COURSE MANUAL

C4: Operations Management

Module 3

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Contents

Module 3

Processes and products

Introduction

This module is about processes and products. A product is an item that is manufactured or a service that is delivered. Before there is a product a process is needed to develop it. This module starts with defining processes and gaining an appreciation of the need to develop “perfect” processes (and we will define the perfect process as an ideal). We then look at the need to improve processes to keep up with the changing needs of customers and to make the most of technological developments.

This module then looks at product design, which is the development of an output (product or service) that completely satisfies the (ever-changing) customer requirement. This leads directly to a discussion on quality products and quality processes.

Upon completion of this module you will be able to:

Outcomes

- *Distinguish* between value-adding and cost-adding processes.
- *Describe* process thinking and the strategic importance of process.
- *Describe* the perfect process.
- *Perform* statistical process control calculations.
- *Describe* the concepts of lean thinking.
- *Describe* various models for developing products.
- *Explain* the relationship between uncertainty and risk in product development together with robust design and participative product development.
- *Define* quality and the characteristics of a total quality management programme.
- *Discuss* various quality management frameworks.
- *Discuss* process capability and six sigma quality.

Unit 5

Designing processes

Introduction

This unit highlights the importance of processes for an organisation. The definition of process is fundamental to establishing any operation; common practice is to innovate, standardise and optimise any process before beginning again with any new requirements taken into consideration. Process thinking is a departure from functional thinking that limits so many organisations. Not only is more process focus needed from organisations, but they also need to understand the supporting theories, tools and approaches that can help restructure organisations to achieve this.

Process-orientated thinking is the foundation of modern quality management and lean practice, so it is fundamental that operations managers understand this before moving on to more advanced theory and tools. Process-orientated thinking is also the basis for successful supply chain management, which essentially is the practice of joining up different organisations' processes with one another as seamlessly as possible.

This unit starts with an activity based on a rather light-handed view on customers. Processes are required to satisfy customer requirements so it helps to have an appreciation of different types of customers. The service profit chain is presented as an approach for process design. Process value is defined and a distinction made between value-adding processes and cost-adding processes. The strategic service vision is presented to gain an understanding of the significance of processes in providing service to customers. This leads directly to a discussion on the characteristics of service organisations and the service encounter. The unit concludes with a discussion on the strategic decisions for process and a look at process industries.

Outcomes

Upon completion of this unit you will be able to:

- *Analyse* the service-profit chain.
- *Identify* value in a process.
- *Distinguish* between value-adding and cost-adding processes.
- *Describe* the strategic service vision.
- *Identify* the characteristics of service operations.
- *Develop* strategic decisions for process.
- *Describe the* product-process matrix.
- *Describe* the process industries.

Terminology

Batch process	Batch process is a process that has a jumbled flow of products and/or customers. This process structure lies between job shop and assembly-line repetitive processing.
Continuous process	Continuous process is a production system in which the productive equipment is organised and sequenced according to the steps required to produce the product. The term denotes that material flow is continuous during the production process.
Cost-adding	Cost-adding is a negative contribution made by a process to the final usefulness or value of a product. Value in this sense is measured by the customer. A cost-adding process does not add value; it just adds cost.
Job shop process	Job shop is a process for creating a large variety of products or services each produced in relatively small volumes.
Product-process matrix	Product-process matrix maps product attributes against the major process structures to help a firm define its production strategy.
Process	Process is a collection of linked activities that delivers a result of value to the customer.
Repetitive process	Repetitive process is the repeated production of the same discrete product or families of products or service.
Service-profit chain	Service-profit chain establishes a relationship between profits for the firm, customer loyalty

and employee satisfaction. These links propose that customer loyalty drives profitability and growth, customer satisfaction drives customer loyalty, service value drives customer satisfaction, employee retention and productivity drives service value, employee satisfaction drives retention and productivity, and internal quality drives employee satisfaction.

Value Value is the amount customers are willing to pay for what a firm provides. It represents a relationship between the benefits received and the price paid. Benefits can be informational and emotional as well as economic. Value can be viewed as the quality received relative to expectations.

Value-adding Value-adding is the contribution made by a process to the final usefulness or value of a product. Value in this sense is measured by the customer.

Terminology sourced from Gardiner (2010).

Customers and relationships

Customer-focused organisations have an excellent understanding and appreciation of their customers. They know why customers need products and services; they know why they buy products and services; they know why they keep coming back; and they know why they recommend products and services to others.

Each organisation has to clearly define and communicate the value proposition and actively engage customers in the product and service design processes that are implemented to deliver the strategy.

Every person in the organisation who is remotely associated with delivering a product or a service to customers needs an understanding of customer behaviour. This means an understanding of why customers behave in certain ways and what motivates them to be a customer, since this may affect how the product is produced or how the service is delivered.

Activity 3.1

Activity

Work through the following list of customer classifications (Johnson & Clark, 2008, p. 58) and try and link each one with a person you know or have met in the past.

Title	Description	Your example
Ally	Arrives in a positive frame of mind, willing to help and provide feedback to facilitate a better service. The happiness of the ally rubs off onto other customers who believe the service must be good.	
Hostage	This customer feels "locked in" contractually and requires the service but has no choice or has a potential financial penalty if he/she goes elsewhere.	
Anarchist	Simply dislikes rules and systems and will object to being told to do something, or will get upset at having to fill in forms without any rhyme or reason.	
Patient	This is the type of customer who already belongs to the organisation and feels they have little chance of escape.	
Tolerant	Will quietly sit and wait for service. They may be passive and are usually ignored. They may not jump up and down and demand immediate service that other customers demand. They will sit quietly and wait.	
Intolerant	Will not sit quietly and wait. They often cause stress and problems. The intolerant customer makes their presence and requirements known. They may not be very clear or even coherent in describing what they want, but they will make sure that supply service staff are handling their problem.	
Victim	This is the recipient of a product or service when something goes wrong. They seem to attract bad luck. The process fails and for some reason the victim just happens to be the customer. It is hard to predict exactly how a victim will react.	
Terrorist	Mounts a damaging attack when you least expect it. The terrorist is a real danger as they will strike without warning and inflict as much damage as possible. They will announce their displeasure knowing other customers are listening.	
Incompetent	This customer is confused by procedures. Often the incompetent will be a first-time customer and simply does not know what to do. They may stumble around looking for answers and may do irreparable damage as they go.	
Champion	Is supportive, helpful and positive. The champion is more than an ally and goes out of their way to be helpful, co-operative and friendly. Every organisation needs champions.	

Most organisations aim to ensure a steady stream of customers and, once a customer has been supplied, the organisation should ensure the customer returns. Customer retention has been recognised as a marketing ploy for a long time. Loyalty cards, frequent flyer programmes, loyalty status (platinum, gold and silver status), credit card incentives, loyalty discounts and rebate systems are all aimed at customer loyalty and retention.

Loyal customers generate long-term revenue streams and create high lifetime values. They tend to buy more than new customers and tend to increase spending over time. Additionally, they may be willing to pay a premium for products and services. Retaining customers is usually significantly cheaper than attracting new ones.

Some organisations do not want loyal customers. One would hope that hospital staff would not want a discharged patient to return with the same symptoms and for the same reason. In a private hospital system (profit-oriented and fee-paying), a satisfied patient can generate future business by spreading the word.

A school and a university have satisfied customers who progress through the system and eventually leave or graduate. The reputation of the institution is built up over time by the ongoing success of the school leavers and the university graduates. The reputation then becomes the measure of satisfaction.

Value represents a relationship between the benefits received and the price paid. Benefits can be informational and emotional as well as economic. Value can be viewed as the quality received relative to expectations.

The price includes monetary considerations as well as all the other things that have to be done to obtain the benefits. These include attributes such as time, convenience, hassle, anxiety and other emotions.

Customer expectation is based on experience. If customers do not know any better, they will accept any level of quality. As soon as they are exposed to a higher level of quality their expectation rises accordingly and this increases the price.

Value is a perception and when customers perceive a competitor has more value than the current supplier, they will defect. The current supplier, in this case, is not lowering standards or failing to deliver. The difference is that a competitor has raised the standard of expectation.

Expectation does not have to increase. A supplier does not have to supply more product or more service. They may supply less. Discount airlines offer significantly less in-flight service than a full-service airline. Discount and bargain basement stores offer less than full-service full-display stores. They compensate for their reduced offering by lowering the actual monetary price.

A supplier with a higher ratio of benefits to price will experience a competitive advantage in the short-term and until competitors catch up. Competitive activity endeavours to close the gap.

Process design considers all these attributes of value. It does not stand still. It is an ever-moving target. Customers pay a premium for agility, flexibility, responsiveness and understanding and because they pay the premium they can be demanding and want more for less. In other words they want more value.

Service-profit chain

Heskett, Jones, Loveman, Sasser and Schlesinger (1994) from the Harvard Business School, developed the concept of the service-profit chain.

When it was republished in 2008, the editor of the Harvard Business Review said the article sets out a simple, elegant and, ultimately, tough-minded way to build profitability in a service business. It offers as much today as it did when first published.

The service-profit chain establishes a relationship between profits for the firm, customer loyalty and employee satisfaction. These links propose that:

Customer loyalty drives profitability and growth

Loyal customers generate higher profits and revenue for the business and they compensate for any loss incurred due to gaining customers at the beginning and the potential profits that are not realised from customers who defect.

Loyal customers source new business for the organisation by way of referrals. Highly satisfied customers generate positive advertising for a company by word of mouth and encourage acquaintances to use the same supplier.

Customer satisfaction drives customer loyalty

A customer who is very satisfied is the most loyal. Such customers are also called apostles, who will not only give the organisation repeat business but will also get the uninitiated to try out the service, thus generating new business. Many organisations strive to be the number one in the industry on customer satisfaction.

Service delivery value drives customer satisfaction

The actual service received by the customer is the end result of the interaction between the service provider and customer and the process that delivered that result. Service designers aim to improve the quality of the service provided by understanding the gap between the perception of the actual service and the service the customer expected. Many companies diligently collect data on customer expectation so they can further improve their standards.

Employee retention drives service value

In many business sectors an employee who leaves one organisation takes valuable customers with them to the employee's new firm. The loss generated with that defection is very difficult to replace with new business. Customers get agitated if they have to deal with a new person every time they contact their supplier.

Employee satisfaction drives retention

A workplace that is conducive to overall employee satisfaction generates respect for other employees. This feeling of employee satisfaction is transferred directly to customers and motivated employees work much harder to satisfy their customers.

Employee satisfaction directly drives employee loyalty. Employees who care about the culture and image of their company will not only strive to improve the quality of their work but also stay longer with the company. The best impression on the consumer is at the emotional level. If employees believe in their own brand, they are most likely to provide good service and enable customers to make the choice when buying their products.

Internal quality drives employee satisfaction

Factors that contribute to the internal quality of an organisation include workplace design, job design, employee selection and development, employee rewards and recognition and the tools available to complete their job and serve customers.

Service-profit chain in perspective

The service-profit chain has an underlying assumption that both employees and customers are treated and valued equally for their contribution to the success of a business. This philosophy is a fundamental shift from a scientific management approach where employees are considered solely for their ability to contribute to the production line, or financially driven thinking where profits are considered in isolation from employees' needs.

The service-profit chain proposes that customers place more value on good service than on a good product. Consequently, customers who do not receive good service do not return to the business and this reduces profits. This highlights the premise that maintaining a loyal customer base provides long-term business opportunities which are more profitable than constantly recruiting a new customer base.

Process value

The design of processes requires an appreciation of the nature of the process and how it can add value to the customer. All organisations are full of processes. Every function performed is executed with a process. In fact, all work is a process. Value is created as a result of a process and a process can only deliver what it is designed to deliver — no more. Therefore, the primary focus is on the process that creates value (the value stream).

Organisational processes describe all the activities that transform inputs into outputs, the methods for conducting business, the ways of acting and interacting, the styles for decision-making, styles for communication and patterns of learning. They also include how performance can be changed and improved over time.

The process itself is composed of inputs, outputs and process variables. Performance depends on how well the process has been designed, built, operated and maintained.

Each process should be studied to see what value it provides to the customer. Ask the customer to state exactly what they expect from the process. Quality, delivery, flexibility and service should all add value. The examination of process should start by looking at every step in the process, determining whether it adds cost or value. The essential issue is to maintain the fit between value and process, making sure every step is in fact adding value. If it is not adding value, it is adding cost and should be eliminated.

Value-adding and cost-adding processes

Value-adding is the contribution made by a process to the final usefulness or value of a product. Value in this sense is measured by the customer.

Cost-adding is a negative contribution made to the final usefulness or value of a product. Value in this sense is measured by the customer. A cost-adding process does not add value; it just adds cost.

A process is either value-adding or cost-adding. They are mutually exclusive. If it is not one, it is the other. Process improvement methodology is not really required. If the aim is process excellence then the objective is to eliminate all cost-adding processes and progressively improve all value-adding processes.

Characteristics of service operations

When designing processes for services, an understanding of the different characteristics of services (compared to production) would provide significant benefit and savings in cost and time.

- Services are often something consumers cannot touch or feel. Dining at a restaurant has an ambience. An insurance policy has reassurance and peace of mind. A news item provides information.
- Services are often created and delivered on the spot. The process is on display and the customer is on hand to perform the quality check.
- Marketing and operations have to work together because of the visibility of the service process and the intangibility of the service.
- Consumption is almost simultaneous with production and the output cannot be stored for later use.
- The entry barrier to services is sometimes quite low and competing firms can enter the market with little capital investment.
- Many service outputs are unique and have inconsistent definition. The customer can take an active part in the design and delivery of the service.

Strategic decisions for process

The layout decision determines the placement of process technology, work stations, machines, operators, queues and stock-holding points within a productive facility. The overall objective is to arrange these to ensure a smooth work flow (in a factory) or a particular traffic pattern (in a service organisation).

