Chalimbana University

Integrity. Service. Excellence

DIRECTORATE OF DISTANCE EDUCATION

PRODUCTION & OPERATIONS MANAGEMENT

First Edition 2020

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MODULE OVERVIEW

Pre-requisite: None

Introduction

Just imagine a world where nothing was delivered or transported between places. Not only is logistics vitally important to the distribution industry, it has made distribution prompt and efficient. Many companies rely on transport and logistics to keep their business strong. Transport and Logistics is an important part of the supply chain, it controls the effective forward and reverse flow of goods and services from the origin to the recipient. This means that logistics has an impact on the shipment of goods and how quickly they can get to the consumer, again adding a competitive edge to other businesses. This means that it helps in economic transactions, serving as a major enabler of growth of trade and commerce in an economy.

Welcome to the course 'introduction to Production and Operations Management.

Rationale of the study

This course provides an overview of how Companies use distribution intermediaries to gain a competitive advantage in local and global markets through the integration of logistics and transport management. The management of the physical flow of products and information throughout the entire supply chain is examined, including physical distribution, transportation, warehousing, customer service, materials management, third-party and global logistics, systems planning, and operations and management of the supply chain.

Aim

The aim of this course is to gain the knowledge of possibilities of efficient optimization and management of operation in logistics and transport management and also the ability to apply them in the company reality.

Learning Outcome

At the end of this course, learners should be able to:

- To gain a working understanding of logistics principles and to expose students to the language of logistics.

- To provide an overview of the key activities performed by the logistics including transport function, distribution, global logistics and inventory control, Different mode of transport.
- To view transport and logistics as more than an operational function that passively executes a plan, but as a strategic function that creates value and competitive advantage.
- To combine the theoretical knowledge with practical knowledge

Summary

The module looks at Transport and Logistics Management

Study Skills

As an adult learner, your approach to learning will be different to that of your school days: you will choose when you want to study, you will have professional and/or personal motivation for doing so and you will most likely be fitting your study activities around other professional or domestic responsibilities.

Essentially you will be taking control of your learning environment. As a consequence, you will need to consider performance issues related to time management, goal setting, stress management, etc. Perhaps you will also need to acquaint yourself with areas such as essay planning, searching for information, writing, coping with examinations and using the internet as a learning resource.

Your most significant considerations will be *time* and *space* i.e. the time you dedicate to your learning and the environment in which you engage in that learning.

It is recommended that you take time now before starting your self-study to familiarise yourself with these issues. There are a number of excellent resources on the web. A few suggested links are:

http://www.how-to-study.com/

The “How to study” website is dedicated to study skills resources. You will find links to study preparation (a list of nine essentials for a good study place), taking notes, strategies for reading text books, using reference sources, test anxiety.

http://www.ucc.vt.edu/stdysk/stdyhlp.html

This is the website of the Virginia Tech, Division of Student Affairs. You will find links to time scheduling (including a "where does time go?" link), a study skill checklist, basic concentration techniques, control of the study environment, note taking, how to read essays for analysis, memory skills ("remembering").

Timeframe

You are expected to spend at least 18 hours of study time on this module. In addition, there shall be arranged contact sessions with lecturers from the University during residential possibly in April, August and December. You are requested to spend your time judiciously so that you reap maximum benefit from the course.

Need Help?

In case you have difficulties during the duration of the course, please get in touch with your lecturer for routine enquiries during working days **(Monday-Friday)** from 08:00 to 17:00 hours on Cell: +260977308107**; E-mail: h_mutale@yahoo.ca ; website: www.chau.ac.zm.**You can also see your lecturer at the office during working hours as stated above.

You are free to utilise the services of the University Library which opens from 07:00 hours to 20:00 hours every working day.

It will be important for you to carry your student identity card for you to access the library and let alone borrow books.

FURTHER READING

Chase, Richard, (2016). Production and Operations Management: Manufacturing and Services (The Irwin/McGraw Hill series) 8th Edition. Krajewski, L.J & Larry P. Ritzman, L.P. & Malhotra, M.K. (2016). Operations Management: Processes and Supply Chains, 10th Ed. Pearson. Liker, J. (2004). The 14 Principles of the Toyota Way, Ann Arbor, Michigan: University of Michigan. Naugton, Sean, (2002), Operations Management: in a Week, Chartered Management Institute. Oliver, Peter, (2016) Operations Management, Concise Books.

List of Equipment

In this module you will need the following tools;

Note books

Assessment

In this course you will be assessed on the basis of your performance as follows:

Continuous Assessment		**50%**
Assignment	10%	
Project	15%	
2 Tests of equal weight	25%	
Final Examination		**50%**
Total		**100%**

UNIT 1

INTRODUCTION TO PRODUCTION AND OPERATION MANAGEMENT

OBJECTIVES:

1. To consider and discuss the Historical evolution of production and Operations Management
2. Justify the nature and meaning of; Concept of production, production system; production management; operating system and operations management. And operations management.
3. To examine how to manage global operations and the scope of production

1.1 INTRODUCTION

Production/operations management is the process, which combines and transforms various resources used in the production/operations subsystem of the organization into value added product/services in a controlled manner as per the policies of the organization. Therefore, it is that part of an organization, which is concerned with the transformation of a range of inputs into the required (products/services) having the requisite quality level.

The set of interrelated management activities, which are involved in manufacturing certain products, is called as production management. If the same concept is extended to services management, then the corresponding set of management activities is called as operations management.

1.2 HISTORICAL EVOLUTION OF PRODUCTION AND OPERATIONS MANAGEMENT

For over two centuries operations and production management has been recognised as an important factor in a country‘s economic growth.

The traditional view of manufacturing management began in eighteenth century when Adam Smith recognised the economic benefits of specialisation of labour. He recommended breaking of jobs down into subtasks and recognises workers to specialised tasks in which they would become highly skilled and efficient. In the early twentieth century, F.W. Taylor implemented Smith‘s theories and developed scientific management. From then till 1930, many techniques were developed prevailing the traditional view.

Production management becomes the acceptable term from 1930s to 1950s. As F.W. Taylor‘s works become more widely known, managers developed techniques that focused on economic efficiency in manufacturing. Workers were studied in great detail to eliminate wasteful efforts and achieve greater efficiency. At the same time, psychologists, socialists and other social scientists began to study people and human behaviour in the working environment. In addition, economists, mathematicians, and computer socialists contributed newer, more sophisticated analytical approaches.

With the 1970s emerges two distinct changes in our views. The most obvious of these, reflected in the new name operations management was a shift in the service and manufacturing sectors of the economy. As service sector became more prominent, the change from '**production'** to '**operations** 'emphasized the broadening of our field to service organizations. The second, more suitable change was the beginning of an emphasis on synthesis, rather than just analysis, in management practices.

1.3 CONCEPT OF PRODUCTION

Production function is that part of an organization, which is concerned with the transformation of a range of inputs into the required outputs (products) having the requisite quality level. Production is defined as "the step-by-step conversion of one form of material into another form through chemical or mechanical process to create or enhance the utility of the product to the user." Thus production is a value addition process. At each stage of processing, there will be value addition.

Edwood Buffa defines production as 'a process by which goods and services are created. Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers, etc., and manufacturing standardized products like, car, bus, motor cycle, radio, television, etc.

1.4 PRODUCTION SYSTEM

The production system of an organization is that part, which produces products of an organization. It is that activity whereby resources, flowing within a defined system, are combined and transformed in a controlled manner to add value in accordance with the policies communicated by management. A simplified production system is shown above.

The production system has the following characteristics: **1)** Production is an organized activity, so every production system has an objective**. 2)** The system transforms the various inputs to useful outputs**. 3)** It does not operate in isolation from the other organization system**. 4)** There exists a feedback about the activities, which is essential to control and improve system performance.

Classification of Production System

Production systems can be classified as

1. Job Shop;

2. Batch;

3. Mass and

4. Continuous Production systems.

1. JOB SHOP PRODUCTION Job shop production are characterised by manufacturing of one or few quantity of products designed and produced as per the specification of customers within prefixed time and cost. The distinguishing feature of this is low volume and high variety of products.

A job shop comprises of general purpose machines arranged into different departments. Each job demands unique technological requirements, demands processing on machines in a certain sequence.

Characteristics;

The Job-shop production system is followed when there is**: 1)** High variety of products and low volume. **2)** Use of general purpose machines and facilities. **3)** Highly skilled operators who can take up each job as a challenge because of uniqueness**. 4)** Large inventory of materials, tools, parts. **5)** Detailed planning is essential for sequencing the requirements of each product, capacities for each work centre and order priorities.

Advantages;

Following are the advantages of job shop production**: 1)** Because of general purpose machines and facilities variety of products can be produced. **2)** Operators will become more skilled and competent, as each job gives them learning opportunities**. 3)** Full potential of operators can be utilised. **4)** Opportunity exists for creative methods and innovative ideas.

Limitations Following are the limitations of job shop production: **1)** Higher cost due to frequent set up changes. **2)** Higher level of inventory at all levels and hence higher inventory cost. **3)** Production planning is complicated. **4)** Larger space requirements.

