are needed to fulfil t objectives of the process, and deciding on the sequence in which these activities are to performed and who is going to do them. There will, of course, be some constraints to th Some activities must be carried out before others and some activities can only be done certain people or machines. Nevertheless, for a process of any reasonable size, the numb of alternative process designs is usually large. Because of this, process design is often do using some simple visual approach such as **process mapping** described next.

Process mapping

Process mapping

Process mapping simply involves describing processes in terms of how the activiti within the process relate to each other. There are many techniques which can be us for *process mapping* (or **process blueprinting**, or **process analysis**, as it is sometim called). However, all the techniques have two main features:

Process blueprinting
Process analysis

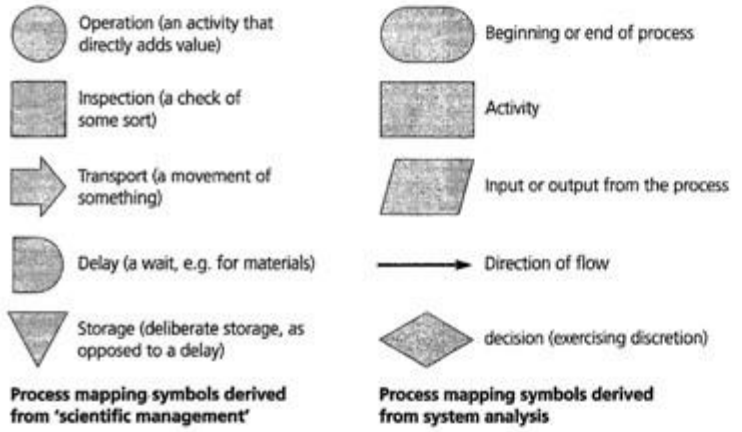
- they identify the different *types of* activity that take place during the process:
- they show the flow of materials or people or information through the process.

Process mapping symbols

Process mapping symbols

Process mapping symbols are used to classify different types of activity. Although the is no universal set of symbols, used all over the world for any type of process, the are some that are commonly used. Most of these derive either from the early days

Figure 4.5 Some common process mapping symbols



'scientific' management around a century ago (see Chapter 9) or, more recently, from information system flowcharting. Figure 4.5 shows the symbols we shall use here.

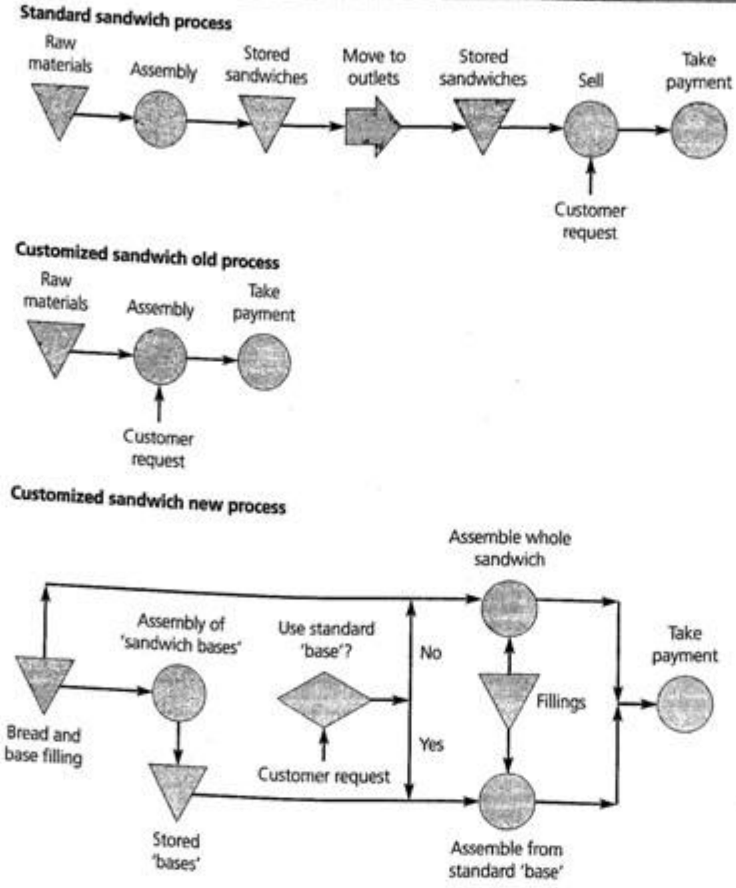
These symbols can be arranged in order, and in series or in parallel, to describe any process. For example, the retail catering operation of a large campus university has a number of outlets around the campus selling sandwiches. Most of these outlets sell 'standard' sandwiches that are made in the University's central kitchens, and transported to each outlet every day. However, one of these outlets is different; it is a kiosk that makes more expensive 'customized' sandwiches to order. Customers can specify the type of bread they want and a very wide combination of different fillings. Because queues for this customized service are becoming excessive, the catering manager is considering redesigning the process to speed it up. This new process design is based on the findings from a recent student study of the current process which proved that 95 per cent of all customers ordered only two types of bread (soft roll and Italian bread) and three types of protein filling (cheese, ham and chicken). Therefore six 'sandwich bases' (2 types of bread × 3 protein fillings) could be prepared in advance and customized with salad, mayonnaise, etc. as customers ordered them. The process maps for making and selling the standard sandwiches, the current customized sandwiches and the new customized process are shown in Figure 4.6.

High level process mapping

Note how the introduction of some degree of discretion in the new process makes it more complex to map at this detailed level. This is one reason why processes are often mapped at a more aggregated level, called **high level process mapping**, before more detailed maps are drawn. Figure 4.7 illustrates this for the new customized sandwich operation. At the highest level the process can be drawn simply as an input–transformation–output process with sandwich materials and customers as its input resources and satisfied customers 'assembled' to their sandwich as outputs. No details of how inputs are transformed into outputs are included. At a slightly lower, or more detailed level, what is sometimes called an **outline process map** (or chart) identifies the sequence of activities but only in a general way. So the activity of finding out what type of sandwich a customer wants, deciding if it can be assembled from a sandwich 'base' and then assembling it to meet the customer's request, is all contained in the general activity 'assemble as required'. At the more detailed level, all the activities are shown (we have shown the activities within 'assemble as required').