Inputs to the layout decision include the specification of the objectives of the system in terms of output and flexibility, a forecast of product or service demand, processing requirements in terms of number of operations and the amount of flow between departments and work centres and space availability within the facility itself.

The basic layouts tend to have a process or product focus.

A process focus occurs when the dominant orientation is to a technology or a material and when in production the process tends to be complex.

A product focus occurs when both plant and staff responsibilities are delineated by product, product line or market segment.

Process focus

When products are produced or services delivered in small lots, often to a customer specification, the supplier will usually use a process focus.

The main advantage of these systems is flexibility, which means they have the ability to produce small batches of a wide variety of products. Additionally, they usually require less initial investment since they typically use general purpose equipment and mobile material handling equipment, which is usually less expensive.

However, they usually require a greater employee skill level, more training for employees, more supervision, more technically trained supervision and more complex production planning and control.

Typical examples of process-focused systems include hospitals, car repairers, shipbuilding, house construction and building design.

Product focus

High-volume, low-variety processes are usually product focused. The process technology is arranged around the products. Products tend to go through production along direct linear paths without backtracking, side-tracking or stopping. They are continuous or highly repetitive.

Assembly lines are a special case of the product focus. The most common assembly line is a moving conveyor that passes a series of workstations in a uniform time interval. At each workstation, work is performed on a product either by adding parts or by completing assembly operations. The work performed at each station consists of many bits of work (termed tasks, elements or work units).

Examples of product-focused systems using an assembly-line approach include vehicle assembly, whiteware and electronics. Examples using a continuous flow are electricity generation, telecommunications, food processing, brewing, chemical production, petroleum refining, petrochemicals, plastics, paper and cement industries.

Process flow structures

Process flow structures can be classified as project, job shop process, batch process, repetitive process and continuous process. Projects are discussed in Module 4, Unit 11.

The job shop is a process for creating a large variety of products or services, each in relatively small volumes.

The job shop process irregularly produces single or small lots in a facility characterised by flexible machines and skilled workers**.** Job shops place their competitive success on a number of strengths. They compete with large-scale producers like batch or repetitive processes stressing their capabilities to fabricate large varieties of products. Smaller job shops compete with larger ones by offering lower costs and often quicker delivery times. Larger job shops compete with smaller ones by offering better, more productive equipment or better order-entry systems.

The batch process is different from the job shop process in that larger quantities are produced and most products or customers follow similar flow patterns and there is some repetition. This process structure lies between job shop and assembly-line repetitive processing. Examples include a suburban bakery that produces regular daily batches of bread and bread products. They use roughly the same process for each batch and just change the recipe of ingredients.

When competing against a job shop, the batch producer must overcome the job shop’s flexibility and ability to respond quickly. Normally they base their success on cost advantages. When competing against high-volume repetitive systems they will stress flexibility and often cost.

The repetitive process is the repeated production of the same discrete product or families of products or service. The method of production minimises set-ups, inventory and production lead times by using production lines, assembly lines or cells.

A repetitive process arranges machines and special-purpose equipment in a rigid sequence to perform repetitive tasks for large orders. This system has the capability to produce standardised products cheaper than any other process. In a cost-competitive environment for products that do not vary much, this provides a key competitive strength. Flexibility is not easily achieved and, to overcome this weakness, a repetitive system will introduce mixed-model scheduling, cellular manufacturing and standardised product designs.

The continuous process organises productive equipment and sequences the steps required to produce the product. The term denotes that material flow is continuous during the production process.

A continuous process produces highly standardised products with little or no variation. Examples include electricity generation, petroleum refining, liquids, gases and minerals. Continuous flow production usually has just one input (for example, oil, milk, timber or iron ore) and processes these inputs into one or more output flows.

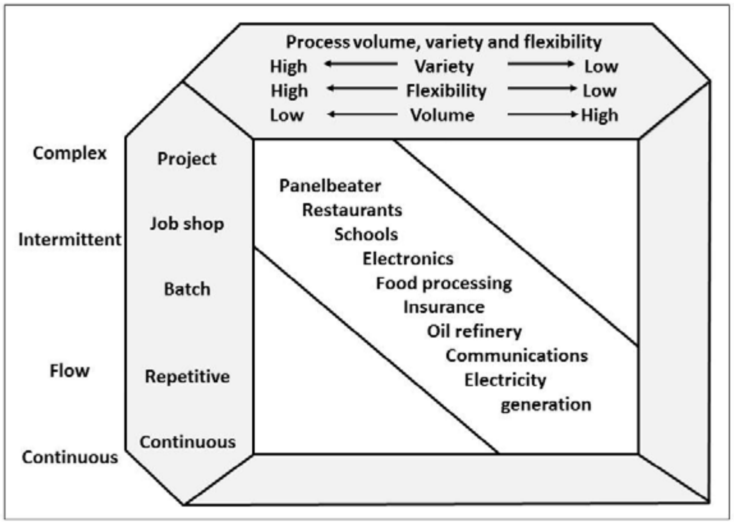
To help a company define its production strategy, we use the product-process matrix which maps product attributes against the major process structures.

The relationship between the process and product structure was suggested by Hayes and Wheelwright (1984).

The vertical axis shows the process structures of project, job shop batch, that are repetitive and continuous, while the horizontal axis shows the product structures based on variety, flexibility and volume. As the volume increases and the product line narrows, standardised equipment and faster material flows become feasible.

The choice of specific production equipment that follows is based on the type of process technology. Key factors to consider should include the initial investment, desired rate or output, quality, labour requirements, flexibility, set-up and operating requirements, maintenance, obsolescence, work-in-process inventory and system-wide impacts.

An ideal combination of process and product structure can be found by placing the organisation on the diagonal in the product-process matrix. It is possible to operate in a relationship that is not on the diagonal line. To be in the top-right sector, an organisation would produce high-volume output using low-volume technology. For most firms, this would be extremely expensive and not an effective use of resources. To operatee in the bottom left of the matrix, a firm would produce low volumes and a high variety using assembly-line or continuous processes. This would seem to be an ideal position and is called mass customisation. The initial investment in technology is high, but the flexibility and customisation benefits that can be achieved signal a competitive advantage.



(Gardiner, 2010, p. 143)

The diagram above shows the product-process matrix with typical example industries on the diagonal.

Process flow scheduling

The concept of process flow scheduling was developed by Taylor and Bolander (1994).

Process flow scheduling is a method for developing a production schedule that uses the process structure as a guide. This is suitable in process industries.

A process industry produces products by mixing, separating, forming and/or performing chemical processes. Dairy production, pulp and paper, refineries and chemical plants are examples of process industries.

The process train is a representation of the flow of materials through production systems showing equipment and inventories. A process unit identifies a piece of equipment that performs a basic manufacturing function such as mixing, blending or packaging. Process units are combined into stages and stages are combined into process trains. Inventories are used to decouple the scheduling of sequential stages within a process train.

Material-dominated scheduling is a technique that schedules materials before equipment or capacity. This aids the efficient use of materials.

Processor-dominated scheduling is a technique that schedules the process before the materials.

Forward flow scheduling is the procedure of building process trains that start with scheduling the first stage and progress towards scheduling the last stage.

Mixed flow scheduling is a procedure used in some process industries for building process train schedules that start at an initial stage and work towards the terminal process stage. This is effective for scheduling where several bottleneck stages may exist.

Reverse flow scheduling is the procedure of building process trains that start with scheduling the last stage and progress against the flow to the first stage.

Process flow scheduling can be applied in manufacturing units where:

- All products have similar routings leading to a flow of material through a series of process stages.
- Production is often scheduled to meet forecast demand rather than individual customer orders.
- Production is authorised by production schedules. Works orders are not used.

Activity 3.2

Activity

Work through the following questions. You may need to go back and reread the unit to help you.

1. Describe the strategic importance of process design.
2. Discuss the concept of process value.
3. Distinguish between job shop, batch, repetitive and continuous processes.
4. Describe the service-profit chain.
5. Distinguish between cost-adding and value-adding processes.
6. Discuss the impact of technology on process design.
7. Describe process flow scheduling.

Unit summary

Summary

In this unit you learned about the service-profit chain and how to identify value in a process. Processes can either be value-adding or cost-adding and we distinguished between these two extremes. The strategic service vision and the characteristics of service operations were presented. We related the strategic decisions for process and described the product-process matrix. We concluded with a short description of the process industries.

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Readings for further study

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Unit 6

Improving processes — lean thinking

Introduction

In the previous unit we designed the process to satisfy customer requirements. However, customers change, customer requirements change, technologies change and processes change. In this unit we ensure the process is improved to match the changing demands placed on processes.

Process improvement and lean thinking are often discussed as synonyms and the improvement is often considered continuous. Lean thinking, essentially, is the elimination of waste in the process. To do this we have to identify where waste is occurring and take necessary steps to eliminate it.

The tools of process improvement are discussed as a means to understand what is happening with a process and identify areas for improvement.

Statistical process control is discussed as a process for monitoring a process to maintain the output as expected.

This leads into thinking of production processes and throughput processes as flowing. The concepts of flow, characterised by lean thinking, are discussed.

This unit begins by describing the strategic importance of process and introduces the concepts of process thinking, process flow analysis and process variability. The perfect process is presented as an ideal. This is followed by describing process improvement tools and techniques and an introduction to statistical process control. The philosophies of lean thinking and value-stream mapping are discussed. The unit concludes with a reflection of lean thinking being applied to services.

Outcomes

Upon completion of this unit you will be able to:

- *Describe* the strategic importance of process.
- *Describe* process thinking.
- *Prepare* process flow diagrams.
- *Identify* process variability.
- *Describe* the perfect process.
- *Describe* the steps for process improvement.
- *Describe* and use the seven basic tools of quality.
- *Describe* the concepts of lean thinking.
- *Apply* lean thinking ideas to services.

Terminology

Continuous improvement	Continuous improvement is an incremental (small and gradual) approach to achieving and sustaining improved processes over time, rather than breakthrough (large and rapid) improvements in processes.
Heijunka	Heijunka is an approach to level production throughout the supply chain to match the planned rate of end-product sales.
Kaizen	Kaizen is a philosophy that means gradual and orderly continuous improvement.
Kanban	Kanban is a flag or a piece of paper that contains all relevant information for an order-part number, description, process area used, time of delivery, quantity available, quantity delivered, production quantity and so on. The type and number of units required by a process are written on Kanban cards and used to initiate withdrawal and production of items through the production process.
Lean thinking	Lean thinking is a strategic initiative that maximises customer value while minimising waste.
Plan-do-check-act	Plan-do-check-act is a four-step process for quality improvement. In the first step (plan), a plan to effect improvement is developed. In the second step (do), the plan is carried out, preferably on a small scale. In the third step (check), the effects of the plan are observed. In the last step (act), the results are studied to determine what was learned and what can be

	predicted.
Process improvement	Process improvement is the activity associated with identifying and eliminating causes of poor quality, process variation and non-value adding activities.
Seven basic tools of quality	Seven basic tools of quality: process flow diagrams, check sheets, histograms, Pareto charts, cause-and-effect diagrams, scatter diagrams and process control charts.
Takt time	Takt time is calculated as the available production time divided by the rate of customer demand. Takt time sets the pace of production to match the rate at which the customer is demanding output.
Waste	Waste is any activity that does not add value to the product or service as valued by the customer.

Terminology sourced from Gardiner (2010).

Strategic importance of process

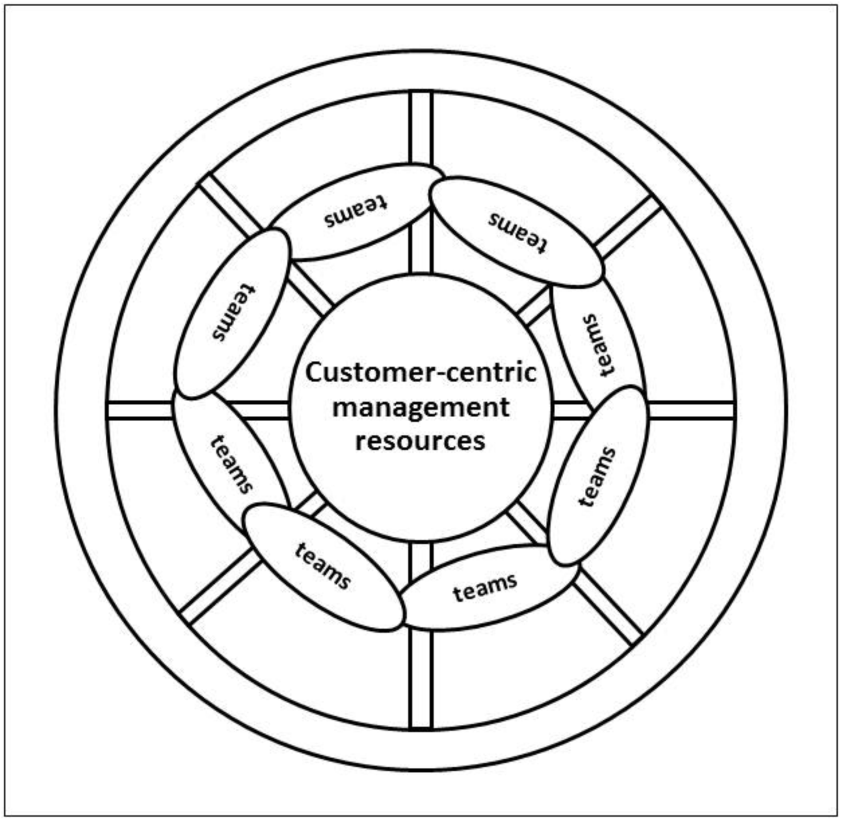
In the previous unit we examined various types of processes. Value-adding primary processes add value for the external customer while supporting secondary processes add value to the internal customer.