2. **BATCH PRODUCTION** Batch production is defined by American Production and Inventory Control Society (APICS) "as a form of manufacturing in which the job passes through the functional departments in lots or batches and each lot may have a different routing." It is characterised by the manufacture of limited number of products produced at regular intervals and stocked awaiting sales.

Characteristics

Batch production system is used under the following circumstances**: 1)** when there is shorter production runs**. 2)** When plant and machinery are flexible. **3)** When plant and machinery set up is used for the production of item in a batch and change of set up is required for processing the next batch**. 4)** When manufacturing lead time and cost are lower as compared to job order production.

Advantages

Following are the advantages of batch production**: 1)** Better utilisation of plant and machinery**. 2)** Promotes functional specialisation. **3)** Cost per unit is lower as compared to job order production**. 4)** Lower investment in plant and machinery. **5**) Flexibility to accommodate and process number of products**. 6)** Job satisfaction exists for operators. Limitations Following are the limitations of batch production: **1)** Material handling is complex because of irregular and longer flows**. 2)** Production planning and control is complex. **3)** Work in process inventory is higher compared to continuous **production. 4)** Higher set up costs due to frequent changes in set up.

3. MASS PRODUCTION Manufacture of discrete parts or assemblies using a continuous process are called mass production. This production system is justified by very large volume of production. The machines are arranged in a line or product layout. Product and process standardisation exists and all outputs follow the same path.

Characteristics

Mass production is used under the following circumstances:

1) Standardisation of product and process sequence. **2) Dedicated** special purpose machines having higher production capacities and output rates**. 3) Large** volume of products**. 4) Shorter** cycle time of production**. 5) Lower** in process inventory. **6) Perfectly** balanced production lines. **7) Flow** of materials, components and parts is continuous and without any back tracking. **8) Production** planning and control is easy. **9) Material** handling can be completely automatic.

Advantages;

Following are the advantages of mass production: **1)** Higher rate of production with reduced cycle time. **2) Higher** capacity utilisation due to line balancing**. 3) Less** skilled operators are required. 4) Low process inventory**. 5) Manufacturing** cost per unit is low.

Limitations

Following are the limitations of mass production**: 1)** Breakdown of one machine will stop an entire production line**. 2)** Line layout needs major change with the changes in the product design. **3)** High investment in production facilities. **4)** The cycle time is determined by the slowest operation.

4. **CONTINUOUS PRODUCTION**

Production facilities are arranged as per the sequence of production operations from the first operations to the finished product. The items are made to flow through the sequence of operations through material handling devices such as conveyors, transfer devices, etc.

Characteristics;

Continuous production is used under the following circumstances: **1)** Dedicated plant and equipment with zero flexibility. **2)** Material handling is fully automated**. 3)** Process follows a predetermined sequence of operations**. 4)** Component materials cannot be readily identified with final product. **5)** Planning and scheduling is a routine action.

Advantages;

Following are the advantages of continuous production: **1)** Standardisation of product and process sequence**. 2)** Higher rate of production with reduced cycle time. **3)** Higher capacity utilisation due to line balancing. **4)** Manpower is not required for material handling as it is completely automatic**. 5)** Person with limited skills can be used on the production line**. 6)** Unit cost is lower due to high volume of production.

Limitations

Following are the limitations of continuous production: 1) Flexibility to accommodate and process number of products does not exist. 2) Very high investment for setting flow lines. 3) Product differentiation is limited.

1.5 PRODUCTION MANAGEMENT

Production management is a process of planning, organizing, directing and controlling the activities of the production function. It combines and transforms various resources used in the production subsystem of the organization into value added product in a controlled manner as per the policies of the organization.

Objectives of Production Management;

The objective of the production management is 'to produce goods/ services of right quality and quantity at the right time and right manufacturing cost'.

i) RIGHT QUALITY

The quality of product is established based upon the customers' needs. The right quality is not necessarily best quality. It is determined by the cost of the product and the technical characteristics as suited to the specific requirements.

ii) RIGHT QUANTITY;

The manufacturing organization should produce the products in right number. If they are produced in excess of demand the capital will block up in the form of inventory and if the quantity is produced in short of demand, leads to shortage of products.

iii) **RIGHT TIME**

Timeliness of delivery is one of the important parameter to judge the effectiveness of production department. So, the production department has to make the optimal utilization of input resources to achieve its objective.

5. RIGHT MANUFACTURING COST

Manufacturing costs are established before the product is actually manufactured. Hence, all attempts should be made to produce the products at pre-established cost, so as to reduce the variation between actual and the standard (pre-established) cost.

1.6 OPERATING SYSTEM

Operating system converts inputs in order to provide outputs which are required by a customer. It converts physical resources into outputs, the function of which is to satisfy customer wants i.e., to provide some utility for the customer. In some of the organization the product is a physical good (hotels) while in others it is a service (hospitals). Bus and taxi services, tailors, hospital and builders are the examples of an operating system.

Concept of Operations.

An operation is defined in terms of the mission it serves for the organization, technology it employs and the human and managerial processes it involves. Operations in an organization can be categorized into manufacturing operations and service operations. Manufacturing operations is a conversion process that includes manufacturing yields a tangible output: a product, whereas, a conversion process that includes service yields an intangible output: a deed, a performance, an effort.

Distinction between Manufacturing Operations and Service Operations;

Following characteristics can be considered for distinguishing manufacturing operations with service operations:

1. Tangible/Intangible nature of
2. **.** Consumption of output
3. **.** Nature of work (job**)**
4. Degree of customer contact
5. Customer participation in conversion
6. **.** Measurement of performance.

Manufacturing is characterised by tangible outputs (products), outputs that customers consume overtime, jobs that use less labour and more equipment, little customer contact, no customer participation in the conversion process (in production), and sophisticated methods for measuring production activities and resource consumption as product are made.

Service is characterised by intangible outputs, outputs that customers consumes immediately, jobs that use more labour and less equipment, direct consumer contact, frequent customer participation in the conversion process, and elementary methods for measuring conversion activities and resource consumption. Some services are equipment based namely rail-road services, telephone services and some are people based namely tax consultant services, hair styling.

1.7 OPERATIONS MANAGEMENT

A Framework for Managing Operations Operation managers are concerned with planning, organizing, and controlling the activities which affect human behaviour through models.

PLANNING

Activities that establishes a course of action and guide future decision-making is planning. The operations manager defines the objectives for the operations subsystem of the organization, and the policies, and procedures for achieving the objectives. This stage includes clarifying the role and focus of operations in the organization‘s overall strategy. It also involves product planning, facility designing and using the conversion process.

ORGANIZING

Activities that establishes a structure of tasks and authority. Operation managers establish a structure of roles and the flow of information within the operations subsystem. They determine the activities required to achieve the goals and assign authority and responsibility for carrying them out.

CONTROLLING

Activities that assure the actual performance in accordance with planned performance. To ensure that the plans for the operations subsystems are accomplished, the operations manager must exercise control by measuring actual outputs and comparing them to planned operations management. Controlling costs, quality, and schedules are the important functions here.

BEHAVIOUR

Operation managers are concerned with how their efforts to plan, organize, and control affect human behaviour. They also want to know how the behaviour of subordinates can affect management‘s planning, organizing, and controlling actions. Their interest lies in decision-making behaviour.

MODELS

As operation managers plan, organise, and control the conversion process, they encounter many problems and must make many decisions. They can simplify their difficulties using models like aggregate planning models for examining how best to use existing capacity in short-term, break even analysis to identify break even volumes, linear programming and computer simulation for capacity utilisation, decision tree analysis for long-term capacity problem of facility expansion, simple median model for determining best locations of facilities etc.

Objectives of Operations Management

Objectives of operations management can be categorised into customer service and resource utilisation.

CUSTOMER SERVICE

The first objective of operating systems is the customer service to the satisfaction of customer wants. Therefore, customer service is a key objective of operations management. The operating system must provide something to a specification which can satisfy the customer in terms of cost and timing. Thus, primary objective can be satisfied by providing the ‘right thing at a right price at the right time‘.

Generally an organization will aim reliably and consistently to achieve certain standards and operations manager will be influential in attempting to achieve these standards. Hence, this objective will influence the operations manager‘s decisions to achieve the required customer service.

RESOURCE UTILISATION

Another major objective of operating systems is to utilise resources for the satisfaction of customer wants effectively, i.e., customer service must be provided with the achievement of effective operations through efficient use of resources. Inefficient use of resources or inadequate customer service leads to commercial failure of an operating system.

Operations management is concerned essentially with the utilisation of resources, i.e., obtaining maximum effect from resources or minimising their loss, underutilisation or waste. The extent of the utilisation of the resources‘ potential might be expressed in terms of the proportion of available time used or occupied, space utilisation, levels of activity, etc. Each measure indicates the extent to which the potential or capacity of such resources is utilised. This is referred as the objective of resource utilisation.

Operations management is also **concerned** with the achievement of both satisfactory customer service and resource utilisation. An improvement in one will often give rise to deterioration in the other. Often both cannot be maximised, and hence a satisfactory performance must be achieved on both objectives. All the activities of operations management must be tackled with these two objectives in mind, and many of the problems will be faced by operations managers because of this conflict. Hence, operations managers must attempt to balance these basic objectives.