Outline process map

Figure 4.6 Process maps for three sandwich making and selling processe

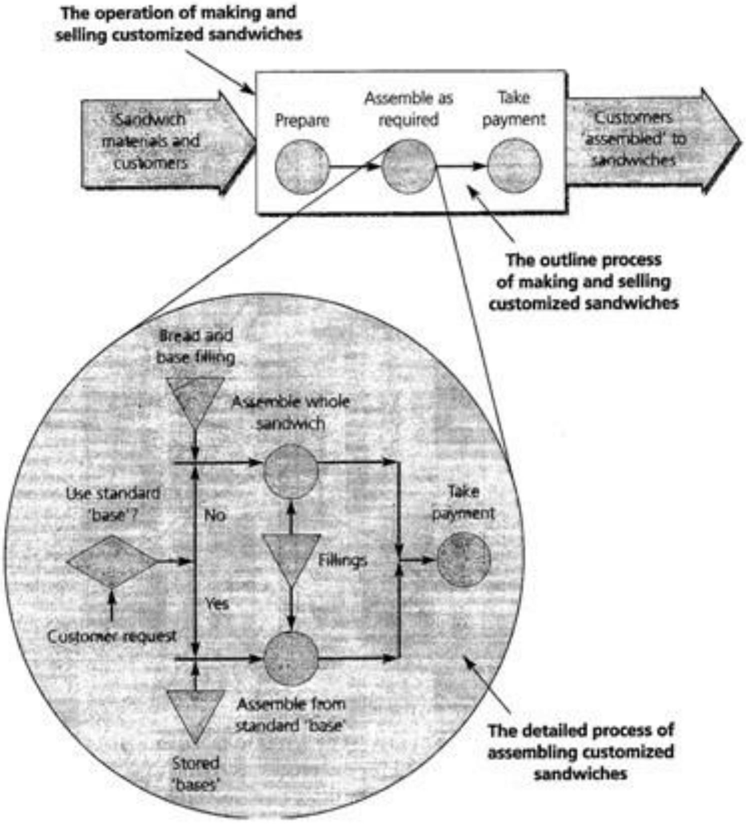


Micro detailed process map

Although not shown in Figure 4.7 an even more micro set of process activiti could be mapped within each of the detailed process activities. Such a **micro detaile process map** could specify every single motion involved in each activity. In fact mo quick service restaurants, such as KFC pictured in the box at the beginning of th chapter, do exactly that. Because consistent quality and efficiency are require throughout their operations around the world, processes have to be designed this micro level. This allows the 'best' process to be developed at the company head offices where it can be written down (or drawn as a process map), transmitte to all the company's restaurants, implemented and controlled in a relatively co sistent manner. A less detailed process map would leave room for differences i interpretation which could, in turn, result in different standards of food preparatio and service.

To illustrate how detailed process maps can be, Figure 4.8 defines each movemer in an assembly process. A standard process chart is used with process activity symbol pre-marked. Also the activities of both hands are defined against the same in suc a way that left- and right-hand movements can be compared (presumably based o

Figure 4.7 The new customized sandwich process mapped at three levels



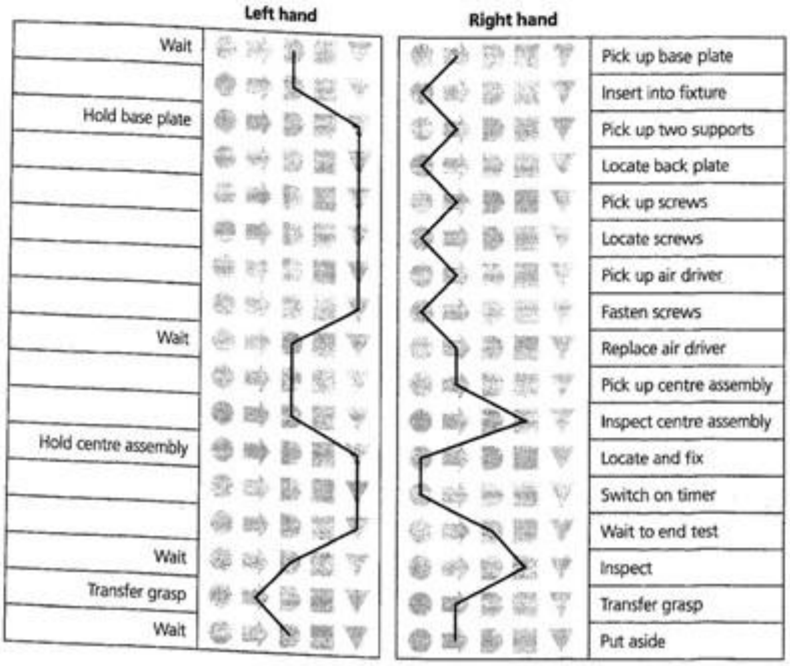
a right-handed person). When this is done the process map is often called a two-handed process chart.

Improving processes

One significant advantage of mapping processes is that each activity can be systematically challenged in an attempt to improve the process. For example, Figure 4.9 shows the flow process chart which Intel Corporation, the computer chip company, drew to describe its method of processing expense reports (claims forms).