If a process is not adding value, it must be adding cost. Value is the relationship of the benefits received to the price paid. The concepts of exciting innovation and emotional benefits come into the picture. You can also think of value as the quality received compared with expectations. As we attempt to improve processes we should look at the value created in the process. Process improvement aims to eliminate cost-adding processes and improve the value created in value-adding processes. When organisations begin cost-saving exercises they should target cost-adding processes.

Process thinking

Process thinking is a structured approach that considers an organisation and its various activities and functions as a system of interrelated processes that must be designed, controlled and continuously improved.

Process thinking considers the organisation as an arrangement of processes that are totally focused on the customer and make it easy for the customer to do business with the organisation. Cross-functional teams work together to focus on the customer and deliver more added value.



(Gardiner, 2010)

The diagram above shows a process thinking organisation that is totally focused on the customer. In this diagram, all resources are teamed and all teams are working together with the customer being the target at the centre. The customer may be clearly defined but the resources used are fluid and keep changing as customer requirements change.

Process flow analysis

Process flow analysis is a procedure to evaluate the effectiveness of a sequence of business activities. The analysis determines which elements of the flow are value adding and eliminates those not adding value.

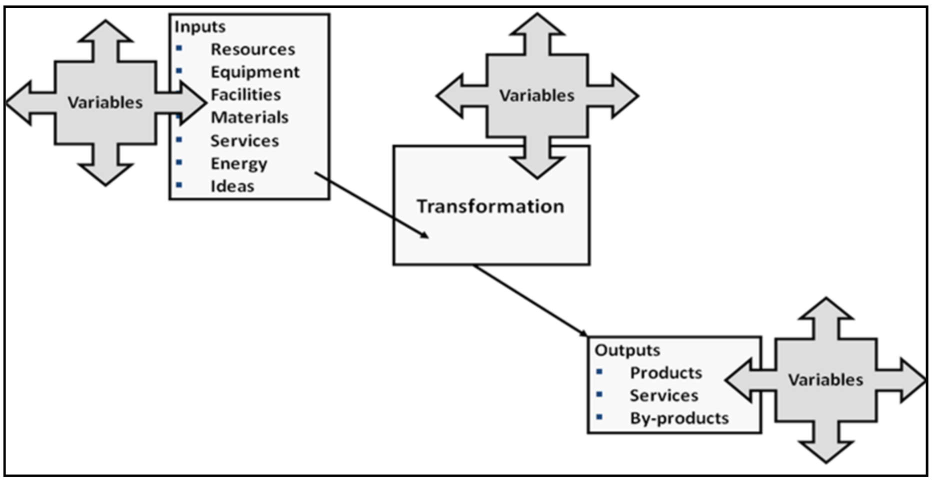
Motorola developed much of the early work on process thinking as it formulated the six sigma quality methodologies. It suggested a simple approach to find the process view of operations:

1. Identify the product or service.

2. Identify the customer.
3. Identify the supplier.
4. Identify the process.
5. Mistake-proof the process.
6. Develop measurement and improvement goals.

Process variability

The input to every process contains input variables, the actual transformation deals with controllable and uncontrollable variables and the output to every process has output variables.



(Gardiner, 2010, p. 157)

The above diagram is an extension of the basic transformation process with the addition of process variables. Inputs and outputs are shown as variables and the transformation process is shown as variable.

Process inputs, including raw materials, human resources, ideas, skills, energy and previous process outputs, can vary in quantity and specification. Some of the variation may be slight and not affect the end result, but it is still a variable. Process design should allow for this variation of inputs. It is a complement to the process itself if it can handle the variation with ease.

The transformation process may include uncontrollable variables such as temperature and humidity, shift, team and operators assigned to the process. It could be argued that the process could be scheduled at a different time and thus have different operators performing the required tasks. After the resource assignment has been made the date, time, shift, team and human resources are uncontrollable. This variation is often called noise.

The operations manager may attempt to control some (or all) of the uncontrollable variation such as temperature and humidity, production rate and process time. Changing a variable from uncontrolled to controlled allows the manager to more accurately predict the outputs.

Note that temperature and humidity appear in the uncontrollable list as well as the controllable list. If the process is performed outside, the temperature and humidity are uncontrollable. However, if the same process is brought indoors those variables become controllable. The natural follow-on suggests that if temperature and humidity are significant in terms of the result, these variables should be made controllable.

Output variables include the actual quantity produced (yield), the production rate (and that determines the elapsed time).

Activity 3.3

Activity

Make a list of two or three processes you are familiar with or choose an example below. Write down the input variables, the uncontrolled transformation variables, the controlled transformation variables and the output variables.

You may choose any process, but here are a few suggestions:

- An order being received from a customer.
- A house being built as a “spec build” (that is, built before a customer signs the order to buy it).
- A sports team being chosen.
- A letter being posted and delivered.

Compare your answers to the model at the end of the module.

Most processes are based on average performances. In fact, most business decisions are based on average. The sales budget for a year might be based on an average monthly figure of, say, $500,000. Therefore, the expected sales for the year are budgeted at $6 million. A production run on average takes 30 minutes for every 1000. Therefore a production run of 10,000 should take five hours.

When Sam Savage (2000, 2002 and 2009) proposed the flaw of averages, he said decisions based on average are wrong on average. Whenever an average is used to represent an uncertain quantity it ends up distorting the result since it ignores the impact of the inevitable variation.

Process variation can be mitigated by avoiding complexity with fewer sources of variability and by finding ways to control process variables. Given that the variables exist we must develop ways to detect variability, plan around it and adjust to the sources of variability.

Perfect process

Womack (2004) describes the perfect process as one that creates exactly the right value for the customer. Each step must be valuable, capable, available, adequate and flexible.

To be valuable it has to add value to the customer and to be recognised by the customer as adding value and not adding cost. A quick check to see if a process step is valuable is to consider removing this step from the process and evaluate if it is absolutely necessary.

The concept of a capable process comes from process capability and six sigma capability and is covered in Unit 8. A capable process can be executed the same way with the same satisfactory result every time it is run.

A process that is available suggests it is able to be executed every time it is necessary without waiting. This implies production machines are available for use, not waiting for parts or maintenance.

The theory of constraints defines processes that are adequate and is discussed in Unit 9. An adequate process has enough capacity to perform this step when it needs to be performed without waiting.

Flexible processes are lean and are based on the Toyota Production System. These are discussed later in this unit. Each step in a flexible process occurs only at the command of the next downstream step within the time available.

Process improvement

Process improvement is all about adding more value to the customer.

Most customers obtain products and services from a supplier because they perceive there is more value in those particular products and services from the chosen supplier, than if they had gone elsewhere.

Operations should be aware of changing perceptions on the part of the customer and treat the management of quality as a dynamic process.

Kaizen is a philosophy for continuous improvement and its aim is to eliminate waste and make life an enjoyable experience.

Continuous in this sense means never-ending. Improvement suggests finding better ways of performing tasks, making products and delivering services. These changes occur incrementally or gradually.

Kaizen operates with three principles:

- process and results and not just results,
- universal process thinking by examining the big picture, and
- non-judgemental and non-blaming.

Continuous improvement seeks a never-ending process of improvement of technology, machinery, materials, labour utilisation, production methods, ideas and results through the application of suggestions and ideas of team members. Under continuous improvement, management views the performance level of the organisation as something to be continuously challenged and incrementally upgraded.

Seven basic tools of quality

The seven basic tools of quality are attributed to Kaoru Ishikawa who maintained that most quality-related problems can be resolved by using these tools.

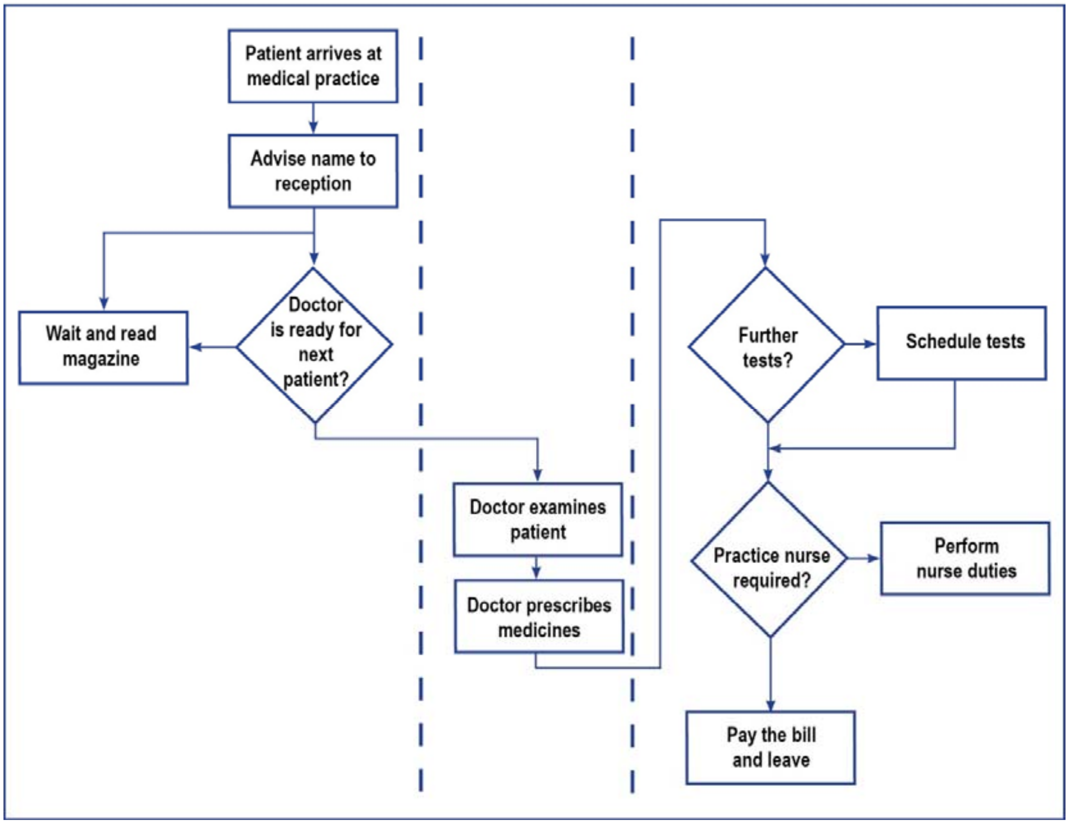
The issue with problem-solving is to identify the real problem. The solution is easy when the real problem is known. Many people implement change without understanding the cause of the issue they are trying to correct, with the result that the problem is not resolved. Valuable time and effort is wasted by applying a change that appeared to be a solution.

The seven basic tools of quality are:

1. Process flow diagrams showing the flow of the process
2. Check sheets showing the frequency of occurrence
3. Histograms showing overall variation
4. Pareto analysis separating the significant few from the trivial many
5. Cause-and-effect diagrams helping identify the causes of the problem
6. Scatter diagrams showing factor relationships
7. Process control charts showing which variations to control and how.

Process flow diagram or process map

A process flow diagram is a visual presentation of the flow of activities in a process. It creates a graphical representation of the steps involved in a process.



(Gardiner, 2010, p. 161)

The diagram above is an example of a process flow diagram for a patient attending a general medical practice. The dotted lines represent the divisions of work. The section in the middle involves the medical professional, the section on the left shows the activities that occur before the examination and the section on the right shows activities after the examination.

The process flow diagram is often drawn with vertical and/or horizontal lines to separate functional activities or activities that involve the customer and producer.

Check sheet

A check sheet is a historical record of data collected. Each check is an occurrence, so the sheet can easily count the number of times a particular occurrence occurs and where or how it occurs.

Histogram

A histogram is a frequency distribution chart used to illustrate patterns that may be difficult to detect in a simple table of numbers. It is used mainly when data is numerical and the analyst wants to see the shape of the distribution of the result of the process, when analysing the process to see if it meets customer requirements, and when analysing the changes occurring in the process from time to time.

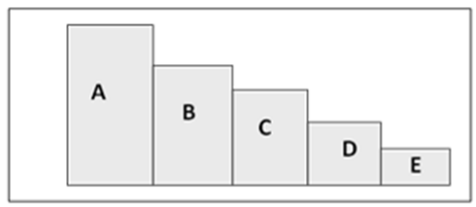
Pareto chart

The Pareto chart is a graphical tool for ranking causes in hierarchical order from most significant to least significant. The format is a bar graph. The lengths of the bar represent the frequency of a particular occurrence such as cost, time, length and reason. The graph is arranged with the longest bars (most frequent occurrence) on the left and shortest bars on the right. This way the graph highlights the situations of most significance. It is often called the 80-20 rule since about 80 per cent of the problems are caused by 20 per cent of the possible sources, as it separates the significant few from the trivial many.