1.8 MANAGING GLOBAL OPERATIONS

The term '**globalization**' describes businesses' **deploymen**t of facilities and operations around the world. Globalization can be defined as a process in which geographic distance becomes a factor of diminishing importance in the establishment and maintenance of cross border economic, political and socio-cultural relations. It can also be defined as worldwide drive toward a globalized economic system dominated by supranational corporate trade and banking institutions that are not accountable to democratic processes or national governments.

There are four developments, which have spurred the trend toward globalization.

These are: **1.** Improved transportation and communication technologies**; 2.** Opened financial systems; **3.** Increased demand for imports; and **4.** Reduced import quotas and other trade barriers.

When a firm sets up facilities abroad it involve some added complexities in its operation. Global markets impose new standards on quality and time. Managers should not think about domestic markets first and then global markets later, rather it could be think globally and act locally. Also, they must have a good understanding of their competitors. Some other important challenges of managing multinational operations include other languages and customs, different management style, unfamiliar laws and regulations, and different costs.

Managing global operations would focus on the following key **issues:**

- To acquire and properly utilize the following concepts and those related to global operations, supply chain, logistics, etc.
- To associate global historical events to key drivers in global operations from different perspectives. To develop criteria for conceptualization and evaluation of different global operations.
- To associate success and failure cases of global operations to political, social, economic and technological environments.
- To envision trends in global operations.
- To develop an understanding of the world vision regardless of their country of origin, residence or studies in a respectful way of perspectives of people from different races, studies, preferences, religion, politic affiliation, place of origin, etc.

1.9 SCOPE OF PRODUCTION AND OPERATIONS MANAGEMENT

Production and operations management concern with the conversion of inputs into outputs, using physical resources, so as to provide the desired utilities to the customer while meeting the other organizational objectives of effectiveness, efficiency and adoptability. It distinguishes itself from other functions such as **personnel**, **marketing, finance**, etc., by its primary concern for 'conversion by using physical resources. '

Following are the activities which are listed under production and operations management functions:

1. Location of facilities

2. Plant layouts and material handling

3. Product design

4. Process design

5. Production and planning control

6. Quality control

7. Materials management

8. Maintenance management.

LOCATION OF FACILITIES

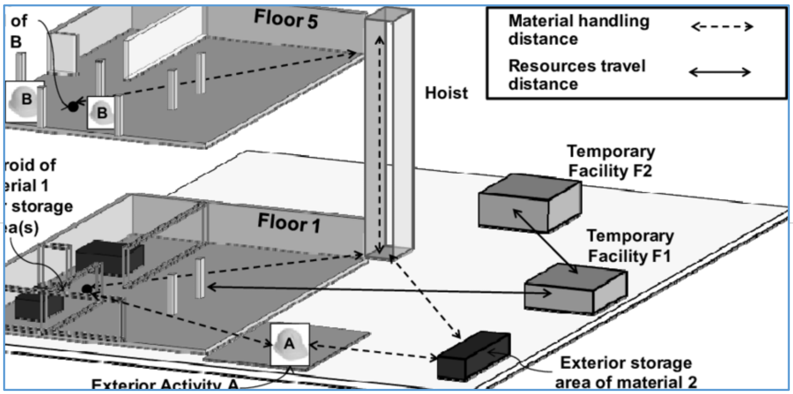
Location of facilities for operations is a long-term capacity decision which involves a long term commitment about the geographically static factors that affect a business organization. It is an important strategic level decision-making for an organization. It deals with the questions such as 'where our main operations should be based? '

The selection of location is a key-decision as large investment is made in building plant and machinery. An improper location of plant may lead to waste of all the investments made in plant and machinery equipment. Hence, location of plant should be based on the company's expansion plan and policy, diversification plan for the products, changing sources of raw materials and many other factors. The purpose of the location study is to find the optimal location that will results in the greatest advantage to the organization.

PLANT LAYOUT AND MATERIAL HANDLING

Plant layout refers to the physical arrangement of facilities. It is the configuration of departments, work centres and equipment in the conversion process. The overall objective of the plant layout is to design a physical arrangement that meets the required output quality and quantity most economically.

Material Handling



‘Refers to the ‘moving of materials from the store room to the machine and from one machine to the next during the process of manufacture‘. It is also defined as the ‘art and science of moving, packing and storing of products in any form‘. It is a specialized activity for a modern manufacturing concern, with 50 to 75% of the cost of production. This cost can be reduced by proper section, operation and maintenance of material handling devices. Material handling devices increases the output, improves quality, speeds up the deliveries and decreases the cost of production. Hence, material handling is a prime consideration in the designing new plant and several existing plants.

PRODUCT DESIGN

Product design deals with conversion of ideas into reality. Every business organization have to design, develop and introduce new products as a survival and growth strategy. Developing the new products and launching them in the market is the biggest challenge faced by the organizations.

The entire process of need identification to physical manufactures of product involves three functions:

(i) marketing,
(ii) **(ii)** product development, and
(iii) **(iii)** Manufacturing. Product development translates the needs of customers given by marketing into technical specifications and designing the various features into the product to these specifications.

Manufacturing has the responsibility of selecting the processes by which the product can be manufactured. Product design and development provides link between marketing, customer needs and expectations and the activities required to manufacture the product.

PROCESS DESIGN

Process design is a macroscopic decision-making of an overall process route for converting the raw material into finished goods. These decisions encompass the selection of a process, choice of technology, process flow analysis and layout of the facilities. Hence, the important decisions in process design are to analyse the workflow for converting raw material into finished product and to select the workstation for each included in the workflow.

PRODUCTION PLANNING AND CONTROL

Production planning and control can be defined as the process of planning the production in advance, setting the exact route of each item, fixing the starting and finishing dates for each item, to give production orders to shops and to follow up the progress of products according to orders.

The principle of production planning and control lies in the statement ‘**First Plan** Your Work and then **Work on** Your Plan‘. Main functions of production planning and control includes planning, routing, scheduling, dispatching and follow-up. **Planning** is deciding in advance what to do, how to do it, when to do it and who is to do it. Planning bridges the gap from where we are, to where we want to go. It makes it possible for things to occur which would not otherwise happen.

Routing may be defined as the selection of path which each part of the product will follow, when being transformed from raw material to finished products**. Routing** determines the most advantageous path to be followed from department to department and machine to machine till raw material gets its final shape.

Scheduling determines the programme for the operations. Scheduling may be defined as 'the fixation of time and date for each operation 'as well as it determines the sequence of operations to be followed.

Dispatching is concerned with the starting the processes. It gives necessary authority so as to start a particular work, which has already been planned under '**Routing' and 'Scheduling**'. Therefore, dispatching is 'release of orders and instruction for the starting of production for any item in acceptance with the route sheet and schedule charts'.

The function of follow-up is to report daily the progress of work in each shop in a prescribed proforma and to investigate the causes of deviations from the planned performance.

QUALITY CONTROL

Quality Control (QC) may be defined as 'a system that is used to maintain a desired level of quality in a product or service'. It is a **systematic** control of various factors that affect the quality of the product. Quality control aims at prevention of defects at the source, relies on effective feedback system and corrective action procedure.

Quality control can also be defined as 'that industrial management technique by means of which product of uniform acceptable quality is manufactured'. It is the entire collection of activities which ensures that the operation will produce the optimum quality products at minimum cost.

The main objectives of quality control are**:**

To improve the company's income by making the production more acceptable to the customers i.e., by providing long life, greater usefulness, maintainability.

To reduce companies cost through reduction of losses due to defects.

To achieve interchange ability of manufacture in large scale production.

To produce optimal quality at reduced price.

To ensure satisfaction of customers with productions or services or high quality level, to build customer goodwill, confidence and reputation of manufacturer.

To make inspection prompt to ensure quality control.

To check the variation during manufacturing.

MATERIALS MANAGEMENT

Materials management is that aspect of management function which is primarily concerned with the acquisition, control and use of materials needed and flow of goods and services connected with the production process having some predetermined objectives in view.

The main objectives of materials management are:

To minimise material cost.

To purchase, receive, transport and store materials efficiently and to reduce the related cost.

To cut down costs through simplification, standardisation, value analysis, import substitution, etc. To trace new sources of supply and to develop cordial relations with them in order to ensure continuous supply at reasonable rates.

To reduce investment tied in the inventories for use in other productive purposes and to develop high inventory turnover ratios.

MAINTENANCE MANAGEMENT

In modern industry, equipment and machinery are a very important part of the total productive effort. Therefore, their idleness or downtime becomes are very expensive. Hence, it is very important that the plant machinery should be properly maintained. The main objectives of maintenance management are:

1. To achieve minimum breakdown and to keep the plant in good working condition at the lowest possible cost.

2. To keep the machines and other facilities in such a condition that permits them to be used at their optimal capacity without interruption.

3. To ensure the availability of the machines, buildings and services required by other sections of the factory for the performance of their functions at optimal return on investment.

UNIT 2

PRODUCT LIFE CYCLE MANAGEMENT

Introduction

This second unit seeks to bring out the understanding of the life cycle of product management, with the stages that products go through in their development.