After critically examining its existing process, the company developed a new process that cut the number of activities from 26 down to 15 (see Figure 4.10). The accounts payable desk's activities were combined with the cash-receipt's activities of checking employees' past expense accounts (activities 8, 10 and 11) which also eliminated activities 5 and 7. After consideration, it was decided to eliminate the activity of checking items against company guidelines, because it seemed '... *more trouble than it was worth*'. Also, logging the batches was deemed unnecessary. All this combination and elimination of activities had the effect of removing several 'delays' from the process. The end result was a much-simplified process which reduced the staff time needed to do the job by 28 per cent and considerably speeded up the whole process.

Figure 4.8 **Two-handed process chart**



Process performance

The whole point of process design is to make sure that the performance of the process i appropriate for whatever the process is trying to achieve. In the case of the customize sandwich process, the new design was attempting to offer as wide a range of sandwiche as was previously offered, without the slow service of the old process. In other words, was maintaining similar levels of flexibility (to offer the same variety) while improv ing the speed of service. The new process would probably also increase the efficiency c the process because the sandwich 'bases' could be assembled during periods of lo demand. This would balance the load on staff and so cost performance would improv The quality of the sandwiches would presumably not suffer, although pre-assemblin the sandwich bases may detract from the fresh appearance and taste. The dependabilit of the new process is less easy to assess. With the old process the time between reques ing a sandwich and its delivery was long but reasonably predictable. The new proces however, will deliver fairly quickly 95 per cent of the time but take longer if the sandwic is non-standard. Table 4.1 summarizes the performance of the new design.

So, a simple and straightforward way of assessing the design of a process is to judg it in terms of the conventional set of performance objectives as in Table 4.1. In a mor general sense, Table 4.2 summarizes the impact that good process design can have i terms of each performance objective.

Throughput, cycle time and work in process

The new customized sandwich process has one indisputable advantage over the ol process; it is faster in the sense that customers (the main transformed resource) spen less time in the process. The additional benefit this brings is a reduction in cost pe

Figure 4.9 The flow process chart for processing expense reports at Intel

Flow process chart

Activity *Processing expense reports* **Location** *Accounts Dept*

	Description of element	○	⇨	D	□	▽
1	*Report arrives at accounts payable desk*					
2	*Wait for processing*					
3	*Check expenses report*					
4	*Stamp and date report*					
5	*Send cash to receipt desk*					
6	*Wait for processing*					
7	*Check to see if advance payment has been made*					
8	*Send to accounts receivable desk*					
9	*Wait for processing*					
10	*Check employee's past account*					
11	*Send to accounts payable desk*					
12	*Attach payment voucher to report*					
13	*Log report*					
14	*Check items against company guidelines*					
15	*Wait for batching*					
16	*Collect reports into batch*					
17	*Batch goes to audit desk*					
18	*Wait for processing*					
19	*Batch of reports logged*					
20	*Check payment vouchers*					
21	*Reports go to batch control*					
22	*Control number applied to batch*					
23	*Copies of reports to filing*					
24	*Reports filed*					
25	*Copies of payment voucher to keyboard*					
26	*Cheque*					
	Totals	*7*	*8*	*5*	*5*	*1*

customer served (because more customers can be served using the same resources). Note, however, that the total amount of work needed to make and sell a sandwich has not reduced. All the new process has done is to move some of the work to a less busy time. So the **work content** (the total amount of work required to produce a unit of output) has not changed but customer **throughput time** (the time for a unit to move through the process) has improved.

Work content

Throughput time

For example, suppose that the time to assemble and sell a sandwich (the work content) using the old process was two minutes and that two people were staffing the

Figure 4.10 The flow process chart for processing expense reports at Intel after critical analysis

Flow process chart

Activity *Processing expense reports* **Location** *Accounts Dept*

	Description of element					
1	Report arrives at accounts payable desk					
2	Stamp and date report					
3	Check expenses report					
4	Attach payment voucher to report					
5	Wait for batching					
6	Collect reports into batch					
7	Batch goes to audit desk					
8	Wait for processing					
9	Check totals of reports and vouchers					
10	Reports go to batch control					
11	Control number applied to batch					
12	Copies of reports to filing					
13	Reports filed					
14	Copies of payment voucher to keyboard					
15	Cheque issued					
	Totals	5	5	2	2	1

Table 4.1 Assessing the performance of the new customized sandwich process

Performance objective	*Change with new process*	*Comments*
Quality	No change?	Check to make sure that sandwich bases do not deteriorate in storage
Speed	Faster for 95 per cent of customers	
Dependability	Less predictable delivery time	Need to manage customer expectations regarding delivery time for non-standard sandwiches
Flexibility	No change	
Cost	Potentially lower cost	Need to forecast the number of each type of sandwich 'base' to pre-assemble

Table 4.2 The impact of process design on operations performance objectives

Performance objective	*Good process design can . . .*
Quality	Provide the appropriate resources which are capable of producing the product or service to its design specifications
Speed	Move materials, information or customers through each stage of the process without delays
Dependability	Provide technology and staff who are themselves dependable
Flexibility	Provide resources which can be changed quickly so as to create a range of products or services
Cost	Ensure high utilization of resources and therefore efficient and low-cost processes

Cycle time

Work-in-process

process during the busy period. Each person could serve a customer every two minutes, therefore every two minutes, two customers were being served, so on average a customer is emerging from the process every minute. This is called the **cycle time** of the process, the average time between units of output emerging from the process. When customers join the queue in the process they become **work-in-process** (or work-in-progress) sometimes written as WIP. If the queue is ten people long (including that customer) when the customer joins it, he or she will have to wait ten minutes to emerge from the process. Or put more succinctly . . .

$$\text{throughput time} = \text{work-in-process} \times \text{cycle time}$$

In this case

$$10 \text{ minutes wait} = 10 \text{ people in the system} \times 1 \text{ minute per person}$$

Little's Law

This mathematical relationship is called **Little's Law.**[5] It is simple but very useful. For example, suppose it is decided that, when the new process is introduced, the average number of customers in the process should be limited to around ten and the maximum time a customer is in the process should be on average four minutes. If the time to assemble and sell a sandwich (from customer request to the customer leaving the process) in the new process has reduced to 1.2 minutes, how many staff should be serving?