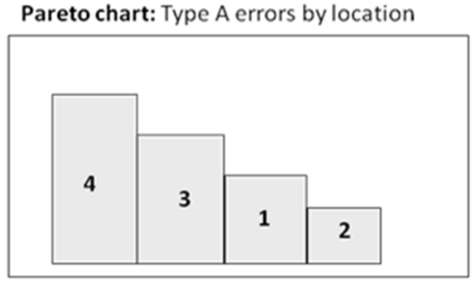
Check sheet:
Type of error by location

Location	Type of Error C	B	D	A	E
1	II	I		III	I
2	I	II	II	II	
3	II	III	I	IIII	
4	II	III	II	~~IIII~~	I

Pareto chart: Type of error



Pareto chart: Type A errors by location



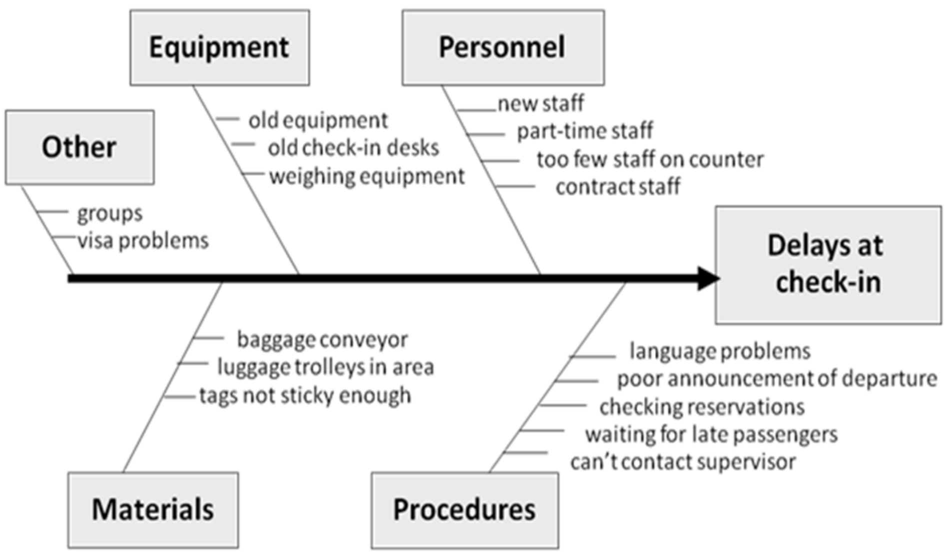
(Gardiner, 2010, p. 164)

The diagram above is an example of a Pareto chart drawn from a check sheet. The check sheet on the left-hand side is counting the type of error by location. The letters C, B, D, A and E do not have any meaning apart from identifying the type of error. They could have been rearranged as A, B, C, D, E. The upper Pareto chart shows the type of error ranked from the most common to the least common. The lower Pareto chart shows the location of the type-A errors.

Cause and effect diagram

The cause and effect diagram is a simple graphical diagram that identifies as many causes for an effect as possible and sorts them into categories. The chart is usually constructed by a team who use brainstorming to identify probable causes by asking the who, what, when, where, why and how questions. Each potential cause is then evaluated and more data collected to narrow the potential causes before any corrective action is implemented. The use of the fishbone diagram helps reduce defects and, therefore, increase quality.

The diagram below illustrates an example of a cause and effect diagram drawn to understand the causes of a problem identified by delays at check-in procedures at an airport.



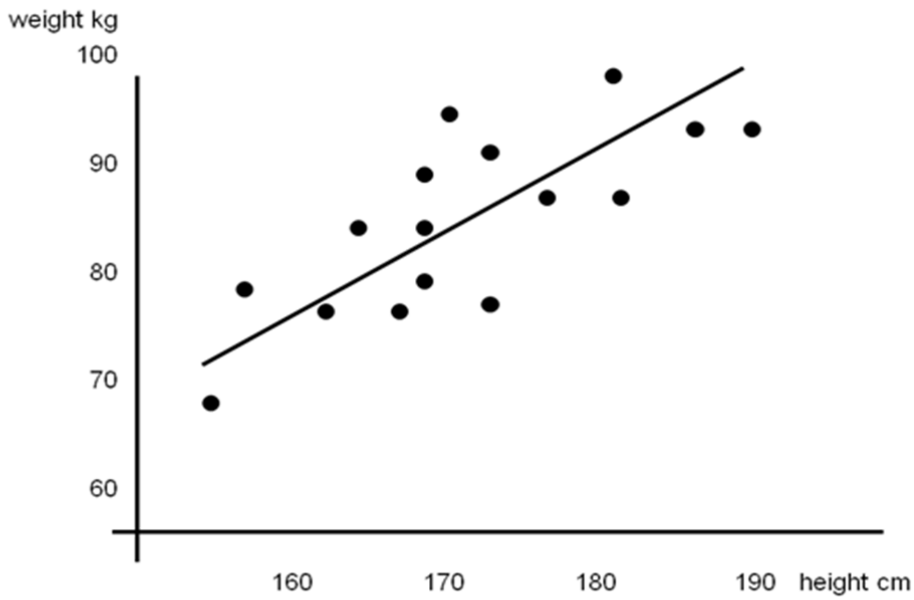
(Gardiner, 2010, p 165)

In this example, an airline has had numerous complaints about slow check-in procedures. This is the effect and is placed at the right-hand side of the diagram. A team of people connected to the process have a brainstorming session and identify possible causes. In this example, they are identified as personnel, equipment, materials, procedures and other causes. These become the bones along the spine and they are then broken down into more-detailed possible causes.

Scatter diagram

A scatter diagram is a graphical technique to show how two variables are related. The two sets of data are plotted on a graph, with the y-axis for one variable and the x-axis for the other. While the relationships are illustrated, the chart does not indicate whether or not the two sets of data are actually related or only appear related.

The scatter diagram is used when the process has numerical pairs of variables (such as height and weight) and when each numerical variable has multiple values, when trying to resolve the relationship between two variables, such as identifying the root causes of the problem and when testing the relationship of variables before constructing control charts.

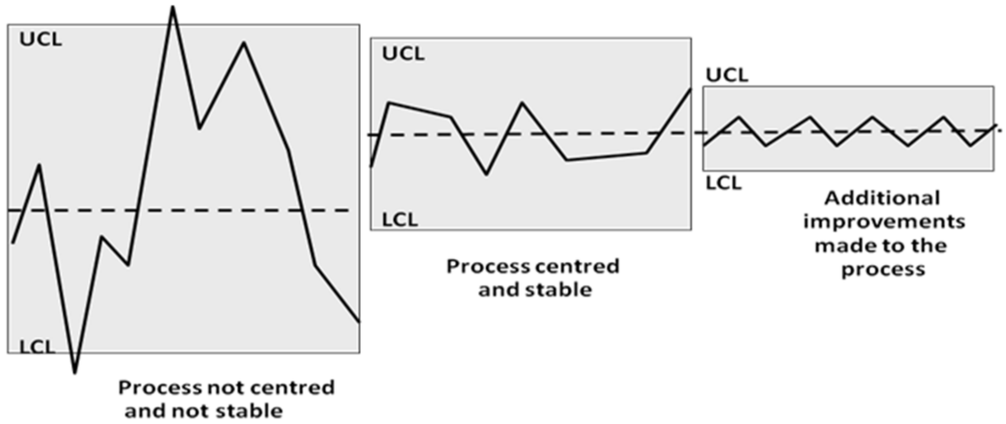


(Gardiner, 2010, p. 166)

The diagram above is an example of a scatter diagram. In this example, the weight and height of each player in the team is measured to establish whether height and weight have any correlation. As the player height increases so does the weight and this shows there is a positive relationship between height and weight.

Process control chart

A process control chart has upper and lower control limits which are calculated from data collected when the process is thought to be in control. Measurements from subsequent samples are plotted to determine if the process is still in control. Any trend within the limits or any samples outside the limits shows the probable existence of assignable causes.



(Gardiner, 2010, p. 167)

The diagram above is an example of three process control charts. Clearly the chart on the left is not centred on target values and is out of control. A process operator entering the values into this chart should take immediate action to correct this problem.

The middle chart shows that the process has stabilised and is now centred. The control limits have been drawn closer together (compared to the left hand chart) and a valid assumption suggests the process is now more predictable and performing better.

The control chart on the right illustrates the result of further process improvements. The control limits have been brought closer together (compared to the middle chart).

Control limits are not specification or tolerance limits. They are calculated from process data when the process is believed to be in control.

Statistical process control

Statistical process control involves testing a random sample of output from a process while the process is running to determine whether the process is producing within a pre-calculated range. This range is calculated when it is believed the process is in control. When the tested output exceeds that range, it is a signal to investigate the cause since it may indicate the process is out of control. The function of control charts is to indicate the possible presence of assignable cause variation.

If the process is out of control, or is heading in that direction, the process should be adjusted to bring it back in control. Statistical process control is maintained by measuring either attributes or variables.

Process controls monitor quality while the product or service is being produced. The most common charts for variable data that are measured along a continuous scale are the $\bar{x}$ charts and *R* charts. Examples of variables data are length, distance, time, weight, pressure, temperature and noise levels. The $\bar{x}$ is the mean of sample measurements. The $\bar{x}$ chart is simply a plot of the means of sample measurements taken from a process. The range is the difference between the highest and lowest numbers in the sample. An *R* chart is the plot of the ranges of sample measurements taken from a process. These charts are usually maintained by process workers and the charts are maintained by hand. If a computer is available and computer programs are maintaining the charts then the standard deviation is a better measure of the variability. The upper and lower control limits are determined by statistical analysis of the past data for a given level of confidence.

The $\bar{x}$ chart tells us whether changes have occurred in the central tendency of the process. This might be due to such factors as tool wear, a gradual increase in temperature, a different method used on the second shift, or new and stronger materials. The *R* chart values indicate a gain or loss in uniformity has occurred. Such a change might be due to worn bearings, a loose tool part, an erratic flow of lubricants to a machine, or to sloppiness on the part of a machine operator. The two types of charts go hand-in-hand when monitoring variables.

Control limits should be drawn on a blank chart and the operator should begin to record samples to monitor the process to ensure the variation observed is within the natural variation of the process. This is called being in control.

The control limits are calculated to represent the range between which all samples are expected to fall if the process is in statistical control. If any samples fall outside the control limits or if any unusual patterns are observed, then some assignable, or special cause, has probably affected the process. It is not normal. When a sample lies outside the control limits, or a number of samples lie on one side of the centre line to indicate a shift in the process, the process should be studied to find the cause.

A process operating in statistical control has variation that is natural and expected. This variation comes from what is essentially uncontrollable sources and is called natural variation. The process has no variation produced by specific, traceable, assignable causes. All its variation is at a minimum, given the process technology applied, and the variation represents merely random statistical variation, and no variation that one can label as having a particular cause. Purists might argue that, in fact, natural variation can be assigned to a cause. Therefore, when natural variation can be assigned it should be treated as assignable and corrected. The basic challenge in process control is to separate the assignable variation from the natural variation. This would follow a careful study of the process dynamics.

Variables data are measured along a continuous scale. Production examples of variables include weight (of chocolate bar), colour (of paper), hardness (of metal surface), viscosity (of oil), temperature (of chemical process). Service examples of variables include arrival time (of airline), errors (in financial statements), teaching evaluation, absenteeism, cleanliness (of hotel room).

Lean thinking

Lean thinking is a strategic initiative that maximises customer value while minimising waste.

An organisation that is lean thinking truly understands customer value and continuously improves processes to create more value with fewer resources. Lean thinking allows an organisation to define customer value, customer requirements and waste created by structural, infrastructural and integration elements in all business operations. Processes that do not effectively deliver value are streamlined to deliver exactly what the customer wants and with fewer resources. Lean thinking is holistic in its approach and practical in its implementation.

The emphasis in lean thinking is to examine and optimise the entire system rather than concentrating on isolated facets. Reducing resources is performed by eliminating waste along the entire value stream.

Processes are created, or modified, to make products and services that require less human effort, space, time and capital. The resulting products and services are produced at less cost and with fewer defects when compared with traditional business systems. Organisations are capable of responding to changing customer desires with higher variety, higher quality, lower cost and with faster throughput times. The whole process becomes simpler and better.

Lean thinking concepts have been around for a very long time but popular current thinking developed with the Toyota Production System (TPS) in the 1950s.

At a Toyota plant, a production instruction is issued to the beginning of the production line as soon as possible after an order is received. The assembly line is stocked with small amounts of all possible parts so any configuration can be produced. As components are used they are replaced by the component producing process at the rate of consumption. Similarly, the process which produces the components can replace the components at the rate of usage.

Just-in-time is a philosophy of the elimination of waste. The primary elements of just-in-time are to have what is needed, when it is needed and in the amount needed. This also means that only the required resources are used when needed, quality is improved to zero defects, lead times are shortened by reducing set-up times, queue lengths and lot sizes and all of this happens incrementally at minimum cost.

Waste

Waste is any activity that does not add value to the product or service as valued by the customer.

The seven wastes are overproduction, waiting, transportation, inventory, motion, making defects and processing steps as identified by Shigeo Shingo. Unused people skills are sometimes included as the eighth waste.

The seven categories of waste are:

1. Overproduction — excess quantity or too early
2. Waiting — queues or delays
3. Transportation — unnecessary movement
4. Processing — poor process design
5. Motion — activities that do not add value
6. Inventory — items adding cost and not value
7. Defects — scrap or rework.

Overproduction – excess quantity or too early

Overproduction is producing a quantity greater than required. It occurs for a number of reasons. The worst is that management believes the cost of set-up can be amortised over a longer production run and that this lowers the unit cost of production. This belief is based on an estimated cost of set-up which, for most organisations, is an arbitrary number with a little science attached. When economic order quantities are incorporated into production thinking the cost of set-up is balanced with the cost of storage and the run size is the quantity that minimises the sum of ordering and storage. Again, these figures are usually arbitrarily established.

Overproduction is the waste of resources, including materials, energy and time, used to produce output that is not wanted. It may be wanted in the future, but at the time of production it is not wanted. Valuable resources are used to make unwanted output when wanted output is not being made.

Waiting — queues or delays

The waste of waiting occurs whenever the production flow is interrupted. Job shop processes are referred to as intermittent because they stop-start-stop-start. Lean thinking endeavours to eliminate the stop and make sure materials and production flow from initial process to final process.

Any time product is waiting for the next step is considered waste. Waiting for resources of transport to arrive, waiting for input materials to be delivered, waiting for staff to turn up for work, and waiting for maintenance on a production machine are all examples of waste of waiting.

Waste occurs when we wait for technology to catch up. For example, if you telephone a call centre you wait for the answering system to start, wait for the advertising messages to be read, wait for the inquiry options to be read, wait for the connection to be made, wait for the operator to call up the account details, wait for the computer technology to provide the required information, wait for the operator to enter the new details and then hang up. Usually, hanging up is the fastest part of the process.

Transportation — unnecessary movement

The waste of transport is any unnecessary movement of materials or products. Inwards goods delivered to the wrong part of the building and having to be transferred to the correct place is a waste of transport. Products sent in bulk to a remote location, then called back to the main centre to meet a customer need represents waste of transport.