OBJECTIVES

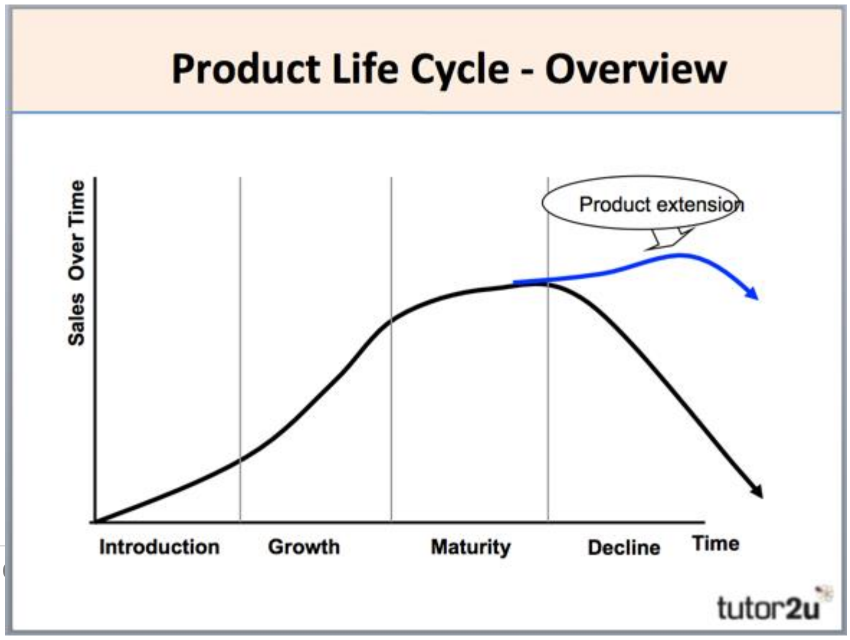
1. Explain factors that are entailed in the setting out to create new products or improve the existing ones.
2. Considering the importance of flexible product development
3. Justify the succession of strategies used by management as a product is going through its product life cycle.

2.1 PRODUCT LIFE CYCLE

The product life cycle goes through many phases, involves many professional disciplines, and requires many skills, tools and processes. Product life cycle **(PLC)** has to do with the life of a product in the market with respect to business/commercial costs and sales measures; whereas product lifecycle management **(PLM)** has more to do with managing descriptions and properties of a product through its development and useful life, mainly from a business/engineering point of view. To say that a product has a life cycle is to assert four things:

1) That products have a limited life,

2) Product sales pass through distinct stages, each posing different challenges, opportunities, and problems to the seller,



3) Profits rise and fall at different stages of product life cycle, and

4) Products require different marketing, financial, manufacturing, purchasing, and human resource strategies in each life cycle stage.

The different stages in a product life cycle are:

Market Introduction stage

- Cost high
- Sales volume low
- No/little competition - competitive manufacturers watch for acceptance/segment growth losses
- demand has to be created
- customers have to be prompted to try the product
- Growth stage
- costs reduced due to economies of scale and
- sales volume increases significantly
- profitability
- public awareness
- competition begins to increase with a few new players in establishing market
- prices to maximize market share

Mature Stage

- Costs are very low as you are well established in market & no need for publicity.
- sales volume peaks
- increase in competitive offerings
- prices tend to drop due to the proliferation of competing products
- brand differentiation, feature diversification, as each player seeks to differentiate from competition with ―how much product‖ is offered
- Industrial profits go down
- Saturation and decline stage
- costs become counter-optimal
- sales volume decline or stabilize
- prices, profitability diminish
- profit becomes more a challenge of production/distribution efficiency than increased sales

2.2 MARKET IDENTIFICATION

A ―micro-market can be used to describe a Walkman, more portable, as well as individually and privately recordable; and then Compact Discs (―CDs) brought increased capacity and CD-R offered individual private recording...and so the process goes. Technology lifecycle is a most appropriate concept in this context.

In short, termination is not always the end of the cycle; it can be the end of a micro entrant within the grander scope of a macro-environment. The auto industry, fast-food industry, petro-chemical industry, are just a few that demonstrate a macro environment that overall has not terminated even while micro-entrants over time have come and gone.

2.3 LESSONS OF THE PRODUCT LIFE CYCLE (PLC)

It is claimed that every product has a life cycle. It is launched; it grows, and at some point, may die. A fair comment is that - at least in the short term - not all products or services die. Jeans may die, but clothes probably will not. Legal services or medical services may die, but depending on the social and political climate, probably will not.

Even though its validity is questionable, it can offer a useful **'model'** for managers to keep at the back of their mind. Indeed, if their products are in the introductory or growth phases, or in that of decline, it perhaps should be at the front of their mind; for the predominant features of these phases may be those revolving around such life and death. Between these two extremes, it is salutary for them to have that vision of mortality in front of them.

However, the most important aspect of product life-cycles is that, even under normal conditions, to all practical intents and purposes they often do not exist (hence, there needs to be more emphasis on model/reality mappings). In most markets the majority of the major brands have held their position for at least two decades. The dominant product life-cycle, that of the brand leaders which almost monopolize many markets, is therefore one of continuity.

In the **criticism** of the product life cycle, **Dhalla & Yuspeh** state: ...clearly, that **PLC** is a dependent variable which is determined by market actions; it is not an independent variable to which companies should adapt their marketing programmes. **Marketing** management itself can alter the shape and duration of a brand's life cycle. Thus, the life cycle may be useful as a description, but not as a predictor; and usually should be firmly under the control of the marketer. The important point is that in many markets the product or brand life cycle is significantly longer than the planning cycle of the organisations involved. Thus, it offers little practical value for most marketers. Even if the PLC (and the **related PLM** support) exists for them, their plans will be based just upon that piece of the curve where they currently reside (most probably in the 'mature' stage); and their view of that part of it will almost certainly be 'linear' (and limited), and will not encompass the whole range from growth to decline.

2.4 NEW PRODUCT DEVELOPMENT

In business and engineering, new product development **(NPD)** is the term used to describe the complete process of bringing a new product or service to market. There are two parallel paths involved in the **NPD** process: one involves the idea generation, product design, and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

2.5 TYPES OF NEW PRODUCTS

There are several general categories of new products. Some are new to the market (ex. DVD players into the home movie market), some are new to the company (ex. Game consoles for Sony), and some are completely novel and create totally new markets (ex. the airline industry). When viewed against a different criterion, some new product concepts are merely minor modifications of existing products while some are completely innovative to the company.

- ✓ Changes to Augmented Product

- ✓ Core product revision
- ✓ Line extensions
- ✓ New product lines
- ✓ Repositioning's
- ✓ Completely new

2.6 THE PROCESS

- **Idea Generation** is often called the ―fuzzy front end of the **NPD** process. Ideas for new products can be obtained from basic research using a SWOT analysis (OPPORTUNITY ANALYSIS), Market and consumer trends, company's R&D department, competitors, focus groups, employees, salespeople, corporate spies, trade shows, or Ethnographic discovery methods (searching for user patterns and habits) may also be used to get an insight into new product lines or product features. Idea Generation or Brainstorming of new product, service, or store concepts - idea generation techniques can begin when you have done your **OPPORTUNITY ANALYSIS** to support your ideas in the Idea Screening Phase. (In the next development steps);

Idea Screening

- The object is to eliminate unsound concepts prior to devoting resources to them.
- The screeners must ask at least three questions:
- Will the customer in the target market benefit from the product?
- What is the size and growth forecasts of the market segment/target market?
- What is the current or expected competitive pressure for the product idea?
- What are the industry sales and market trends the product idea is based on?
- Is it technically feasible to manufacture the product?
- Will the product be profitable when manufactured and delivered to the customer at the target price?

Concept Development and Testing

- Develop the marketing and engineering details
- Who is the target market and who is the decision maker in the purchasing process?
- What product features must the product incorporate?
- What benefits will the product provide?
- How will consumers react to the product?
- How will the product be produced most cost effectively?
- Prove feasibility through virtual computer aided rendering, and rapid prototyping
- What will it cost to produce it?
- Testing the Concept by asking a sample of prospective customers what they think of the idea. Usually via Choice Modelling.

Business Analysis

- Estimate likely selling price based upon competition and customer feedback
- Estimate sales volume based upon size of market and such tools as the FourtWoodlock equation
- Estimate profitability and breakeven point
- Beta Testing and Market Testing

- Produce a physical prototype or mock-up
- Test the product (and its packaging) in typical usage situations
- Conduct focus group customer interviews or introduce at trade show
- Make adjustments where necessary
- Produce an initial run of the product and sell it in a test market area to determine customer acceptance
- Technical Implementation
- New programme initiation
- Resource estimation
- Requirement publication
- Engineering operations planning
- Department scheduling
- Supplier collaboration
- Logistics plan
- Resource plan publication
- Programme review and monitoring
- Contingencies - what-if planning
- Commercialization (often considered post-NPD)
- Launch the product
- Produce and place advertisements and other promotions
- Fill the distribution pipeline with product

These steps may be iterated as needed. Some steps may be eliminated. To reduce the time that the NPD process takes, many companies are completing several steps at the same time (referred to as concurrent engineering or time to market). Most industry leaders see new product development as a proactive process where resources are allocated to identify market changes and seize upon new product opportunities before they occur (in contrast to a reactive strategy in which nothing is done until problems occur or the competitor introduces an innovation). Many industry leaders see new product development as an on-going process (referred to as continuous development) in which the entire organization is always looking for opportunities.