Putting this into Little's Law:

$$\text{throughput time} = 4 \text{ minutes and,}$$

$$\text{work in progress, WIP} = 10$$

So, since

$$\text{throughput time} = \text{WIP} \times \text{cycle time}$$

$$\text{cycle time} = \frac{\text{throughput time}}{\text{WIP}}$$

$$\text{the cycle time for the process} = \frac{4}{10} = 0.4 \text{ minutes}$$

That is, a customer should emerge from the process every 0.4 minutes, on average. Given that an individual can be served in 1.2 minutes

$$\text{the number of servers required} = \frac{1.2}{0.4} = 3$$

In other words, three servers would serve three customers in 1.2 minutes. Or one customer in 0.4 minutes.

Worked example

Mike was totally confident in his judgement, *'You'll never get them back in time,'* h said. *'They aren't just wasting time, the process won't allow them to all have their coffee an get back for 11 o'clock.'* Looking outside the lecture theatre, Mike and his colleagu Dick were watching the 20 business men who were attending the seminar queuing t be served coffee and biscuits. The time was 10.45 and Dick knew that unless they wer all back in the lecture theatre at 11 o'clock there was no hope of finishing his pres entation before lunch. *'I'm not sure why you're so pessimistic,'* said Dick, *'they seem t be interested in what I have to say and I think they will want to get back to hear how ope ations management will change their lives.'* Mike shook his head, *'I'm not questioning the motivation'*, he said, *'I'm questioning the ability of the process out there to get through the all in time. I have been timing how long it takes to serve the coffee and biscuits. Each coff is being made fresh and the time between the server asking each customer what they wa and them walking away with their coffee and biscuits is taking 48 seconds. Remember tha according to Little's Law, throughput equals work in process multiplied by cycle time. If th work in process is the 20 managers in the queue and cycle time is 48 seconds, the tot throughput time is going to 20 multiplied by 0.8 minutes which equals 16 minutes. Add t that sufficient time for the last person to drink their coffee and you must expect a tot throughput time of a bit over 20 minutes. You just haven't allowed long enough for th process.'* Dick was impressed. *'Err . . . what did you say that law was called again?'* *'Little Law,'* said Mike.

The volume–variety effect on design

In Chapter 1 we saw how processes in operations can range from producing a very l volume of products or services (for example, a food canning factory) to a very low ume (for example, major project consulting engineers). We also saw how they can r from producing a very low variety of products or services (for example, in an electr utility) to a very high variety (as, for example, in an architects' practice). Usually the dimensions of volume and variety go together. Low-volume operations processes c have a high variety of products and services, and high-volume operations proc often have a narrow variety of products and services. Thus there is a continuum l low volume–high variety through to high volume–low variety, on which we position operations.

If you have had the opportunity to study operations, even at a superficial level, may have noticed that different operations, perhaps within the same industry, a different types of processes. For example, not all retail operations are organized ir same way, or even look the same. Even within a single operation, different approa to designing processes can be found. A manufacturing plant may have a large organized on a 'mass-production' basis, in which it makes its high-volume 'best sel products. In another part of the plant it may also have an area where it makes a variety of products in much smaller volumes. The design of each of these proces likely to be different. Similarly, in a medical service, compare the approach taken d mass medical treatments, such as large-scale immunization programmes, with that t for a transplant operation where the treatment is designed specifically to meet the r of one person. These differences go well beyond their differing technologies, o different processing requirements of the products or services the produce. The explained by the fact that no one type of process design is best for all types of oper in all circumstances. The differences are explained largely by the diff **volume–variety positions** of the operations.

Volume–variety positions

Process types

Process types

The position of an operation on the volume–variety continuum shapes the general approach it takes to managing its processes. These 'general approaches' to managing processes are called **process types**. Different terms can be used to identify process types in manufacturing and service industries.

In manufacturing, these process types are (in order of increasing volume and decreasing variety):

- project processes
- jobbing processes
- batch processes
- mass processes
- continuous processes.

In service operations there is less consensus on the terms of the process type. The terms we use here are (again in order of increasing volume and decreasing variety):[6]

- professional services
- service shops
- mass services.

Note that there is some variation in how the names of these process types are used and you may find slightly different definitions used. Also it is not uncommon to find the 'manufacturing' terms used in service industries. Each process type implies a different way of organizing operations' activities with different volume and variety characteristics (see Figure 4.11).

Process types in manufacturing

Project processes

Project processes

Project processes are those which deal with discrete, usually highly customized products. Often the timescale of making the product or service is relatively long, as is the interval between the completion of each product or service. So low volume and high

Figure 4.11 Different process types imply different volume–variety characteristics for the process