Transport waste includes using a transport method that is unnecessary given all the circumstances. An example may be using air transport to cover a short distance when road transport would work just as well. Air transport requires road transport to deliver to and from the airport. Road transport on its own can go direct from supplier to customer without additional handling.

Transport waste is also the use of an inappropriate transport method such as a vehicle that is twice the size and twice as expensive to operate as a smaller, more suitable vehicle.

Processing — poor process design

The waste of processing is any processing step that does not add value. It usually arises from poor process design. Examples include heating ingredients to a temperature, allowing them to cool and then having to heat them again when the rest of the process is ready. This is poor co-ordination of processing steps. Another example is packing products into small containers, then having to open several containers for the next processing step. This could be improved by storing the intermediate output in bulk.

Motion — activities that do not add value

Waste of motion is the use of activities that do not add value, such as placing heavy items on the floor rather than at waist height. Assuming an operator can lift the items, it is better to place them on a table rather than bending to place them on the floor and then subsequently bending to pick them up.

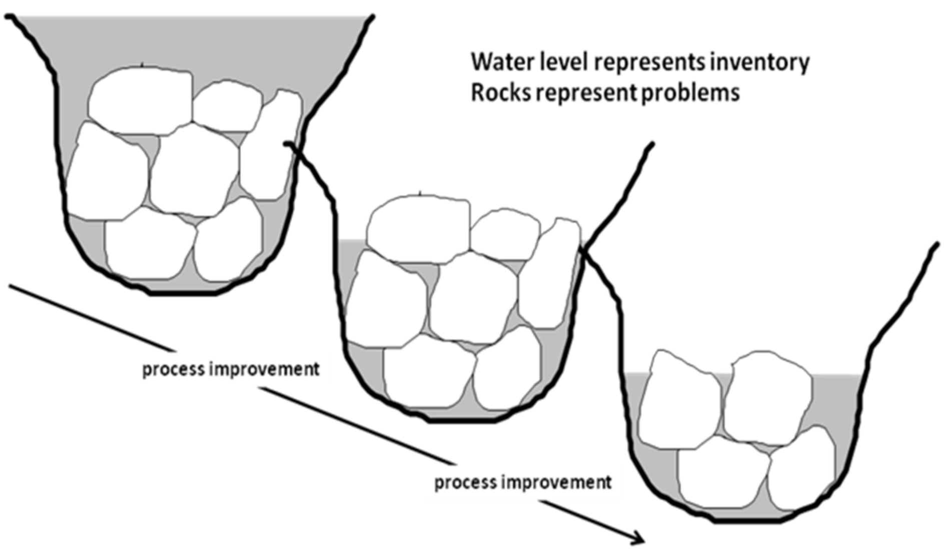
Inventory — items adding cost and not value

Inventory waste is the storage of items that are not needed. This requires storage in a warehouse at a cost which would not occur if the inventory did not exist.

Defects — scrap or rework

Producing defects, scrap and rework is waste. Scrap is an output that is dumped at the end of processing because it does not meet customer specification. Why is that product made in the first place? It may be quicker to just throw money away or flush it down the toilet. Rework occurs when a product is made and it is determined that a defect can be corrected if it passes through the processing step again. Painting and repainting is an example. When this waste occurs the item is made twice, but the customer only pays once.

River of rocks



(Gardiner, 2010, p. 179)

The diagram above illustrates the river of rocks analogy. The analogy can take various forms and this example shows the cross section of a river. In the top left-hand corner, the cross-section of the river has a number of rocks on the river bed. The moving river is the movement of materials, the depth of water represents the inventory and the rocks represent problems. The problems are not visible because the water in the river completely covers them.

Organisations are often unaware problems exist because they are not visible. It does not matter that suppliers deliver late because sufficient is already in stock; it does not matter that a production machine continuously breaks down because there is sufficient output in stock; it does not matter that scheduling problems exist because the inventory is not needed anyway; it does not matter that a production run exceeds the quantity required and uses valuable resources because the products that could have been made are in plentiful supply and there are sufficient stocks.

Inventory is progressively reduced, as shown in the middle example, until rocks start to appear. The rocks are problems inherent in the system. They previously were not visible but now, with reduced inventory in the total system, these problems have surfaced. Using continuous improvement these problems are eliminated. When the exercise starts it is not known which problems will surface first. The whole idea is to slowly lower the level of water (inventory) until the first rocks (problems) occur and deal with the first problems.

Now the water level can be lowered further to reveal even more problems.

Kanban

Kanban is a flag or a piece of paper that contains all relevant information for an order: part number, description, process area used, time of delivery, quantity available, quantity delivered, production quantity and so on. The type and number of units required by a process are written on Kanban cards and used to start withdrawal and production of items through the production process.

The prerequisite of relatively repetitive demand is difficult for most firms to achieve. Service organisations use reservations and appointment books to level the demand. Production organisations use finished goods, supermarkets and load-levelling mechanisms.

In traditional production organisations and when low-volume, intermittent usage products are being made, an order release mechanism is typically used. When lean thinking is applied for high-volume products and services with relatively continual usage, the best way to communicate requirements is using demand-pull methods. Pull signals indicate the need to replenish finished goods inventory or deliver a service replenishment inventory.

Takt time is calculated as the available production time divided by the rate of customer demand. Takt time sets the pace of production to match the rate the customer demands output.

Takt time is the basic rate of production that must be maintained to match the rate of demand. It is calculated as the total operating time divided by the required quantity and represents the demand for capacity.

Heijunka is an approach to level production throughout the supply chain to match the planned rate of end-product sales.

Lean production is a streamlined system for production that provides high levels of quality, productivity and customer response. It was developed by the Toyota Motor Corporation and focuses on the elimination of waste in all forms, including defects requiring rework, unnecessary processing steps, unnecessary movement of materials or people, waiting time, excess inventory and overproduction.

Activity 3.4

Activity

Make a list of the steps you would introduce to an organisation that was implementing a lean thinking approach to production.

Compare your answers to the model at the end of the module.

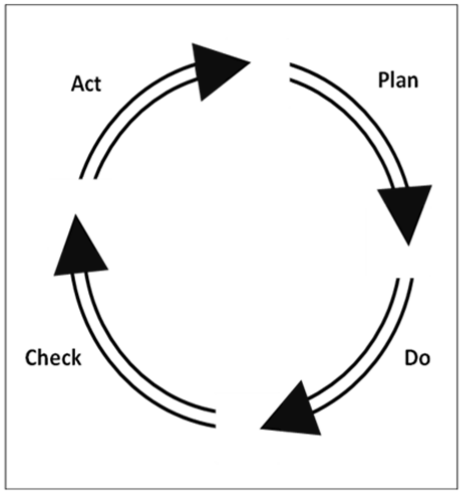
Plan-do-check-act cycle

Plan-do-check-act is a four-step process for quality improvement. In the first step (plan), a plan to effect improvement is developed. In the second step (do), the plan is carried out, preferably on a small scale. In the third step (check), the effects of the plan are observed. In the last step (act), the results are studied to determine what was learned and what can be predicted.

The plan-do-check-act cycle is a very simple process for implementing change. The first step is planning by determining the process goals and targets and methods of reaching those goals. During the second stage the improvement is implemented on a small scale. The third step checks on the effect of the implementation. If the earlier stages have been done properly then this step is positive. The fourth step takes appropriate action and makes the improvement permanent.

Part of the fourth step is to ensure the old process does not return. The improvement is implemented because it provides a better result so any return to the previous method would signal a worse result and this is not allowed.

The diagram below illustrates the plan-do-check-act process.



(Gardiner, 2010, p. 185)

Lean services

The concepts of lean production developed from the Toyota Production System and it is easy to consider that lean thinking benefits manufacturing companies and not service organisations.

The concepts of lean thinking can be applied directly to a service environment and many services already think lean although they may not realise the terminology. Some of these concepts are:

- Consistently high quality and defect-free services that deliver to the customer exactly what is wanted, when it is wanted, first time and every time.
- Uniform facility loads using reservation systems, appointments and differential pricing.
- Standardised work methods for consistency and repeatability of performance.
- Close ties with suppliers who provide frequent deliveries and short lead times.
- Demand-pull scheduling.
- Customised services using a flexible workforce.
- Automation to provide continuous services, such as online banking and automatic teller machines.

Activity 3.5

Activity

Work through the following questions. You may need to go back and reread the unit to help you.

1. Discuss the strategic value of lean thinking.
2. Describe the seven wastes.
3. Describe the perfect process.
4. Discuss lean thinking applied to services.
5. Discuss process variability.

Unit summary

Summary

In this unit you learned about the strategic importance of process and how managers should think about process as they design and modify work practices. This is process thinking. We examined process variability and identified the perfect process. Established processes may need to be modified or improved to keep up with changing customer requirements and changing technological advancement.

We looked at the steps for process improvement and described the seven basic tools of quality. This led to the concepts of lean thinking and the application of lean thinking to a services environment.

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Readings for further study

Reading

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Unit 7

Product design

Introduction

There is increasing pressure for firms to be competitive in the market place, by shortening the product development time, offering a wide range of customised products, or shortening the actual supply chain of products from suppliers to the final customer. These firms gain simultaneously from economies of scale (such as through standardisation of components for production, mass advertising and mass distribution) and economies of scope (such as through customisation, incremental innovations and product variations through flexible manufacturing systems).

In the days before the two-pronged attack of globalisation and instantly available information, markets had only partial knowledge of products available and limited access to those they were aware of. Therefore, firms could prosper using a combination of brand loyalty, localisation and limited product differentiation. However, with more efficient balancing of supply and demand, these generic strategies for business success are becoming less effective. This leaves only the ability to innovate as a way to effectively differentiate from the competition. Operations management is increasingly required to act in innovative ways as innovation becomes one of the few sources of competitive advantage available.

This unit introduces concepts crucial to the successful management of products (including services) for firms to gain and/or sustain competitive advantage.

This unit begins by exploring tools to create innovation in product design such that the customer increases satisfaction. The concepts of strategic design and structured product development are discussed alongside an appreciation of risk and uncertainty. The principles of robust design and design for operations are also discussed.

Outcomes

Upon completion of this unit you will be able to:

- *Describe* the Kano model.
- *Explain* how the voice of the customer should be used in product design.
- *Explain* quality function deployment.
- *Discuss* structured product development processes.
- *Explain* the relationship between uncertainty and risk in product development.
- *Describe* the product development portfolios.
- *Explain* robust design.
- *Explain* participative product development or concurrent engineering.

Terminology

Design for assembly: Design for assembly (DFA) is the process of creating designs that fit well with assembly operations thus reducing assembly costs and increasing the quality of conformance.

Design for manufacturability: Design for manufacturability (DFM) is the process of designing a product for efficient production and high levels of quality by simplifying parts, products and processes.

House of quality: A structured process that relates customer-demanded quality attributes to the product's technical features needed to support and generate these attributes. This technique forces designers to consider customer needs and the degree to which the proposed designs satisfy those needs.

Quality function deployment: Quality function deployment is a methodology that identifies customer needs (the voice of the customer) and ensures these needs are met or exceeded with the technical (design) requirements throughout the product development and production process. Quality function deployment can be viewed as a set of communication and translation tools. It tries to eliminate the gap between what the customer wants in a new product and what the product is capable of delivering.

Quality loss function: Quality loss function is a parabolic approximation of the quality loss that occurs when a quality characteristic deviates from the target value. The cost of deviating from the target increases quadratically as the quality

	characteristic moves further from the target. It was introduced by Genichi Taguchi.
Taguchi methods	Taguchi methods are used in product design. It is a concept of considering system design, parameter design and tolerance design as three phases of product design. The objective is to reduce quality loss by reducing the variability of the characteristics of the product.
Voice of the customer	Voice of the customer (VOC) is the actual customer description of the functions and features the customer desires.

Terminology sourced from Gardiner (2010).

Design for the customer

What do customers want from a product or service? They want more for less. But when we say “more”, what does that actually mean? They want more value. They want more benefits received compared to the price they pay for the product or service.

When a current product exists, the designer can gauge the current customer reaction to that product and the designer can make a reasonable determination of the characteristics that would improve the product and create more value. The marketing function should help with this process.

When there is no existing product and the designer is starting with a concept, it is considerably harder to get customer inputs. The challenge for the designer is to get the product or service to market so it creates excitement on the part of the customer and it reaches the market before anyone else.

Activity 3.6

Activity

Think back a few years when mobile phones that take digital photographs were introduced. Consider who wanted one. Designers introduced a “wow” factor that truly caught the imagination of millions of customers worldwide.

Now put yourself on the design team of the early models. What would you do first? How would you introduce this product?

What features would you include/exclude?

How would you sell the concept and convince people of the benefits?

Kano model

The Kano model (Kano, Seraku, Takahashi & Tsuji, 1984) is a product development method to understand customer-defined quality. It starts by classifying customer preferences into three categories:

1. Basic needs
2. Performance wants
3. Excitement.

Basic needs

Basic needs are characteristics of the product that must be present every time. Customers assume they are already present and usually will not specifically ask for them. This could be considered the price of entry into the market. As an example, when buying a new house a customer would expect to find at least one bathroom and toilet.

When basic needs are supplied, the customer may not even notice them, but when absent, the customer will complain. For example, when a bus service operates on schedule, the customer learns to accept that, but when it operates erratically, or not at all, the customer complains.

Performance wants

Increased performance of the product or service provides increased satisfaction. Conversely, decreased performance provides decreased satisfaction. Customer satisfaction is proportional to performance for some products. Price is often related to one-dimensional attributes.

When buying a new house, a customer may want a second bathroom and toilet and an en-suite bathroom. If these are present the customer is satisfied.

Excitement

Customers are prepared to pay a premium to get features that offer excitement. Customers do not expect these features and are delighted and excited when they are available.

When buying the new house the customer may be delighted with a home-security system that senses the individual home-owners and allows them access without having to press buttons. Or when buying a new car the customer may prefer the brand with a built-in GPS system.