For the more innovative products indicated on the diagram above, great amounts of uncertainty and change may exist, which makes it difficult or impossible to plan the complete project before starting it. In this case, a more flexible approach may be advisable.

Because the NPD process typically requires both engineering and marketing expertise, cross-functional teams are a common way of organizing projects. The team is responsible for all aspects of the project, from initial idea generation to final commercialization, and they usually report to senior management (often to a vice president or Programme Manager). In those industries where products are technically complex, development research is typically expensive, and product life cycles are relatively short, strategic alliances among several organizations helps to spread the costs, provide access to a wider skill set, and speeds the overall process.

Also, notice that because engineering and marketing expertise are usually both critical to the process, choosing an appropriate blend of the two is important. However, this article is slanted more toward the marketing side by marketing specialists and for more of an engineering slant by **Ulrich and Eppinger.**

People respond to new products in different ways. The adoption of a new technology can be analyzed using a variety of diffusion theories such as the **Diffusion of innovations theory.**

2.7 FUZZY FRONT END

The Fuzzy Front End is the messy ―getting started period of new product development processes. It is in the front end where the organization formulates a concept of the product to be developed and decides whether or not to invest resources in the further development of an idea. It is the phase between first consideration of an opportunity and when it is judged ready to enter the structured development process (**Kim and Wilemon, 2002**; **Koen et al., 2001).** It includes all activities from the search for new opportunities through the formation of a germ of an idea to the development of a precise concept. The Fuzzy Front End ends when an organization approves and begins formal development of the concept.

Although the Fuzzy Front End may not be an expensive part of product development, it can consume 50% of development time, and it is where major commitments are typically made involving time, money, and the product‘s nature, thus setting the course for the entire project and final end product. Consequently, this phase should be considered as an essential part of development rather than something that happens ―before development, and its cycle time should be included in the total development cycle time. **Koen et al. (2001**) distinguish five different front-end elements (not necessarily in a particular order): **1.** Opportunity Identification **2.** Opportunity Analysis **3.** Idea Genesis **4.** Idea Selection **5**. Concept and Technology Development

The first element is the **opportunity identification**. In this element, large or incremental business and technological chances are identified in a more or less structured way. Using the guidelines established here, resources will eventually be allocated to new projects.... which then lead to a structured NPPD (**New Product & Process Development**) strategy. The second element is the opportunity analysis. It is done to translate the identified opportunities into implications for the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research. The third element is the **idea genesis**, which is described as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside inputs, e.g. a supplier offering a new material/technology, or from a customer with an unusual request. The fourth element is the **idea selection**. Its purpose is to choose whether to pursue an idea by analysing its potential business value. The fifth element is the **concept and technology development**. During this part of the front-end, the business case is developed based on estimates of the total available market, customer needs, investment requirements, and competition analysis and project uncertainty. Some organizations consider this to be the first stage of the **NPPD process** (i.e., Stage 0). The Fuzzy Front End is also described in literature as '**Front End of Innovation'**, -Phase 0,-Stage 0' or '**Pre-Project-Activities.**

2.8 FLEXIBLE PRODUCT DEVELOPMENT

Flexible product development is the ability to make changes in the product being developed or in how it is developed, even relatively late in development, without being too disruptive.

Consequently, the later one can make changes, the more flexible the process is, and the less disruptive the change is, the greater the flexibility.

Flexibility is important because the development of a new product naturally involves change from what came before it. Change can be expected in what the customer wants and how the customer might use the product, in how competitors might respond, and in the new technologies being applied in the product or in its manufacturing process. The more innovative a new product is, the more likely it is that the development team will have to make changes during development.

Flexible development counteracts the tendencies of many contemporary management approaches to plan a project completely at its outset and discourage change thereafter. These include Six Sigma, which aims to drive variation out of a process; lean, which acts to drive out waste; and traditional project management and phased development systems (including the popular Stage-Gate model), which encourage upfront planning and following the plan. Although these methodologies have strengths, their side effect is encouraging rigidity in a process that needs flexibility to be effective, especially for truly innovative products.

For more mature product categories, flexibility techniques are not only overly expensive but often unwise. Therefore, flexibility techniques must be used with preference, for instance, only in the portions of a product likely to undergo change.

When applied to the development of software products, these methods are commonly known as **agile software development**. However, agile software methods generally rely on special characteristics of the software medium, especially object technologies, which are not available to non-software products. Consequently, flexible product development draws from some of the roots of agile software development but tends to use other tools and approaches that apply beyond the software medium. Flexible development uses several techniques to keep the cost of change low and to make decisions at the last responsible moment. These techniques include modular architectures to encapsulate change, experimentation and iteration to sample results and check them out with the customer frequently, set-based design to build and maintain options, and emergent processes that develop during a project in response to its needs.

UNIT 3

CHALLENGES FACING OPERATIONS MANAGERS TODAY

Introduction

This unit will expand upon various challenges that plague productions and operations with the perspective of the modern work environment seeking to highlight common problems faced in the modern work environment.

OBJECTIVES;

1. **T**ackling challenges facing operations' managers today in developing countries.
2. Consider and discuss Globalization, Customer satisfaction and Resource productivity. Workforce and social trends, economic and environmental factors, technology, and ethical conduct.

3.1 INTRODUCTION

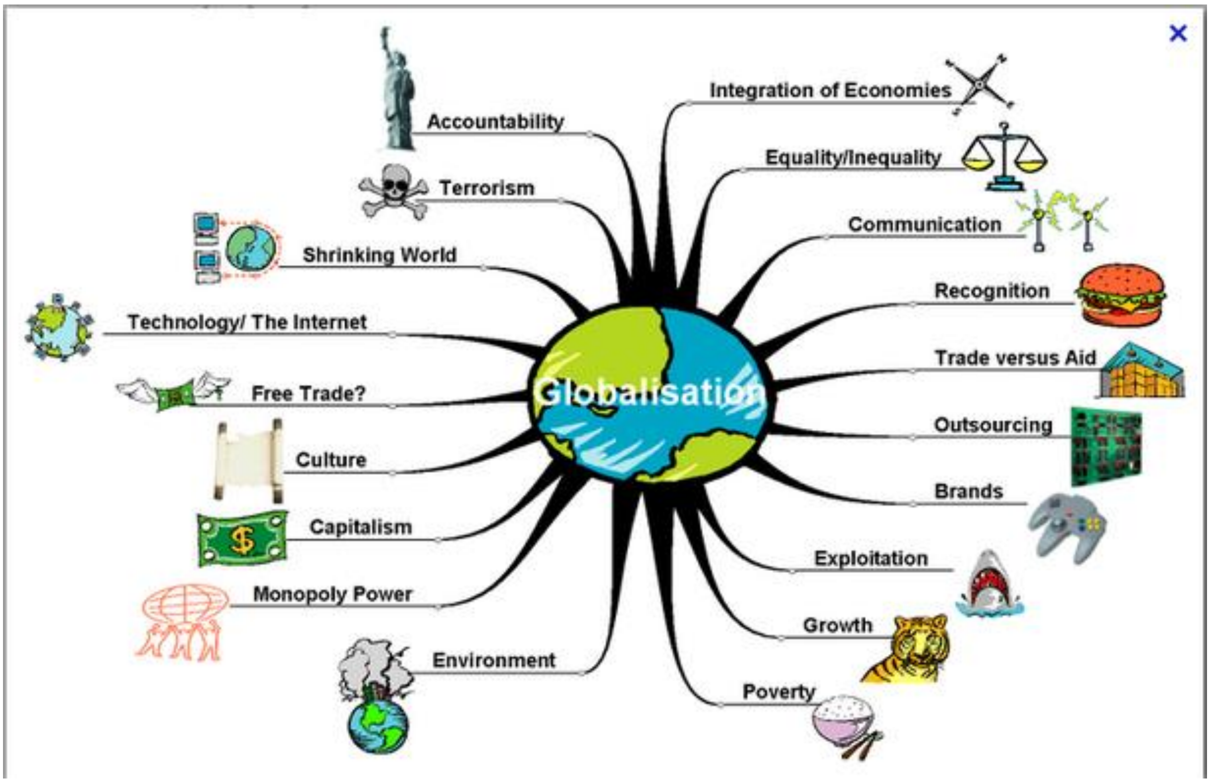
The main field which operations management is concentrated on is managing the sources directly taking share in product manufacturing or providing a service by the organisation. These sources are in the form of people, materials, technologies and information. They are combined together by a number of processes in order to acquire a service or a product. Operations management is therefore the transformation process in which inputs (resources) are by means of this process transformed into outputs (products or services). The operations manager is responsible for managing the resources involved in this process. '**Operations management**, ''therefore, refers to performing the traditional managerial functions (planning, organizing, directing, and controlling) on the organization's operations. Below are the challenges faced by operations managers in the manufacturing industry and the strategies adopted by them in order to meet these challenges.