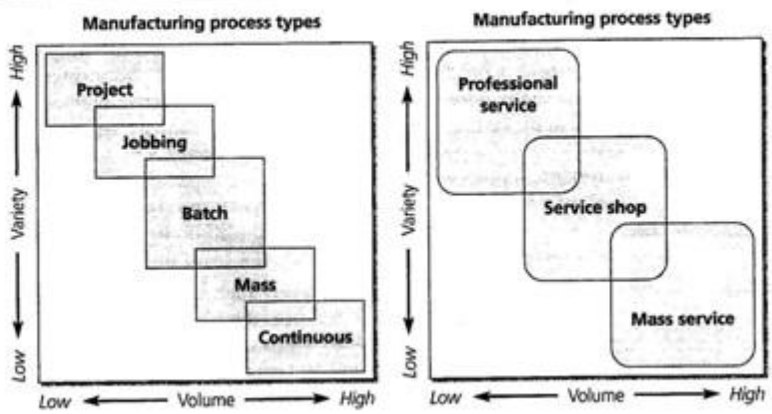
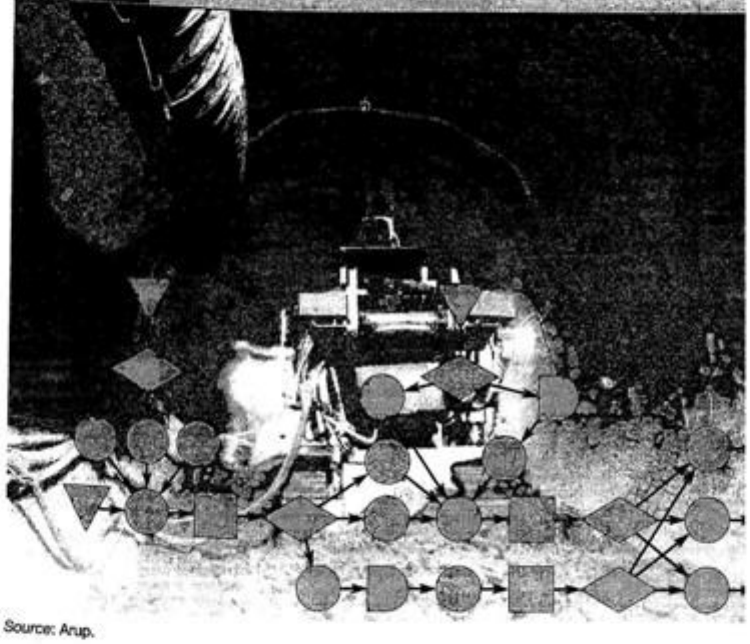


Figure 4.12 A project process with a small part of the process map tha would describe the whole process



Source: Arup.

variety are characteristics of project processes. The activities involved in makin product can be ill-defined and uncertain, sometimes changing during the produ process itself. Examples of project processes include shipbuilding, most constru companies, movie production companies, building the Mass Rapid Transport Sys large fabrication operations such as those manufacturing turbo generators, drillir wells and installing a computer system. The essence of project processes is that eac has a well-defined start and finish, the time interval between starting different jobs i atively long and the transforming resources which make the product will probably been organized especially for each product.

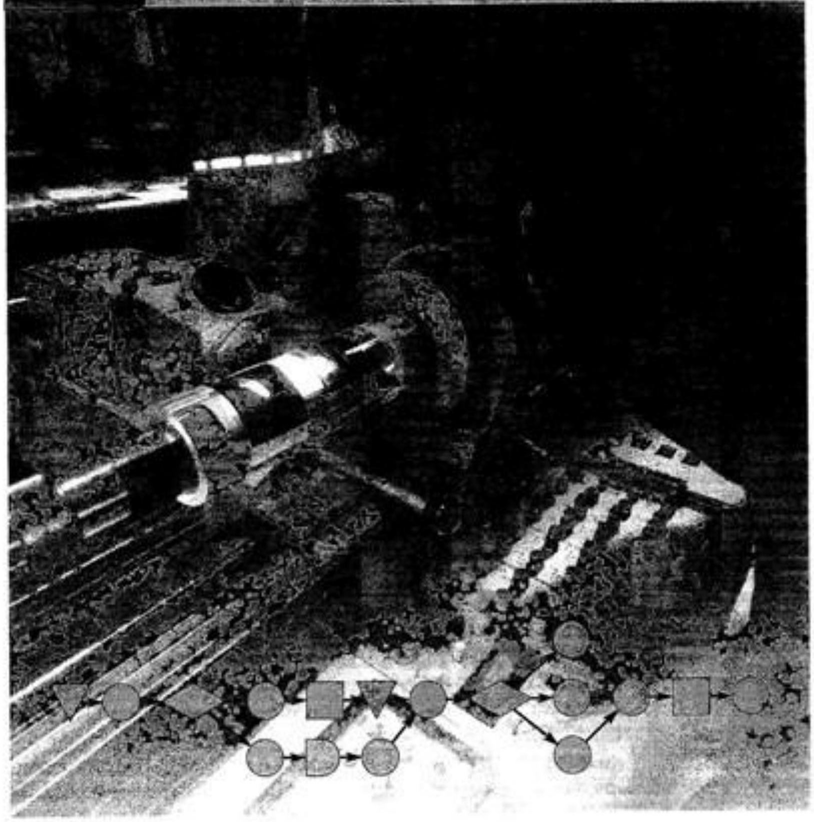
The process map for project processes will almost certainly be complex, partly be each unit of output is so large with many activities occurring at the same time and p because the activities in such processes often involve significant discretion to act ac ing to professional judgement. Figure 4.12 shows a typical project process (a tunn project) and a process map which indicates the activities in one small part of the process. A process map for a whole project would be extremely complex, so rarely w all of a project be mapped, but small parts may be.

Jobbing processes

Jobbing processes

Jobbing processes also deal with very high variety and low volumes. Whereas in pr processes each product has resources devoted more or less exclusively to it, in job processes each product has to share the operation's resources with many others. resources of the operation will process a series of products but, although all the proc will require the same kind of attention, each will differ in its exact needs. Exan of jobbing processes include many precision engineers such as specialist toolma

Figure 4.13 Preparing photolithography materials on a jobbing basis with a typical process map



Source: Corbis.

furniture restorers, bespoke tailors, and the printer who produces tickets for the local social event. Jobbing processes produce more and usually smaller items than project processes but, like project processes, the degree of repetition is low. Many jobs will probably be 'one-offs'.

Again, any process map for a jobbing process could be relatively complex for similar reasons to project processes. However, jobbing processes usually produce physically smaller products and, although sometimes involving considerable skill, such processes often involve fewer unpredictable circumstances. Therefore, their process maps are usually less complex than those for project processes. Figure 4.13 shows a typical jobbing process preparing photolithography materials and part of its process map. Although the process routes for different jobs can be similar, each job is slightly different.