The essence of excitement is surprise and the essence of surprise is the unexpected.

Designers have to be aware that customer expectations change and what is portrayed as excitement one day may turn into a performance want tomorrow and maybe even a basic need next week.

Questionnaire

The Kano model assumes customer requirements can be established using a questionnaire that recognises that it is not what the customer is saying that is important; it is what they think that matters.

The questions are asked as a positive and a negative. The questions ask, “What is your reaction if this feature was present?” and “What is your reaction if this feature was not present?”

Possible answers are, “I like it that way”, “It must be that way”, “I am neutral”, “I can live with it that way”, and “I dislike it that way”.

The answers are tabulated to arrive at a ranked list of customer requirements.

Voice of the customer

Capturing the voice of the customer is of paramount importance when trying to establish true customer needs. The voice of the customer (VOC) is the actual customer description of the functions and features the customer desires. The Kano model is one methodology for gaining an in-depth understanding of the real customer needs.

Market research, customer interviews, focus group and Delphi interviews all provide an insight into customer requirements. Too often, though, the style of question being asked, or topic discussed, is limited by the ability of the person asking the questions and by the understanding and expressive capability of the person providing the ideas.

Market researchers often telephone prospects (or suspects) during the evening and hope to gain an interview. The choice of responders is immediately limited to those who choose to stay on the line and answer the questions. The responses, if offered, have little preconceived thought and may even be the opposite of true feelings and attitudes. There is no way of telling if an individual is actually playing a game or is providing good, honest opinions.

The voice of the customer focuses on customer needs and drives the design process and must be continually monitored to ensure it is meeting customer needs. This is the starting point for designing products and processes.

Quality function deployment (QFD)

Quality function deployment is a methodology that identifies customer needs (the voice of the customer) and ensures these needs are met or exceeded with the technical (design) requirements throughout the product development and production process.

Quality function deployment can be viewed as a set of communication and translation tools. It tries to eliminate the gap between what the customer wants in a new product and what the product is capable of delivering. The process assesses the true quality obtained from the customer, the quality characteristics of the product and the process characteristics.

Quality function deployment is a methodology to:

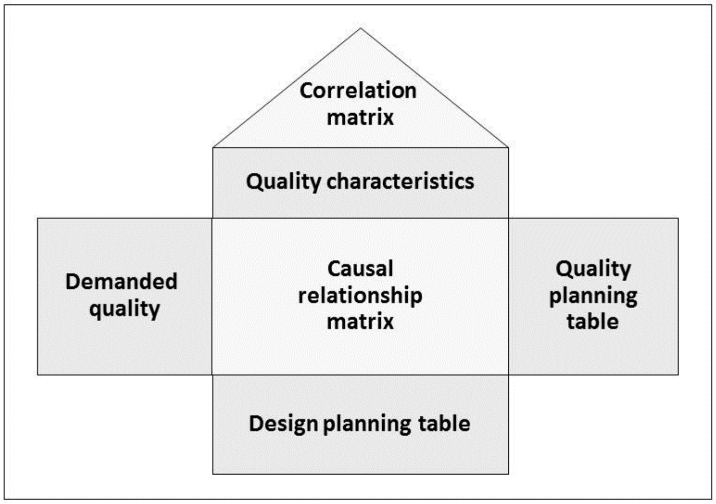
- Prioritise spoken and unspoken customer excitement, performance wants and basic needs.
- Translate these needs into actions and designs such as technical characteristics and specifications.
- Build and deliver quality products and services by focusing business functions on a common goal of achieving customer satisfaction (QFD Institute, n.d.)

Traditional design aims at minimising negative aspects such as defects and poor service. The aim of traditional design in this sense is to obtain zero defects.

Quality function deployment is knowledge-based and allows invisible customer requirements to become visible. The main tool within quality function deployment is the house of quality.

House of quality

The house of quality is actually an assembly of other deployment hierarchies and tables. These include the demanded quality hierarchy (rows), quality characteristics hierarchy (columns), the causal relationships matrix which relates them using any one of several distribution methods, the quality planning table (right side room), and design planning table (bottom room).



The diagram above illustrates the house of quality (Gardiner, 2010, p. 256).

Demanded quality hierarchy (rows)

The demanded quality hierarchy is the left side room. Customer requirements that come from customer statements are arranged in rows. These state in customer terminology exactly what the customer wants.

As an example, the customer requirements for a cell phone might be:

- Light, collapsible, ergonomically designed.
- Long-lasting battery that can be recharged quickly.
- Video camera suitable for business use.
- Web-enabled with high-speed connection.
- Differentiating features such as a clock at the top cover of the phone which glows, or a flat membrane keypad giving a feel of etched metal.

Quality characteristics hierarchy (columns)

The quality characteristics are arranged in columns and these constitute the technical response to the demanded quality. If the demanded quality is the voice of the customer then quality characteristics is the voice of the engineer.

Relationships matrix

The relationships matrix relates the demanded quality hierarchy with the quality characteristics hierarchy. Design engineers have choices in materials, technologies, composition and specifications at their disposal. This matrix gives a relative rating score of their technical solution to the customer requirements.

Quality planning table

The quality planning table or competitive assessment is in the right side room. This provides a qualitative benchmark comparison with other products, other solutions and other methods.

Design planning table

The design planning table or target values is located in the bottom room. This provides the target values that the design team are trying to reach. Using the cell phone example, above, the design planning table might provide the target weight in grams, the target battery life in days, the target recharge time in minutes, the quality of the video camera and the target Internet connection in megabytes per second. It provides relevant and measurable technical requirements and product characteristics. It provides observations from market surveys that show customers' perceptions. Design planning assigns benchmarks and measures performance compared to competitive products and how difficult it is to develop each requirement.

Correlation

The correlation of technical requirements to support or impede product design is located in the roof.

The house of quality is a critical tool for design for six sigma. It forms a relationship between factors that are critical to customer satisfaction and factors that are critical to quality. The house of quality is not quality function deployment.

Activity 3.7

Activity

Use the **house of quality model** for the design of a laptop computer.

1. Start by making a list of customer requirements that will form the demanded quality hierarchy. Customer requirements state in customer terminology exactly what the customer wants with their laptop computer. List five-to-eight features a customer might want from their laptop computer.
2. Then list the quality characteristics that constitute the technical response to the demanded quality. This will be a list of five-to-eight design attributes the designer would incorporate in the laptop computer. Use generic terms such as "display type" and "memory type".
3. Prepare the relationships matrix relating the demanded quality hierarchy with the quality characteristics hierarchy. For each entry in the demanded quality hierarchy indicate whether or not the quality characteristics have answered the customer need. For this activity just use general terms such as "yes", "no", "somewhat" and "mostly".
4. Develop the quality planning table or competitive assessment which provides a qualitative benchmark comparison with other products, solutions and methods. To do this, imagine you have two competitive products in the market. They are A and B and your product is designated X. Now, for each demanded quality characteristic, rank the three products by how well they answer the customer need. (Note, this is purely hypothetical since you do not have the details of the competitive products.)
5. Construct the design planning table with the target values the design team is trying to reach. To do this properly you would need to be a designer with computer design skills. For this activity, this is not necessary. Just quantify each quality characteristic.
6. Finally, consider the correlation of technical requirements to support or impede product design. Do this by evaluating the quality characteristics for compatibility and non-compatibility.

Compare your answers to the model at the end of the module.

Strategic design

Design quality is the inherent value of the product in the marketplace, and is thus a strategic decision for the firm.

Design review is a process to help standardisation and reduce the costs associated with frequent design changes by evaluating proposed design to ensure the design is supported by adequate materials, will perform successfully when in use, can be manufactured at low cost and is suitable for prompt field maintenance.

Product design is usually a significant part of the operations strategy. When products are designed the detailed characteristics of each product are established and these directly affect how a product can be produced and this determines the design of the production system. Additionally, product design directly affects product quality, production costs and customer satisfaction.

Design is a strategic decision for any organisation. When a new product or service is introduced the firm has to live with that product for the entire product life cycle. For some products this may be just a few weeks and in others it may be many years.

Structured product development

The first stage of a conventional design process starts with a recognition that a customer has a need for a product. Thus, the design concept initiates design activity.

The second phase is a screening process which includes the determination of the physical and functional characteristics of the product and how it is going to work.

This is followed by the preliminary design which is a very creative phase. It is often believed that this phase of the design process is the most crucial and is where the designer’s creativity is employed. Preliminary or conceptual design, usually involves producing several design choices and the start of the product specification.

During the design phase, the design is analysed, evaluated and improved. This analysis includes compatibility (fitting together and proper articulation of parts during operation) and simplification (exclusion of features that raise production costs). Analysis also includes material selection and testing, and structural design and analysis. Techniques for structural design include finite element modelling (FEM) and finite element analysis (FEA).

The final stage is to implement the final design and launch the product.

Uncertainty and risk in product design

New product and service development requires a careful balance between uncertainty and risk. Craig Davis (2002) identifies uncertainty as a property of nature that resists quantification while risk is quantifiable and manageable.

During new product development, knowledge is discovered but the objectives are often unclear, measurements of success ambiguous and the process used to develop new products does not affect success or failure (Davis, 2002).

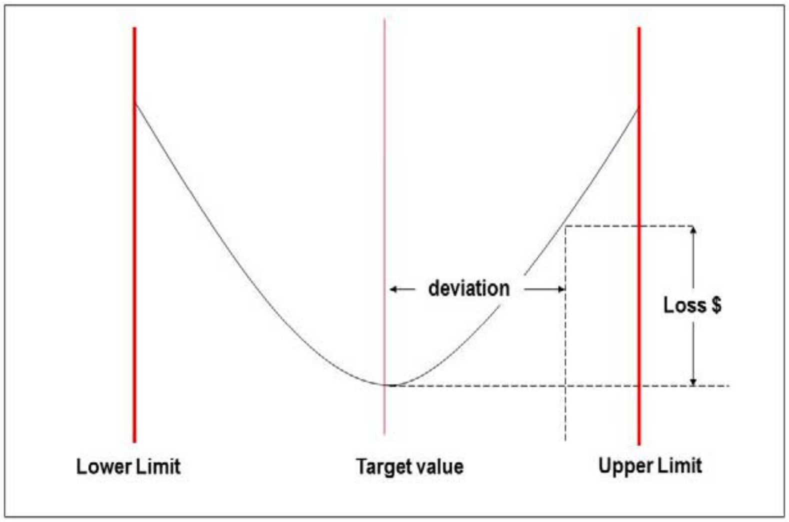
The challenge with research is to overcome technology that may not work while the challenge in development is to avoid products or services that may not be successful.

Robust design

Quality loss function is a parabolic approximation of the quality loss that occurs when a quality characteristic deviates from the target value. The cost of deviating from the target increases quadratically as the quality characteristic moves further from the target. It was introduced by Genichi Taguchi.

Taguchi methods are used in product design. It is a concept of considering system design, parameter design and tolerance design as three phases of product design. The objective is to reduce quality loss by reducing the variability of the characteristics of the product.

Participative design, also called concurrent engineering and simultaneous engineering, is a concept that refers to the simultaneous participation of all the functional areas of the firm in the product design activity, Suppliers and customers are often included. The overall intent is to enhance the design with the input of all key stakeholders.



The diagram above illustrates Taguchi's quality loss function (Gardiner, 2010).

Design for operations

Design for operations outlines some fairly basic ideas that should be incorporated into product and service design. Earlier versions of these guidelines were called design for assembly, design for manufacturing and design for manufacturing and assembly. These other terms have a strong manufacturing connotation whereas design for operations applies to services as well as production industries.

The design for operations guidelines are:

- Link product and process designs to operational success factors.
- Design to target markets and target costs.
- Minimise the number of components and number of operations.
- Ensure customer requirements are known and design to those requirements.
- Ensure process capabilities are known (and this includes supplier capabilities) and design to those capabilities.
- Use standard procedures, materials and processes with already known and proven quality.
- Design multifunctional and multiuse components and service elements and modules.
- Design for ease of joining, separating, rejoining (goods) and ease of coupling and decoupling (services).

- Design for one-way assembly, one-way travel by avoiding backtracking and return visits.
- Avoid special fasteners and connectors (products) and off-line or misfit service elements.
- Avoid fragile designs requiring extraordinary effort or attentiveness or processes that tempt substandard or unsafe performance.

Activity 3.8

Activity

Work through the following questions. You may need to go back and reread the unit to help you.

1. How is the problem of technology choice related to process selection and product design?
2. How much detailed technical knowledge on the part of managers is required to make a decision regarding selection of computer hardware?
3. Suppose you need to select a computer terminal to use in your office. What performance characteristics of the technology would you assess? How would you get the necessary information to make the decision?
4. What is the main obstacle to using a manufacturing approach to the delivery of services?

Unit summary

Summary

In this unit you learned how to describe the Kano model and explain how the voice of the customer should be used in product design. Quality function deployment was introduced as a process for translating customer requirements into product requirements. The main tool is the house of quality. The structured product development process was discussed and the relationship between uncertainty and risk in product development was explained.

We concluded by explaining robust design and Taguchi's quality loss function and explaining participative product development or concurrent engineering.

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Unit 8

The concept of quality

Introduction

Traditional total quality management (TQM) systems have worked well for many firms. However, with increasing outsourcing activities and globalisation, the role of quality management systems has to be redefined, especially with respect to innovation, supply chain management and service management. Manufacturers of electronic components, IT services and automotive industry, for instance, face fierce pricing pressure and have recently considered sourcing in markets with low labour markets. The quest for survival has, furthermore, made matters even worse with rising costs in Latin America, the expansion of European Union, and the increasing economic power of Asian markets.

Quality should be the paramount driving force for all organisations. While quality is a word used by most managers in most organisations, there is still a widespread misconception as to what that actually entails and the process for implementing quality is not fully understood.