Challenges faced by operations managers;

There are many challenges faced by operation managers in the field of operation management. Operation managers should equip themselves with all the necessary tools and knowledge across all the business function. Operation Managers need to understand the whole business flows, the products, the customers, the operation and the technology. With this in mind, they will be able deal better with various groups to improve the process and operation's productivity and efficiency to the next level, understand problem-solving from technical point of view and be able to discuss intellectually with technical parties for various operation issues. Managing a service system has become a major challenge in the global competitive environment. Organisations are subject to more ups and downs in their day to day activities. As a manufacturer today, the basic approaches to managing operations are no longer sufficient to meet the difficult challenge of continuously achieving and improving manufacturing excellence. Leading companies are turning to a broader type of solution to enable manufacturing transformation - one that encompasses not just the plant floor, but also the warehouse, quality and material flow throughout the production process and product supply network. Only then manufacturing excellence can be achieved and sustained. As such the work of operations managers in the manufacturing industry is becoming more and more challenging in view of the various factors that will be explained further.

3.2 GLOBALIZATION

It is commonly said that the world is gradually becoming a global village. In 1990s, reduction in trade barriers and advancement in communications and transportation technology made global manufacturing networks more effective and efficient. Globalization is increasingly becoming a challenge in the manufacturing industry and in turn for operations managers. It does not only imply that local firm faces competition from abroad, but also means that the former goes international. Competing with firms from abroad means a firm will have to remain competitive by providing quality goods and services at lower prices. The operations manager would definitely be concerned with this as he would have to engage in the four functions of planning, organising, leading and controlling to ensure that the product or service remains competitive in the market. Moreover, there would be a demand for the operations manager's creative skills as innovation is a key factor for the success of the business in this highly competitive world. The case whereby more companies are going international, the operations managers will need to have greater knowledge of international



business and different cultures. Either products or services need to be adapted to suit the demand in such countries. Again, this will be a challenge for the operation managers as it would require their creative skills. To overcome the challenges due to globalization, the operation managers need to set a specialised product and target market which will keep the uniqueness of a product or service to be able to compete in the global market. Also, they must have a good understanding of their competitors. For instance, taking the case of a textile firm, if the management knows which types of garments are in demand in Australia and after taking into consideration the threat of competitors, if any, the firm can go global.

3.3 CUSTOMER SATISFACTION AND RESOURCE PRODUCTIVITY

Given a boost by the ‘quality revolution of the1980s’, quality is now ingrained in business. Organisations use the term total quality management (**TQM)** to describe their quality efforts. A quality focus emphasizes customer satisfaction and often involves teamwork. It is a fact that low cost and high quality are key attributes that a good or service needs to possess. To satisfy customers and remain competitive in the market, a firm must be able to supply the right quantity of goods and services as high quality, at a low price and at the right time. However, there is a trade-off between cost, quality, quantity and time. It is the responsibility and a challenge for the operating manager to ensure that this trade-off is minimized. The operations manager needs to make sure that either the product or service is to the standard required by the customer. Thus, it is important for the operations manager to maintain their engagement in Total Quality Management and the extent to which he is able to meet the standard required by the customer will definitely be a challenge for him. It is crucial for manufacturers to emphasize on improving productivity and hence satisfying customers. Empowering employees by giving them timely information boosts productivity, and this is exactly what an integrated information system - an enterprise resource planning (**ERP)** system does. For instance, the textile industry is so vast and comprises of many departments, teams, offices, cities, countries. This makes it very difficult to track the performance, productivity and usage of employee‘s capability and availability companywide. This lack of employee visibility may negatively affect smooth work load distribution, optimization of employee usage and accurate employee productivity and effectiveness. So it is critical to build up a companywide central system, which records and displays details about the capability and availability of individual employees. Hence, the IT software for enterprise resource planning **(ERP)** is specifically designed for this purpose.

3.4 WORKFORCE AND SOCIAL TRENDS

Changing society values, cultures and interests have a great impact on the work of operation managers. Since some of the managers have to deal directly with operating employees, they have to take into account social trends. The managers also have to bear in mind the demographic changes while planning, organising and controlling. Nowadays, the large swath of the workforce (boomers) is retiring and a new wave (millennial /gen Y) is entering the workforce. Hiring qualified workers to replace the old ones who have been working for 30 years or more is a challenge for many organisations. This change of guard is seen mostly across the manufacturing industry. Moreover, finding the right employees, and managing these people becomes a constant battle for operations managers as the younger generation have turned their back on the manufacturing job. Most of the time, in the textile industry, workers don't stick with one employer for decades like they used to, and the operation manager may sponsor a star employee's machine-tool course only to see that worker get lured away by a firm across town. In order to meet these challenges, firstly, the operating managers should take a proactive approach to attract and retain quality new hires, who are very well qualified and those having certain levels of experience in the manufacturing field. Secondly, they have to implement effective on-the-job mechanisms to transfer knowledge and retain the older experts for as long as possible. The manager must also prevent culture clashes and sex inequalities in order to maintain a friendly working environment.

3.5 ECONOMIC AND ENVIRONMENTAL

The dramatic change in the economic landscape also affects the work of operations managers. Economic variable such as inflation, unemployment, interest rates, exchange rates, economic growth, or recession have an impact on the price of raw materials and the price of finished products. For instance, in the case of inflation, the operations manager is torn apart between two extremes: one**, the high price of raw materials and second, he will have to produce at a low cost. Natural calamities such as cyclones and droughts and other unforeseen events also affect the price of certain raw materials and again, the skills of the operations manager as a resource allocator and negotiator will be put into value. Operations managers play a critical role in determining the environmental impact of manufacturing operations through choice of raw materials used, energy co**nsumed, pollutants emitted and wastes generated. Business organisations are coming under increasing pressure to reduce their carbon footprint and to generally operate sustainable processes. Sustainability refers to service and production processes that use resources in ways that do not harm ecological systems that support both current and future human existence. Sustainability measures often go beyond traditional environmental and economic measures to include measures that incorporate social criteria in decision making. Operation management is central to dealing with these issues. Sometimes referred to as '**green initiatives'**, the possibilities include reducing packaging, materials, water and energy use, and the environmental impact of the supply chain, including buying locally. Other possibilities include reconditioning used equipment (e.g., printers and copiers) for resale, and recycling. One good example is the **Sri Lankan tea** manufacturing industry. Finlay's tea estates have adopted a more systematic triple bottom line reporting method which covers the full spectrum of economic, environmental and social impacts. Finlay's factories are now entirely powered by renewable sources of timber and they are in the process of developing a system of establishing their carbon balance sheet or footprint, with the aim of reducing emissions of global **greenhouse gases**. They have launched a project of cultivating tea with a view to enriching the organic matter content of the soil through mulching, and to minimizing the use of furnace oils for tea drying. This not only led to savings in foreign exchange owing to fewer imports, but it provided employment for surplus labour. They have also started hydroelectric power generation on the plantation, which helps the country to meet its energy needs at low cost and saves foreign exchange through the low consumption of oil.

3.6 TECHNOLOGY

Technological advances have led to a vast array of new products and processes. Undoubtedly the computer has had and will continue to have the greatest impact on business organizations. It has revolutionized the way companies operate. Currently the following technologies are under focus to support operations in the manufacturing sector: **Robotics,** Computer controlled manufacturing, Biotechnology and global positioning systems. Technological advances in new materials, new methods, and new equipment have also made their mark on operations. Technological changes in products and processes can have major implications for production systems, affecting competitiveness and quality, but unless technology is carefully integrated into an existing system, it can do more harm than good by raising costs, reducing flexibility, and even reducing productivity. In order to overcome this challenge, operations managers will have to adapt his skills in view of the recent developments that have been taking place in production. It is also important to underline that with the advances in technology, products are becoming out-dated over time. Therefore, the operations manager has to constantly keep pace with new technology to ensure that the firm does not lag behind with regards to the product being unique. Furthermore, it is expected that the operations manager will have to face and cope with an integration of business needs, people needs and technology.

Manufacturing industry such as automotive industry makes use of automation to reduce the need for human's interaction in the workplace. The use of technology in this particular industry helps to improve efficiency and effectiveness. New technologies also provide opportunities to create more flexible work environments. For example, in the automotive industry-- available technologies include the self-propelled, computer-guided carriers that help to keep the floor clear of equipment because all equipment is mobile. This technology also makes it possible to change the layout of equipment to fit particular work organizations.

3.7 ETHICAL CONDUCT

The need for ethical conduct in business is becoming increasingly obvious, given numerous examples of questionable actions in recent history. In making decisions, managers must consider how their decisions will affect shareholders, management, employees, customers, the community at large, and the environment. Finding solutions that will be in the best interests of all of these stakeholders is not always easy, but it is a goal that all managers should strive to achieve. Furthermore, even managers with the best intentions will sometimes make mistakes. If mistakes do occur, managers should act responsibly to correct those mistakes as quickly as possible, and to address any negative consequences. Operations managers, like all managers, have the responsibility to make ethical decisions. Ethical issues arise in many aspects of operations management, including: safety (product & employee), quality and environment. In the manufacturing industry, business ethics codes are commonly used to keep business activities legal and maintain the company‘s public image. Manufacturing industry normally adopt a "No Harm" policy. Refraining from harming others is an ethical consideration that also helps hold society together. For example, the toy industry refused to employ child labour and ensure human rights are respected. Fairness is another important factor that is taken into consideration in this particular industry. For example, in most manufacturing organizations, the same criterion is being used to determine employee treatment, such as promotion and firing. Manufacturing firm make use of contracts, handbooks and code of conduct to set out the standard, rules and regulation to follow.