Batch processes

Batch processes

Batch processes can often look like jobbing processes, but batch does not have quite the degree of variety associated with jobbing. As the name implies, each time batch processes produce a product they produce more than one. So each part of the operation has periods when it is repeating itself, at least while the 'batch' is being processed. The size

Figure 4.14 A batch process in a garment manufacturer together with an illustrative process map

of the batch could be just two or three, in which case the batch process would di little from jobbing, especially if each batch is a totally novel product. Conversely, if batches are large, and especially if the products are familiar to the operation, ba processes can be fairly repetitive. Because of this, the batch type of process can be fou over a wider range of volume and variety levels than other process types. Examples batch processes include machine tool manufacturing, the production of some spe gourmet frozen foods, the manufacture of most of the component parts which go i mass-produced assemblies such as automobiles, and the production of most clothing

Figure 4.14 shows part of a garment manufacturing process. Batches of the vari parts that make up the garments move through the work stations, each of which has specialized machinery. Although the process can look complex because different p can take different paths through the process, each part will take a predictable route w relatively standard activities being performed at each stage (as the process map show

Mass processes

Mass processes

Mass processes are those which produce goods in high volume and relatively narr variety – narrow, that is, in terms of the fundamentals of the product design. An au mobile plant, for example, might produce several thousand variants of car if ev option of engine size, colour, extra equipment, etc. is taken into account. Yet essentia it is a mass operation because the different variants of its product do not affect the ba process of production. The activities in the automobile plant, like all mass operatio are essentially repetitive and largely predictable. Examples of mass processes include t automobile plant, most consumer durable manufacturers such as a television pla most food processes such as a frozen pizza manufacturer, a beer bottling plant a CD production.

Figure 4.15 shows part of a packing process. As is usual with such processes, seve types of package are produced on the line but the process itself is unaffected. In fact, t equipment used at each stage of the process can be designed to handle several differe

Figure 4.15 A mass process map – a packing process

Source: Tibbett and Britten.

types of components loaded into the packing line. So, provided the sequence of components in the process is synchronized with the sequence of packs moving through the process, the process seems to be almost totally repetitive.

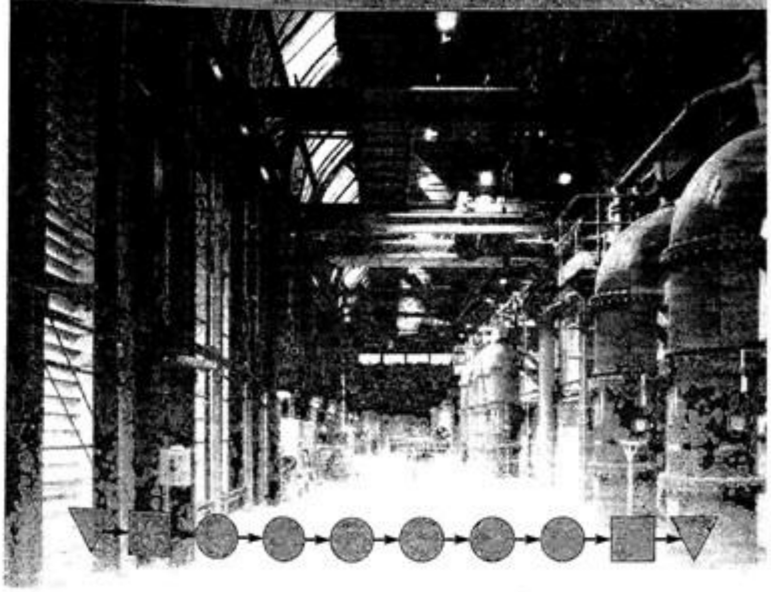
Continuous processes

Continuous processes

Continuous processes are one step beyond mass processes insomuch as they operate at even higher volume and often have even lower variety. They also usually operate for far longer periods of time. Sometimes they are literally continuous in that their products are inseparable, being produced in an endless flow. They may even be continuous in that the operation must supply the products without a break. Continuous processes are often associated with relatively inflexible, capital-intensive technologies with highly predictable flow. Examples of continuous processes include petrochemical refineries, electricity utilities, steel making and some paper making.

Figure 4.16 shows part of the San Miguel brewery in Hong Kong. There are often few elements of discretion in this type of process and although products may be stored during the process, the predominant characteristic of most continuous processes is of smooth flow from one part of the process to another. Inspections are likely to form part

Figure 4.16 Part of a continuous process and a typical continuous process map



Source: Arup.

of the process, although the control applied as a consequence of those inspections often automatic rather than requiring human discretion.

Process types in service operations

As with manufacturing operations, each process type in service operations implies a diff ent way of organizing the operation to cope with different volume–variety characteristi