This study unit will introduce key concepts and philosophies of total quality management. It will emphasise the role of quality in product designs, manufacturing processes, marketing and services. It will highlight why quality has become such a central issue for value creation and competitiveness and why it is increasingly more challenging to manage. The costs of quality will be analysed and some quality management frameworks discussed. The contributions of some quality leaders will be discussed to place into perspective the modern approach to quality. Finally, the concepts of process capability and six sigma will be analysed.

Outcomes

Upon completion of this unit you will be able to:

- *Define* quality.
- *Define* the characteristics of a total quality management programme.
- *Discuss* the four traditional categories of quality costs.
- *Distinguish* between inherent capability and capability to meet specifications.
- *Explain* the process capability ratio C_p .
- *Explain* the process capability index C_{pk} .
- *Discuss* six sigma quality.
- *Explain* the concept of design for six sigma.

Terminology

Assignable variation	A shift in the output process caused by specific factors such as environmental conditions and changes in input parameters. The variation arises from external sources that are not inherent in the process and which appear sporadically and disrupt the random pattern of common causes. When all assignable causes are isolated they can potentially be removed to allow the process to continue with just common or normal variation.
Common variation	A variation that is inherent in the process over time. Its cause is random and is the opposite of assignable variation.
Costs of quality	The overall costs associated with prevention activities, improvement activities and recovering from cases in which the product fails to completely satisfy the customer. There are four categories of costs: external failure costs (incurred after the customer receives the product or service), internal failure costs (incurred before the customer receives the product or service), appraisal costs (incurred to determine the degree of conformance to quality requirements), and prevention costs (incurred in preventing errors).
Lean six sigma	An approach that combines principles of lean thinking with six sigma quality initiatives to enhance operations performance.

Participative design	Also called concurrent engineering and simultaneous engineering. It is a concept that refers to the simultaneous participation of all the functional areas of the firm in product design activity. Suppliers and customers are often included. The intent is to enhance the design with the input of all key stakeholders.
Process capability	The ability of a process to produce outputs that conform to customer-defined specifications. The base starting point for process capability is ±3 standard deviations (±3σ) of the process. At this point 99.73 per cent of the process output is deemed to be acceptable. A higher percentage is better; a lower percentage is not acceptable.
Six sigma quality	A business improvement approach that seeks to find and eliminate causes of defects and errors in manufacturing and service processes by focussing on outputs that are critical to customers and a clear financial return for the organisation. It is a business process that allows organisations to improve bottom-line performance, creating and monitoring business activities to reduce waste and resource requirements while increasing customer satisfaction.
Total quality management	A management approach to long-term success through customer satisfaction.

Terminology sourced from Gardiner (2010).

What is quality?

Quality can be defined as exceeding or surpassing excellence. This is a very high-level view of quality. Excellence is defined as being exceptionally good, having extreme merit and superiority. That was excellence. Now quality is exceeding in excellence; exceeding this lofty standard. In many ways, quality is an ideal; it is transcendent.

Quality is fitness for intended use, as defined by the customer. A customer has a need for a product or service and this need may be stated or implied. The customer walks into a store to satisfy that need and may be confronted with a variety of excellent products. But are they all suitable for the purpose the customer intends? As an example, consider purchasing a high performance sports car with carbon fibre chassis, magnesium alloy wheels, ceramic disc brakes and capable of accelerating to 200 km/h in 9.9 seconds. That is a perfectly fine choice and there is a significant market for this type of vehicle. But, in this case the customer wanted a vehicle to go off the main road and into the mountains for some recreational hunting and fishing. Clearly, the sports car is not fit for the particular use the customer intended.

Quality is the degree of customer satisfaction with the product's characteristics and features. Customer expectations are constantly changing and often extremely difficult to define. The ideal expectation is the best possible and sometimes this may not be achievable, given the price or the industry standard.

A desirable expectation is the standard the customer wants to receive while a deserved expectation is the level of performance the customer ought to receive given the perceived costs. As an example, a tourist staying in a backpackers' hostel should not expect the service and standards of a luxury hotel.

Garvin (1987) proposed the dimensions of quality to help understand customer expectations. Additionally, they provide a language for describing quality.

- Performance is the primary operating characteristics of the product such as the colour and clarity of a television set.
- Features are the little extras that come with the product and often these are the exciters, such as whether a new car has a global positioning system installed.
- Reliability is the consistency of performance over time and whether it will need repair or some corrective action to be taken.
- Durability determines the useful life of the product and defines how long it will last before having to be scrapped or replaced.
- Serviceability defines the speed, courtesy and competence of repairs and also how difficult and expensive it is to repair.
- Conformance measures how well the product meets the documented design specifications.
- Aesthetics includes sensory characteristics such as sound, feel, look, smell and taste.
- Perception is a confidence based on past performance and intangibles and includes brand name as an example.

The product dimensions of Garvin do not apply directly to services, although some people have attempted to draw an analogy. Zeithaml, Parasuraman and Berry (1990) have published numerous qualitative studies on the dimensions of quality and their list of dimensions has evolved into five dimensions for service:

Tangibles	Tangibles or the appearance of physical facilities, equipment, appearance of staff and communication materials. This measures whether the facilities are attractive, whether the staff are dressed appropriately, whether written materials are easy to understand and whether technology looks modern.
Reliability	Reflects on the ability to perform the promised service dependably and accurately. It determines whether the exact specifications of the client are followed, whether service is performed right the first time, whether promised delivery dates are met and whether the service level is the same at all times of the day and from all members of staff.
Responsiveness	Is a willingness to help customers and provide prompt service. This dimension measures how willing service people are to answer customer questions and whether the organisation responds quickly when there is a need or a problem.
Assurance	Is the knowledge and courtesy of employees and their ability to convey trust and confidence.
Empathy	Is the degree of the caring and individualised attention the firm provides its customers. Examples of empathy include the scheduling of deliveries to fit customer requirements rather than keeping to a schedule and avoiding the use of technical jargon when explaining problems and solutions. This use of language is evident in the information and communications technology industry.

Quality is conformance to requirements based on product attributes. This is a production-based definition of quality and it is identified by the absence of defects. Once the product has been designed to meet customer expectations, and the customer has seen the specifications, it is reasonable to expect those specifications to be delivered.

Total quality management

Total quality management is a management approach to long-term success through customer satisfaction.

Quality is not perfection; it is not a standard; it is not a procedure; it is not a measure and it is not even an adjective. Quality is everywhere and is used to evaluate how a specific need is satisfied.

Total quality management (TQM) is managing the entire organisation so it excels in all dimensions of products and services that are important to the customer. The key notions are that quality extends throughout the organisation in everything it does and that quality is ultimately defined by the customer. Translating customer quality demands into specifications requires marketing (or product development) to accurately assess what the customer wants and requires product designers to develop a product (or service) that can be produced to consistently achieve that level of quality.

Quality can be used as a competitive or strategic weapon for an organisation. Many will argue that, if you are competing on the basis of quality, you have missed the boat. They say quality is a "given". This is a rather narrow view because if we examine the definition of quality it is apparent that we are striving to improve the product or service in the hands of the customer. Customer needs are changing so our delivery of quality must also change.

Total quality management is a way of thinking about processes and people to ensure the right things are done right first time and every time. This thought process changes attitudes and behaviours, and achieves better results.

Service definition of quality

Quantitative measures may not be appropriate for observing quality in a service environment. For example, how do you define and measure friendliness, courtesy, ambience, excitement, physical and mental well-being, health and memories?

The travel industry provides transport and accommodation services for customers and the actual services provided and the connections made are quantifiable. But, what about the experience? How do you value a week of relaxation on a tropical beach, or a tour through the vineyards of France, or the sense of accomplishment after ascending a high mountain in the Himalayas, or attending a Broadway concert, or sailing around the Caribbean?

Health services provide a quantifiable service which diagnoses illnesses, prescribes medicines and drugs, performs surgical operations, assists with the delivery of new-born babies and provides long-term care for the terminally ill. But, what about the physical and mental well-being of the whole community? How do you measure wellness or just feeling good?

So, service takes on a different meaning when attempting to describe quality. The service delivery may be difficult to repeat reliably, especially as it usually involves the interaction and participation of the customer.

Traditional costs of quality

The overall costs associated with prevention activities, improvement activities and recovering from cases in which the product fails to completely satisfy the customer are described as the costs of quality. There are four categories: external failure costs (incurred after the customer receives the product or service), internal failure costs (incurred before the customer receives the product or service), appraisal costs (incurred to determine the degree of conformance to quality requirements), and prevention costs (incurred in preventing errors).

External failure costs

External failure costs relate to problems found after the product reaches the customer. They are the costs incurred to correct nonconforming work after delivery to the customer or to correct work that did not satisfy a customer's specified needs. Examples include customer warranty replacements, product recalls, replacements, allowances, handling complaints, product repairs, returns, liability and legal judgements, payment of interest penalties, negative word-of-mouth, loss of customer or goodwill and loss of future business.

Internal failure costs

Internal failure costs are those incurred within the system before it is seen or used by the customer. They are costs incurred to correct work before delivery to the customer. Examples include scrap, rework, retest, yield losses, machine downtime and disposing of defective material.

Appraisal costs

Appraisal costs are the costs of inspection, testing and other tasks to ensure the product or process is acceptable. They are the costs incurred to ascertain the condition of a product or service to determine whether it conforms to quality standards. Examples include inspection of incoming goods, inspection and testing of work-in-process, testing of new products before installation, maintaining accuracy of test equipment, process control procedures, checking process data, balancing process outputs, verifying process data and the materials and services consumed during testing.

Prevention costs

Prevention costs are the costs of preventing defects, identifying the causes of defects, implementing corrective action to eliminate the cause, training personnel, redesigning the product or system, redesigning the process, and for the purchase of new equipment or modifications. They are the costs associated with operations or activities that keep failure from happening and minimise detection costs. Examples include product design and review, process design and review, recruitment, selection and education of staff, job design and job training, quality improvement projects, quality planning and working with suppliers.

Activity 3.9

Activity

Classify the following costs as:

- external failure costs,
- internal failure costs,
- appraisal costs, or
- prevention costs.

Example	Type of cost
A manufacturer realises there is a potential fault in their products and issues a product recall to correct it.	
Purchasing works with suppliers to ensure the required standard of raw materials are delivered.	
Testing equipment is maintained for accuracy.	
A production run produces product that does not meet specification and has to be run again.	
A customer claims a replacement product while under warranty.	
A staff training course is run to introduce new procedures.	
A sample is tested and the incorrect measurements taken, so another sample has to be tested.	
Inwards goods are inspected on arrival to ensure they meet specification.	
Reject material has to be disposed at a hazardous materials dump.	
A new product is designed so that it can easily be manufactured with current equipment.	
A customer tells a friend that they have received poor service from a firm and discourages the friend from using that service.	

A new production process is tested to ensure it is capable of meeting specification.	

Process variation

All processes have variation. Variation occurs in input variables and output variables. Also we can have controlled and uncontrolled variables in process transformation. Temperature and humidity, for example, can be controlled variables when the process is performed inside a building and they can be uncontrolled when the process is performed outside.

Common variation is one that is inherent in the process over time. Its cause is random and is the opposite of assignable variation.

Assignable variation is a shift in the output process caused by specific factors such as environmental conditions and changes in input parameters. The variation arises from external sources that are not inherent in the process, and which appear sporadically and disrupt the random pattern of common causes.

As an example, you are working in a room when the air-conditioning unit fails and the outside temperature is very hot. Quickly the temperature in the room rises to the point that it is unbearable and the occupants complain. The temperature is usually controlled by the air-conditioning unit but when the unit fails, the temperature can no longer be controlled. We can explain the reason for the temperature rise by isolating the air-conditioning unit. This is an assignable cause.

When all assignable causes are isolated they can potentially be removed to allow the process to continue with just common or normal variation.

Using the air-conditioning unit example above, when the air-conditioning unit is working as expected the temperature in the room will have slight variations as the room cools and heats up. The variation is very small and may not even be detected by the people in the room. This variation is called common or normal variation.

Process capability

Process capability is the ability of a process to produce outputs that conform to customer-defined specifications. The base starting point for process capability is ±3 standard deviations ($\pm 3\sigma$) of the process. At this point 99.73 per cent of the process output is deemed to be acceptable. A higher percentage is better; a lower percentage is not acceptable.

(This 99.73 percentage can be found in z-tables which show the area in the right-hand tail of a normal distribution. Look for the value corresponding to z = 3 and note the value = 0.00135. Alternatively, use Excel and enter =NORMDIST(1000-3,1000,1,TRUE) This use of statistics is beyond the scope of this course.)

The process variation may not fall within a range and may need to be greater than a given value or less than a given value. For example, the delivery of a parcel should be less than three days. There is no lower limit; just an upper limit of three days.

Having demonstrated that only random causes of variation are present, the next task is to compare the precision of the process with the required specification tolerances. Calculation of the process capability ratio, C_p, and the process capability index, C_{pk}, allows this to be done quickly and quantitatively.

C_p measures the spread (or variation) of the process, while C_{pk} measures the spread and positioning of the process. C_p measures the theoretical capability while C_{pk} measures the actual capability.

C_p is the process capability ratio, calculated by dividing the difference between upper tolerance limit and lower tolerance limit by six times the standard deviation of the process. C_p measures theoretical process capability.

C_{pk} is the process capability index, calculated by dividing the difference between the process mean and the nearest tolerance limit by three times the standard deviation of the process. Ideally C_{pk} should equal C_p and this occurs when the process is centred. C_{pk} measures actual process capability.

Process capability is relative to $\pm 3\sigma$ so when the numerator is greater than 3σ the C_{pk} is greater than 1. A value less than 1.00 indicates that less than 99.73 per cent of the process output is within tolerance limits.

Activity 3.10

Activity

Calculate the process capability for the following examples:

If specifications say the oven temperature must be 175 ± 5°C and the standard deviation of temperature readings is 0.9°C. Calculate C_p .