3.8 SUMMING UP

We can conclude that many evolutionary terms and shifts have led the need for Operations Management. It can be said that the operations function in business organizations is responsible for producing goods and providing services. After the Industrial Revolution, countries evolved to an industrial economy. But for a time, manufacturing was more of an art than a science and element of management was missing. This changed when Taylor introduced the method of scientific management. The Operations Manager in the manufacturing industry faces many challenges and these are in the form of: globalization, customer satisfaction and resource productivity, workforce and social trends, economic and environmental issues and technology. Operations managers in the manufacturing industry are being able to meet new challenges. However, it requires much effort. Firms within this industry are operating in a dynamic environment and changes are inevitable. Firms are able to adapt to changes by adopting new technology and combing machine and human power to improve efficiency. To be successful, the firms are adopting code of ethics and professional standard to improve employee morale and production level. Quality enforcement like TQM and Lean management are used to continuously improve process, people and product. More emphasis is being put in recruiting the best people. Operation management is putting more emphasis on green initiatives for the industry to remain sustainable. All the strategies discussed above, if well developed and maintained, will overcome the challenges which the operation managers face in the manufacturing industry. This is how the industry will also reach a high competitiveness and it will be able to maintain it.

UNIT 4

SIX SIGMA STRATEGY

Introduction

The fourth unit introduces to you to something called “six sigma”. It is an approach to production and operations managed, that was devised by Motorola, and is being used around the world.

Objectives

We will see;

- What is its purpose
- How is it implemented.
- List the chief implementers of six sigma
- Consider some of the benefits of using six sigma in a company.
- Understand the criticisms levelled against six sigma.

Discussion

After research, what are the highlights of six sigma in a company other than its implementation in Motorola. Research on various industries and business sectors.

4.1 WHAT IS SIX SIGMA?

This is a business management strategy, originally developed by Motorola, that today enjoys widespread application in many sectors of industry.

Six Sigma seeks to identify and remove the causes of defects and errors in manufacturing and business processes. It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization (―Black Belts‖ etc.) who are experts in these methods. Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction or profit increase).

Historical overview Six Sigma was originally developed as a set of practices designed to improve manufacturing processes and eliminate defects, but its application was subsequently extended to other types of business processes as well. In Six Sigma, a defect is defined as anything that could lead to customer dissatisfaction.

The particulars of the methodology were first formulated by Bill Smith at Motorola in 1986. Six Sigma was heavily inspired by six preceding decades of quality improvement methodologies such as quality control, TQM, and Zero Defects, based on the work of pioneers such as Shewhart, Deming, Juran, Ishikawa, Taguchi and others.

Like its predecessors, Six Sigma asserts that – 1. Continuous efforts to achieve stable and predictable process results (i.e. reduce process variation) are of vital importance to business success. 2. Manufacturing and business processes have characteristics that can be measured, analyzed, improved and controlled. 3. Achieving sustained quality improvement requires commitment from the entire organization, particularly from top-level management.

Features that set Six Sigma apart from previous quality improvement initiatives include:

- ✓ A clear focus on achieving measurable and quantifiable financial returns from any Six Sigma project. An increased emphasis on strong and passionate management leadership and support.
- ✓ A special infrastructure of ―Champions, ‘’Master Black Belts,’’ ‘’Black Belts’’, etc. to lead and implement the Six Sigma approach.
- ✓ A clear commitment to making decisions on the basis of verifiable data, rather than assumptions and guesswork.

The term ―Six Sigma is derived from a field of statistics known as process capability studies. Originally**, it referred to the ability of manufacturing processes to produce a very high proportion of output within specification**. Processes that operate with **―six sigma quality** over the short term are assumed to produce long-term defect levels below 3.4 defects per million opportunities (DPMO). Six Sigma's implicit goal is to improve all processes to that level of quality or better.

Six Sigma is a registered service mark and trademark of Motorola, Inc. Motorola has reported over US$17 billion in savings from Six Sigma as of 2006.

Other early adopters of Six Sigma who achieved well-publicized success include Honeywell (previously known as AlliedSignal) and General Electric, where the method was introduced by Jack Welch. By the late 1990s, about two-thirds of the Fortune 500 organizations had begun Six Sigma initiatives with the aim of reducing costs and improving quality.

In recent years, Six Sigma has sometimes been combined with lean manufacturing to yield a methodology named Lean Six Sigma

Origin and meaning of the term “six sigma process”

Graph of the normal distribution, which underlies the statistical assumptions of the Six Sigma model. The Greek letter σ marks the distance on the horizontal axis between the mean, μ, and the curve's inflection point. The greater this distance is, the greater is the spread of values encountered. For the curve shown in red above, $\mu = 0$ and $\sigma = 1$. The other curves illustrate different values of μ and σ.

The following outlines the statistical background of the term Six Sigma: Sigma (the lower-case Greek letter σ) is used to represent the standard deviation (a measure of variation) of a statistical population. The term ―six sigma process,‖ comes from the notion that if one has six standard deviations between the mean of a process and the nearest specification limit, there will be practically no items that fail to meet the specifications. This is based on the calculation method employed in a process capability study.

In a capability study, the number of standard deviations between the process mean and the nearest specification limit is given in sigma units. As process standard deviation goes up, or the mean of the process moves away from the center of the tolerance, fewer standard deviations will fit between the mean and the nearest specification limit, decreasing the sigma number.

The role of the 1.5 sigma shift Experience has shown that in the long term, processes usually do not perform as well as they do in the short. As a result, the number of sigma's that will fit between the processes mean the nearest specification limit is likely to drop over time, compared to an initial short-term study. To account for this real-life increase in process variation over time, an empirically-based 1.5 sigma shift is introduced into the calculation. According to this idea, a process that fits six sigma's between the process mean and the nearest specification limit in a short-term study will in the long term only fit 4.5 sigma's – either because the process mean will move over time, or because the long-term standard deviation of the process will be greater than that observed in the short term, or both. Hence the widely accepted definition of a six sigma process is one that produces 3.4 defective parts per million opportunities (DPMO). This is based on the fact that a process that is normally distributed will have 3.4 parts per million beyond a point that is 4.5 standard deviations above or below the mean (one-sided capability study). So the 3.4 DPMO of a ―Six Sigma process in fact corresponds to 4.5 sigmas, namely 6 sigma's minus the 1.5 sigma shift introduced to account for long-term variation. This is designed to prevent underestimation of the defect levels likely to be encountered in real-life operation.

Sigma levels Taking the 1.5 sigma shift into account, short-term sigma levels correspond to the following long-term DPMO values (one-sided): □ One Sigma = 690,000 DPMO = 31% efficiency □ Two Sigma = 308,000 DPMO = 69.2% efficiency □ Three Sigma = 66,800 DPMO = 93.32% efficiency □ Four Sigma = 6,210 DPMO = 99.379% efficiency □ Five Sigma = 230 DPMO = 99.977% efficiency □ Six Sigma = 3.4 DPMO = 99.9997% efficiency

METHODS

Six Sigma has two key methods: DMAIC and DMADV, both inspired by Deming's Plan-Do-Check-Act Cycle. DMAIC is used to improve an existing business process; DMADV is used to create new product or process designs.

DMAIC
The basic method consists of the following five steps**: 1.** Define process improvement goals that are consistent with customer demands and the enterprise strategy. **2.** Measure key aspects of the current process and collect relevant data. **3**. Analyze the data to verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. **4**. Improve or optimize the process based upon data analysis using techniques like Design of experiments. **5**. Control to ensure that any deviations from target are corrected before they result in defects. Set up pilot runs to establish process capability, move on to production, set up control mechanisms and continuously monitor the process.

DMADV
The basic method consists of the following five steps:

1. Define design goals that are consistent with customer demands and the enterprise strategy. 2. Measure and identify CTQs (characteristics that are Critical to Quality), product capabilities, production process capability, and risks. 3. Analyze to develop and design alternatives, create a high-level design and evaluate design capability to select the best design. 4. Design details, optimize the design, and plan for design verification. This phase may require simulations. 5. Verify the design, set up pilot runs, implement the production process and hand it over to the process owners.

DMADV is also known as DFSS, an abbreviation of ―Design For Six Sigma.

4.3 IMPLEMENTATION ROLES

One of the key innovations of Six Sigma is the professionalizing of quality management functions. Prior to Six Sigma, quality management in practice was largely relegated to the production floor and to statisticians in a separate quality department. Six Sigma borrows martial arts ranking terminology to define a hierarchy (and career path) that cuts across all business functions and a promotion path straight into the executive suite.