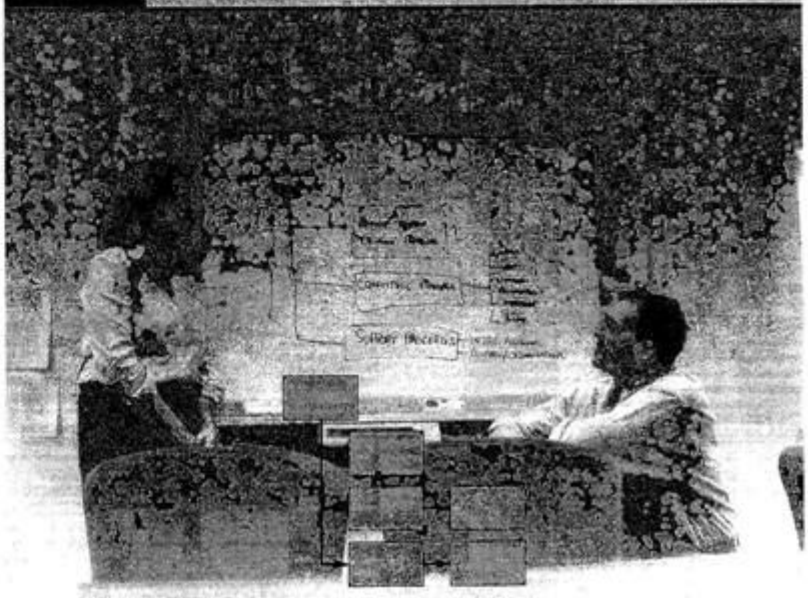
Professional services

Professional services

Professional services are defined as high-contact organizations where customers spe a considerable time in the service process. Such services provide high levels customization, the service process being highly adaptable in order to meet individu customer needs. A great deal of staff time is spent in the front office and contact staff a given considerable discretion in servicing customers. The amount of time and attenti provided for each customer probably means that the ratio of staff to customers is hig Professional services tend to be people-based rather than equipment-based, with empl sis placed on the process (how the service is delivered) rather than the 'product' (wh is delivered). Professional services include management consultants, lawyers' practic architects, doctors' surgeries, auditors, health and safety inspectors and some compu field service operations.

A typical example would be OEE, a consultancy that sells the problem-solvi expertise of its skilled staff to tackle clients' problems. Typically, the problem will fi be discussed with clients and the boundaries of the project defined. Each 'product' different. The project manager's role is to create a project team with the appropri mix of skills to tackle the problem. A high proportion of work takes place at the clien

Figure 4.17 A professional service process map – consultants planning how best to help their client



premises, with frequent contact between members of the project team and the client. Figure 4.17 shows consultants at the consultancy company, OEE, preparing to start a consultancy assignment. They are discussing how they might approach the various stages of the assignment, from understanding the real nature of the problem through to the implementation of their recommended solutions. This is in itself a process map, although a very high level one. It guides the nature and sequence of the consultants' activities. In fact, this consultancy specializes in helping their clients to develop processes, so the output from the consultancy process in the picture is an improved process for their client.

At the other extreme are mass services.

Mass services

Mass services

Mass services have many customer transactions, involving limited contact time and little customization. Such services are often predominantly equipment-based and 'product' oriented, with most value added in the back office and relatively little judgement applied by front-office staff. The mainly non-professional staff are likely to have a closely defined division of labour and to follow set procedures. Mass services include supermarkets, a national rail network, an airport, telecommunications service, library, television station, the police service and the enquiry desk at a utility. For example, rail services such as Virgin Trains in the UK or SNCF in France all move a large number of passengers with a variety of rolling stock on an immense infrastructure of railways. Passengers pick a journey from the range offered. The rail company ticket-office staff can advise passengers on the quickest or cheapest way to get from A to B, but they cannot 'customize' the service by putting on a special train for them.

Figure 4.18 A mass service process map – a call centre can handle a very high volume of customer enquiries because it standardizes its processes

Source: Royal Bank of Scotland Group.

One of the most common types of mass service are the call centres used by almost all companies that deal directly with consumers. Coping with a very high volume of enquiries requires some kind of structuring of the process of communicating with customers. This is often achieved by using a carefully designed enquiry process (sometimes known as a script). Figure 4.18 shows a bank's call centre together with part of the process used by call centre staff to help answer customer queries.

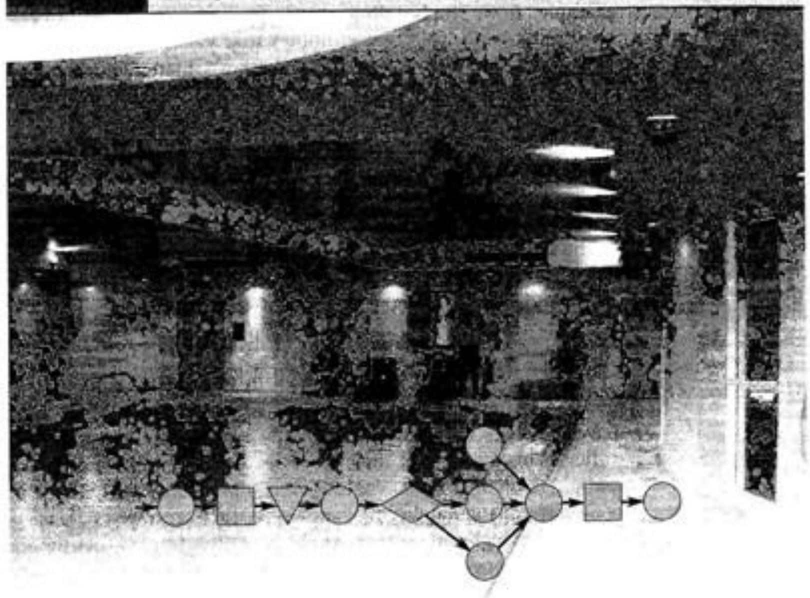
Service shops

Service shops

Service shops are characterized by levels of customer contact, customization, volumes of customers and staff discretion, which position them between the extremes of professional and mass services. Service is provided via mixes of front- and back-office activities, people and equipment, and of product/process emphasis. Service shops include banks, high street shops, holiday tour operators, car rental companies, schools, most restaurants, hotels and travel agents. For example, television and entertainment centre rental organizations offer both rental and retail sales of home electronic products. Their range of products is displayed in front-office outlets, while back-office operations look after purchasing and administration. The front-office staff are not there solely to take money; they have some technical training and can advise customers during the process of selling the product. Essentially the customer is buying a fairly standardized product but will be influenced by the process of the sale which can be customized in the sense that the individual customer's needs are diagnosed and, within the limits of the operation's product range, met.