If specifications say the oven temperature must be 175 ± 5°C and the standard deviation of temperature readings is 0.9°C.

Calculate C_{pk} if currently the process mean is 177°C.

Six sigma quality

Six sigma quality is a business improvement approach that seeks to find and eliminate causes of defects and errors in manufacturing and service processes by focusing on outputs that are critical to customers and a clear financial return for the organisation. It is a business process that allows organisations to improve bottom-line performance, creating and monitoring business activities to reduce waste and resource requirements while increasing customer satisfaction.

Business strategy has for a long time been based almost entirely on financial figures. Performance measurement has been almost entirely based on financial figures in isolation. But what is the point of having a financial profit target, or a revenue target, if that target cannot physically be attained?

Six sigma quality is a proven methodology for driving and achieving transformational change within an organisation. It is a business improvement process that focuses an organisation on customer requirements, process alignment, analytical rigour and timely execution.

In its original form it concentrated on manufacturing variables, both controlled and uncontrolled, such as temperature, pressure, flow rate and time. It also improved the process output variables such as yield, waste, capacity, downtime and production rate.

This has now been extended to include non-manufacturing variables, both controlled and uncontrolled, such as communication methods, completeness, accuracy, training, inventory levels, shipping methods, promise dates, days of the week, seasons of the year and customer-required date. It improves output variables such as order correctness, delivery time and package quality.

It has its foundations in statistics – well, that is where the name comes from. Originally it was termed ± six sigma capability and it measured the variation of each process. The process had to be designed such that it was capable of producing ± six standard deviations (sigma) of the process within the customer-defined process limits.

Six sigma quality allows organisations to identify the customer requirements and to design, and subsequently modify, business processes to consistently achieve nothing less than the minimum of customer requirements. Keep the customer happy, supply them with exactly what they want and when they want it, and they will come back for more.

Design for six sigma (DFSS) is a product-development process to ensure goods and services will meet customer needs and achieve performance objectives, and that the processes used to make and deliver them achieve six sigma capabilities.

Critical to quality (CTQ) are characteristics of the product or service that must be met to satisfy the customer.

Lean six sigma, an approach that combines principles of lean thinking with six sigma quality initiatives to enhance operations performance, analyses processes and eliminates the non value-adding steps in the process.

This translates to getting rid of all the waste in a process to produce a process that is as effective as possible. Every step in the process adds value to the product or service. The lean process is then simplified and processes to improve quality further are implemented. Service organisations add more sensitivity and understanding towards customer needs.

Activity 3.11

Activity

Work through the following questions. You may need to go back and re-read the unit to help you.

1. What is quality?
2. Are the traditional costs of quality appropriate in today's business environment? Explain your response.
3. Explain process capability.
4. Explain how six sigma quality could be used by an organisation to improve its competitive position.

Unit summary

Summary

In this unit you learned to define quality and the characteristics of a total quality management programme. The four traditional categories of quality costs were discussed and a distinction made between inherent capability and the capability to meet specifications. The six sigma improvement approach was discussed and the concept of designing for six sigma was introduced.

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Readings for further study

Readings

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Assignment 2

Assignment

There are four questions in this assignment. You need to complete all four. Each question has a different value to make the assessment worth 100 marks.

Question 1 50 marks

Cole & Sons Shoemakers Co. Ltd. is a shoemaking company established by the entrepreneur, Edward Cole, in the 1950s. The company has been designing and producing leather shoes and supplying them to various retailers including specialty shoe stores and department stores throughout the country for nearly 60 years. In the early 1970s, the business went through a major change in its operations. David and John Cole, Edward's two sons, introduced changes which led the company into rapid diversification (also producing sports and leisure shoes) and growth from a localised shoe producer into a major player in the global shoe market.

However, the core vision and direction of the company has not changed. It remains a high-volume, low-customisation shoe producer whose aim is to minimise costs. Also, Edward (as an entrepreneur) always believed that if you keep a high level of inventory, you can minimise dissatisfaction from customers.

About a year ago Edward retired and David (a natural-born leader with excellent interpersonal skills) assumed the position of president, while John (skilled in operations management) remained as director of operations.

The brothers always dreamed of radically changing the company's operations style to better suit the needs for survival in today's business environment (they started by changing the name of the company into Sneakers.com). One day, John approached David and suggested the change of their operations into a lean-thinking (just-in-time production) environment.

Help John explain the theory of lean thinking to David (assuming David has no explicit knowledge on this topic) in a simple way. Enhance your explanation with an appropriate analogy or example.

Question 2 30 marks

“The only acceptable performance is zero defects.” Discuss the application of that phrase to each of the following situations:

- surgeons performing elective surgery
- builder constructing a house
- machinists fabricating automobile engines
- lawyers defending accused child molesters
- grocers stocking the supermarket deli display
- investment counsellors giving financial advice
- police officers apprehending a suspect
- Inland Revenue Department (government tax collection) recording tax payments
- merchants selling exercise equipment
- students completing an assessed assignment.

Question 3 10 marks

How do you determine quality in products?

For example, how do you distinguish a good car (or piece of furniture, garment, medicine or golf ball) from a bad one? Does the item’s price influence your thinking? What are society’s beliefs regarding a relationship between price and quality? Are these beliefs realistic?

Question 4 10 marks

How do you determine quality in services?

For example, how do you distinguish between a good lawyer (or accountant, lecturer, athlete, hairdresser or surgeon) from a bad one? Does the service price (fee charges or salary received) have any influence on your thinking? Does society pay the same attention to price when judging the quality of services as it does in the case of goods? Why or why not?

Activity feedback

Activity 3.1

Activity 3.1 required you to think of your own examples of customer types.

Activity 3.2

All answers are in the learning material.

Activity 3.3

Consider an order being received from a customer:

- Variable inputs include the method of order receipt (email, fax, postal service, telephone, sales representative, customer service representative), the completeness of the order and the accuracy of the order.
- Controlled process variables include the amount of training given to the person receiving the order, the amount of inventory on hand, the shipping methods available and the delivery date promised.
- Uncontrolled process variables include the attitude of the person taking the order, the day of the week, the season, the customer-required date, the shift and the service team.
- Process output variables include the correctness of the order, the delivery time and the package quality.

Activity 3.4

The activities in a lean environment include:

- Develop strategies for dealing with highly variable demand.
- Focus on reducing variability and reducing the impact of variability on production.
- Level the schedule for both volume and mix.
- Create a flow of products that supports the drumbeat of expected customer deliveries.
- Monitor customer order patterns and validating daily production.

- Produce to customer orders whenever possible at the exact day's mix using load-levelling techniques.
- Drive improvement activities so all processes can produce smaller quantities at shorter intervals.
- Create a true mixed-model schedule as well as more repetitive demand for components being pulled from upstream processes.

Activity 3.5

All answers are in the learning material.

Activity 3.6

With this activity you were asked to imagine yourself as part of the design team that developed mobile phones that take photographs.

The primary function of the mobile phone is to make and receive phone calls. However, with products like this, the marketing function may often try to develop a "wow" factor (this is a feature or a characteristic of the products that really catches the imagination of the customer and makes it imperative that the customer purchases the product).

This definitely happened with the camera feature on mobile phones. It is hard to say exactly what should be done first since each example may provide a different set of circumstances and thus a different end result. Definitely two things have to happen: the technology has to work and the customers have to recognise a need for the particular feature and demand the feature.

The introduction of the feature is usually in a test market or to a group of friendly customers who can provide feedback on why they like it or why they do not like it. This introduction phase also provides valuable information that the marketing function will need when the feature is launched across more markets or to more potential customers. The duration of this introduction and market testing may take several months or even years depending on how well the feature is accepted and how the technology develops.

Think of these ideas when you read the next section of the course on Kano models and voice of the customer.

Activity 3.7

1. The list of customer requirements that will form the demanded quality hierarchy for the laptop could include:
    - light weight (less than 2 kg)

- small size (fit in briefcase)
- long operation between recharging (last for one day's usage)
- large keys on keyboard (enter data with big fingers)
- short time to recharge (less than two hours)
- readable screen (even in full sunlight)
- durable (unbreakable)
- fast processor/large memory capacity.

2. The list of the quality characteristics that constitute the technical response to the demanded quality might include:

   - case material
   - battery type and size
   - screen size and type
   - RAM memory
   - hard drive type and size
   - keyboard type and size.

3. Prepare the relationships matrix relating the demanded quality hierarchy with the quality characteristics hierarchy. At the intersection between each entry in the demanded quality hierarchy and each entry in the quality characteristics we have entered a Y for "yes", an N for "no", an S for "somewhat" and we have not used "mostly". In cases where the relationship does not exist we have left blank.

	Quality characteristics					
Demanded quality hierarchy	**Case material**	**Battery/type/size**	**Screen type/size**	**RAM memory**	**Hard drive type/size**	**Keyboard type/size**
Light weight	Y	N	Y	Y	Y	Y
Small size (fit in briefcase)	Y	N	S		Y	Y
Long operation between recharging		Y				
Large keys on keyboard						Y
Short time to recharge		N				
Readable screen			S			
Durable (unbreakable)	Y		Y		Y	Y
Fast processor/large memory capacity				Y	Y	

4. Develop the quality planning table or competitive assessment which provides a qualitative benchmark comparison with other products, other solutions and other methods. Two competitive products are marked A and B and your product is marked X. For each demanded quality characteristic, the three products are ranked by how well they answer the customer need. (Note, this

is purely hypothetical since you do not have the details of the competing products.) A joining line is created to show your product X.

Quality characteristics

Demanded quality hierarchy	Case material	Battery/type/size	Screen type/size	RAM memory	Hard drive type/size	Keyboard type/size	
Light weight	Y	N	Y	Y	Y	Y	A X B
Small size (fit in briefcase)	Y	N	S		Y	Y	A X B
Long operation between recharging		Y					X A B
Large keys on keyboard						Y	B A X
Short time to recharge		N					B A X
Readable screen			S				X B A
Durable (unbreakable)	Y		Y		Y	Y	B A X
Fast processor/large memory capacity				Y	Y		A B X

5. The design planning table will have the target values that the design team is trying to reach and this is written in the basement part of the house. We have not included these values since this requires technical computer design skills
6. Finally, the correlation of technical requirements to support or impede product design does not, in this case, suggest any negative correlation.

Activity 3.8

1. How is the problem of technology choice related to process selection and product design?

   Technology choice has a significant effect on process selection and product design. Technology choice is sometimes called manufacturing geometry and, in simple terms, means the combination and sequencing of production machines and the labour requirements to make it all happen.

   So, if we have a fully automated line with robotic machines, the product has to be capable of being made and assembled using automated lines and robots.

   If the product is to be produced using human labour with little or no automation, the process design has to be designed so as to minimise the labour effort.

   Technology choice decision is usually made first, followed by process selection and product design. Simultaneous engineering (or concurrent engineering) is the term applied to the simultaneous design of process and product.

2. How much detailed technical knowledge on the part of managers is required to make a decision regarding selection of computer hardware?

   Strict technical knowledge is not required, but the manager needs to ask questions and be assured that the answers are satisfactory. Often with technical products (such as computers) managers are afraid to ask questions because it makes them look stupid. The reality is that managers should ask all the questions and insist on satisfactory answers.

3. Suppose you need to select a computer terminal to use in your office. What performance characteristics of the technology would you assess? How would you get the necessary information to make the decision?

   For an exercise like this you should develop a checklist and make sure the essential items on that list are being addressed. If you have used a computer terminal before you probably have some idea of the requirements. If not, you should check with people who have used a computer terminal in similar circumstances to your planned usage.

   Typical characteristics relate to hardware properties and software capability, the type of technology proposed and technical issues such as screen clarity, definition, colours, reliability, service and so on.

4. What is the main obstacle to using a manufacturing approach to the delivery of services?

   In most cases in this course we have not made a distinction between manufacturing and services because the general principles of operations management can be applied to both. With manufacturing, the output is usually tangible, the customer is not present during production, the product is produced and then consumed and any errors can be corrected before the customer is aware an error has occurred. The opposite applies to services because the output is usually not tangible, the customer is often present during the production phase, the product is often produced and consumed simultaneously and the customer is present when errors occur.

Activity 3.9

Example	Type of cost
A manufacturer realises that there is a potential fault in their products and issues a product recall to correct it.	External failure cost.
Purchasing works with suppliers to ensure the required standard of raw materials are delivered.	Prevention cost.
Testing equipment is maintained for accuracy.	Appraisal cost.
A production run produces product that does not meet specification and has to be run again.	Internal failure cost.
A customer claims a replacement product while under warranty.	External failure cost.
A staff training course is run to introduce new procedures.	Prevention cost.
A sample is tested and the incorrect measurements taken, so another sample has to be tested.	Internal failure cost.
Inwards goods are inspected on arrival to ensure they meet specification.	Appraisal cost.
Reject material has to be disposed at a hazardous materials dump.	Internal failure cost.
A new product is designed so that it can easily be manufactured with current equipment.	Prevention cost.
A customer tells a friend they have received poor service from a firm and discourages the friend from using that service.	External failure cost.
A new production process is tested to ensure it is capable of meeting specification.	Appraisal cost.

Activity 3.10

$$C_p = \frac{\text{Upper Tolerance Limit} - \text{Lower Tolerance Limit}}{6\sigma}$$
$$= \frac{(175 + 5) - (175 - 5)}{6 \text{ x } 0.9}$$
$$= \frac{180 - 170}{5.4}$$
$$= 1.85$$

The closest tolerance limit in this example is the upper tolerance limit (175 + 5 = 180)

$$C_{pk} = \frac{\text{Upper Tolerance Limit} - \text{the current process mean}}{6\sigma}$$
$$= \frac{(175 + 5) - 177}{3 \text{ x } 0.9}$$
$$= \frac{3}{5.4}$$
$$= 0.56$$

Activity 3.11

All answers are in the learning material.