Similarly, the health club shown in Figure 4.19 has front-office staff who can give advice on exercise programmes and other treatments. To maintain a dependable

Figure 4.19 A service shop process map – this health club offers some variety within a standard set of facilities and processes



service the staff need to follow defined processes every day. For example, the process map shows part of the process of checking the state of the water in the swimming pool. If this process is not followed correctly local health inspectors could close the whole operation down.

critical commentary

Although the idea of process types is useful in so much as it reinforces the, sometimes important, distinctions between different types of process, it is in many ways simplistic. In reality there is no clear boundary between process types. For example, many processed foods are manufactured using mass production processes but in batches. So, a 'batch' of one type of cake (say) can be followed by a 'batch' of a marginally different cake (perhaps with different packaging), followed by yet another, etc. Essentially this is still a mass process, but not quite as pure a version of mass processing as a manufacturing process that only made one type of cake. Similarly, the categories of service processes are likewise blurred. For example, a specialist camera retailer would normally be categorized as a service shop, yet it also will give, sometimes very specialized, technical advice to customers. It is not a professional service like a consultancy of course, but it does have elements of a professional service process within its design. This is why the volume and variety characteristics of a process are sometimes seen as being a more realistic way of describing processes. The product-process matrix described next adopts this approach.

The product–process matrix

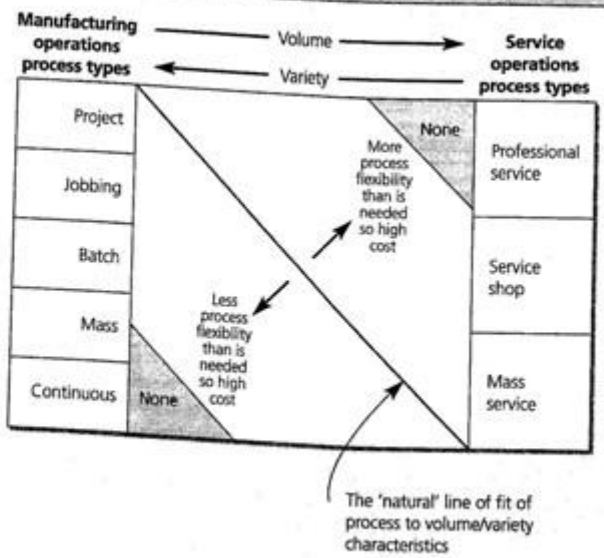
Product–process matrix

The 'natural' diagonal

Making comparisons between different processes along a spectrum which goes, for example, from shipbuilding at one extreme to electricity generation at the other has limited value. No one grumbles that yachts are so much more expensive than electricity. The real point is that in both manufacturing and service operations, because the different process types overlap, organizations often have a choice of what type of process to employ. This choice will have consequences to the operation, especially in terms of its cost and flexibility. The classic representation of how cost and flexibility vary with process choice in the **product–process matrix** that comes from Professors Hayes and Wheelwright of Harvard University.[7] They represent process choices on a matrix with the volume–variety as one dimension, and process types as the other. Figure 4.18 shows their matrix adapted to fit with the terminology used here. Most operations stick to **the 'natural' diagonal** of the matrix, and few, if any, are found in the extreme corners of the matrix. However, because there is some overlap between the various process types, operations might be positioned slightly off the diagonal.

The diagonal of the matrix shown in Figure 4.20 represents a 'natural' lowest cost position for an operation. Operations which are on the right of the 'natural' diagonal have processes which would normally be associated with lower volumes and higher variety. This means that their processes are likely to be more flexible than seems to be warranted by their actual volume–variety position. Put another way, they are not taking advantage of their ability to standardize their processes. Because of this, their costs are likely to be higher than they would be with a process that was closer to the diagonal. Conversely, operations that are on the left of the diagonal have adopted processes which would normally be used in a higher volume and lower variety situation. Their

Figure 4.20 Deviating from the 'natural' diagonal on the product–process matrix has consequences for cost and flexibility



Source: Based on Hayes and Wheelwright.[7]

processes will therefore be 'over-standardized' and probably too inflexible for their volume–variety position. This lack of flexibility can also lead to high costs because the process will not be able to change from one activity to another as efficiently as a more flexible process.

Design – the structure of Part Two

The various aspects of the design activity in operations management are treated in the remaining five chapters of Part Two. All these aspects are shown in Figure 4.1 at the beginning of this chapter.

The design of products and services is a prerequisite (Chapter 5)

esign of products
ıd services

Notwithstanding our emphasis on the desirability of overlapping the design of products and services and the design of the processes which create them, some understanding of the product or service must be the starting point for all design considerations in operations management. This is why we began with an examination of the **design of products and services** in Chapter 5.

Process design includes the whole network (Chapter 6)

ɹpply network
ɜsign

At its most strategic level design means considering the whole supply network of operations which together produce and deliver products and services to the customers. From the perspective of a single operation within the network, design decisions will include how much of the network the operation wants to own, where to place its sites, and how large to make each site. Chapter 6, **Supply network design,** covers all these design decisions.

Designing the operations layout defines its flow (Chapter 7)

ıyout and flow

The location decision is also significant within each individual site in the total supply network. At this level the decisions concerning where to locate machines, equipment, facilities and people relative to each other is usually termed the operation's *layout.* Layout decisions are particularly important because they determine the pattern of flow through the operation. Chapter 7, **Layout and flow,** deals with these decisions.

Technology plays a key role (Chapter 8)

ocess technology

Location of the machines and equipment within the operation will determine the pattern of its flow, but the nature of its *technology* will determine its capability. Although operations managers do not always need to know all the detailed science that lies behind the technologies they use, it is necessary to understand the implications of using alternative technologies. Chapter 8, **Process technology,** describes some of the more significant technologies which process materials, information and customers.

People make the processes work (Chapter 9)

Even after the products and services have been designed, the network configured, each site's layout determined and the process technology chosen, the operation cannot work until it is staffed. The people in any operation are the catalyst which makes the whole operation come alive. While the subject of this text is not human resources management as such, it is important to understand how the staff in the operation interact with its