Six Sigma identifies several key roles for its successful implementation:

 Executive Leadership includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements. Champions are responsible for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentors to Black Belts. Master Black Belts, identified by champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from statistical tasks, their time is spent on ensuring consistent application of Six Sigma across various functions and departments. Black Belts operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma. Green Belts are the employees who take up Six Sigma implementation along with their other job responsibilities. They operate under the guidance of Black Belts.

4.4 QUALITY MANAGEMENT TOOLS AND METHODOLOGIES USED IN SIX SIGMA

Six Sigma makes use of a great number of established quality management methods that are also used outside of Six Sigma. The following table shows an overview of the main methods used.

 5 Whys Analysis of variance ANOVA Gauge R&R Axiomatic design Business Process Mapping Catapult exercise on variability Cause & effects diagram (also known as fishbone or Ishikawa diagram) Chi-square test of independence and fits Control chart Correlation Cost-benefit analysis CTQ tree Quantitative marketing research through use of Enterprise Feedback Management (EFM) systems Design of experiments

 Failure mode and effects analysis General linear model Histograms Homoscedasticity Pareto chart Pick chart Process capability Regression analysis Root cause analysis Run charts SIPOC analysis (Suppliers, Inputs, Process, Outputs, Customers) Stratification Taguchi methods Thought process map TRIZ

4.5 EVALUATING SIX SIGMA

Six Sigma has made a huge impact on industry and is widely employed as a business strategy for achieving and sustaining operational and service excellence. However, there have also been various criticisms of Six Sigma.

1. **Lack of originality** Noted quality expert, Joseph M. Juran, has described Six Sigma as ―a basic version of quality improvement, stating that ―[t]here is nothing new there. It includes what we used to call facilitators. They've adopted more flamboyant terms, like belts with different colours. I think that concept has merit to set apart, to create specialists who can be very helpful. Again, that's not a new idea. The American Society for Quality long ago established certificates, such as for reliability engineers.

2. **Role of consultants** The use of ―Black Belts as itinerant change agents is controversial as it has created a cottage industry of training and certification. Critics argue there is overselling of Six Sigma by too great a number of consulting firms, many of which claim expertise in Six Sigma when they only have a rudimentary understanding of the tools and techniques involved. 3. **Studies that indicate** negative effects caused by Six Sigma. A Fortune article stated that ―of 58 large companies that have announced Six Sigma programmes, 91 percent have trailed the S&P 500 since.‖ The statement is attributed to ―an analysis by Charles Holland of consulting firm Qualpro (which espouses a competing quality-improvement process).‖ The gist of the article is that Six Sigma is effective at what it is intended to do, but

that it is ―narrowly designed to fix an existing process‖ and does not help in ―coming up with new products or disruptive technologies.‖ Many of these claims have been argued as being in error or ill-informed.

A Business Week article says that James McNerney's introduction of Six Sigma at 3M may have had the effect of stifling creativity. It cites two Wharton School professors who say that Six Sigma leads to incremental innovation at the expense of blue-sky work.

4. **Based on arbitrary standards** While 3.4 defects per million opportunities might work well for certain products/processes, it might not be ideal or cost-effective for others. A pacemaker process might need higher standards, for example, whereas a direct mail advertising campaign might need lower ones. The basis and justification for choosing 6 as the number of standard deviations is not clearly explained. In addition, the Six Sigma model assumes that the process data always conform to the normal distribution. The calculation of defect rates for situations where the normal distribution model does not apply is not properly addressed in the current Six Sigma literature.

5. **Criticism of the 1.5 sigma** shift Because of its arbitrary nature, the 1.5 sigma shift has been dismissed as ―goofy‖ by the statistician Donald J. Wheeler. Its universal applicability is seen as doubtful.

The 1.5 sigma shift has also been contentious because it results in stated ―sigma levels‖ that reflect short-term rather than long-term performance: a process that has long-term defect levels corresponding to 4.5 sigma performance is, by Six Sigma convention, described as a ―6 sigma process.‖ The accepted Six Sigma scoring system thus cannot be equated to actual normal distribution probabilities for the stated number of standard deviations, and this has been a key bone of contention about how Six Sigma measures are defined. The fact that it is rarely explained that a ―6 sigma‖ process will have long-term defect rates corresponding to 4.5 sigma performance rather than actual 6 sigma performance has led several commentators to express the opinion that Six Sigma is a confidence trick.

Discussion

1. Sum up in your own words what is meant by "six sigma"
2. What is its purpose and how is it implemented?
3. Who are the chief implementers of six sigma?
4. What are some of the benefits of six sigma for a company?
5. What are some of the criticisms levelled against six sigma?

UNIT 5

LEAN PRODUCTION

Introduction

The fifth unit is about 'lean production'. We will begin by examining the origins of the concept of lean manufacturing and list some of the types of wastes that it is meant to address.

Learning Outcomes

By the end of this unit students should be able to;

- Consider the benefits of utilizing a lean approach to production and operating practices in business.
- Cite its usage from the Toyota story.
- Explain the concept of Mura,Muda and Muri

5.1 OVERVIEW

Lean production, which is often known simply as ―Lean‖, is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. In a more basic term, More value with less work. Lean manufacturing is a generic process management philosophy derived mostly from the Toyota Production System (TPS) (hence the term Toyotism is also prevalent) and identified as ―Lean‖ only in the 1990s. It is renowned for its focus on reduction of the original Toyota seven wastes in order to improve overall customer value, but there are varying perspectives on how this is best achieved. The steady growth of Toyota, from a small company to the world's largest automaker, has focused attention on how it has achieved this.

Lean principles come from the Japanese manufacturing industry. The term was first coined by John Krafcik in a Fall 1988 article, ―Triumph of the Lean Production System,‖ published in the Sloan Management Review and based on his master's thesis at the MIT Sloan School of Management. Krafcik had been a quality engineer in the Toyota-GM NUMMI joint venture in California before coming to MIT for MBA studies. Krafcik research was continued by the International Motor Vehicle Programme at MIT, which produced the international best-seller book co-authored by James Womack, Daniel Jones, and Daniel Roos called ‗The Machine That Changed the World'(1990).

For many, Lean is the set of ―tools‖ that assist in the identification and steady elimination of waste (muda). As waste is eliminated quality improves while production time and cost are reduced. Examples of such ―tools‖ are Value Stream Mapping, Five S, Kanban (pull systems), and poka-yoke (error-proofing).

There is a second approach to Lean Manufacturing, which is promoted by Toyota, in which the focus is upon improving the ―flow‖ or smoothness of work, thereby steadily eliminating mura (―unevenness‖) through the system and not upon 'waste reduction' per se. Techniques to improve flow include production levelling, ―pull production (by means of kanban) and the Heijunka box. This is a fundamentally different approach to most improvement methodologies which may partially account for its lack of popularity.

The difference between these two approaches is not the goal but the prime approach to achieving it. The implementation of smooth flow exposes quality problems which already existed and thus waste reduction naturally happens as a consequence. The advantage claimed for this approach is that it naturally takes a system-wide perspective whereas a waste focus has this perspective, sometimes wrongly, assumed. Some Toyota staff have expressed some surprise at the tool-based approach as they see the tools as work-around made necessary where flow could not be fully implemented and not as aims in themselves.

Both Lean and TPS can be seen as a loosely connected set of potentially competing principles whose goal is cost reduction by the elimination of waste. These principles include: Pull processing, Perfect first-time quality, Waste minimization, Continuous improvement, Flexibility, Building and maintaining a long term relationship with suppliers, Automation, Load levelling and Production flow and Visual control. The disconnected nature of some of these principles perhaps springs from the fact that the TPS has grown pragmatically since 1948 as it responded to the problems it saw within its own production facilities. Thus what one sees today is the result of a 'need' driven learning to improve where each step has built on previous ideas and not something based upon a theoretical framework. Toyota's view is that the main method of Lean is not the tools, but the reduction of three types of waste: muda (―non-value-adding work‖), Muri (―overburden‖), and mura (―unevenness‖), to expose problems systematically and to use the tools where the ideal cannot be achieved. Thus the tools are, in their view, workarounds adapted to different situations, which explains any apparent incoherence of the principles above.

5.2 ORIGINS

Also Known as the flexible mass production. The TPS has two pillar concepts: Just-in time (JIT) or ―flow‖, and ―automation‖ (smart automation). Adherents of the Toyota approach would say that the smooth flowing delivery of value achieves all the other improvements as side-effects. If production flows perfectly then there is no inventory; if customer valued features are the only ones produced then product design is simplified and effort is only expended on features the customer values. The other of the two TPS pillars is the very human aspect of automation, whereby automation is achieved with a human touch. The ―human touch‖ here meaning to automate so that the machines/systems are designed to aid humans in focusing on what the humans do best. This aims, for example, to give the machines enough intelligence to recognize when they are working abnormally and flag this for human attention. Thus, in this case, humans would not have to monitor normal production and only have to focus on abnormal, or fault, conditions. A reduction in human workload that is probably much desired by all involved since it removes much routine and repetitive activity that humans often do not enjoy and where they are therefore not at their most effective.

Lean implementation is therefore focused on getting the right things, to the right place, at the right time, in the right quantity to achieve perfect work flow while minimizing waste and being flexible and able to change. These concepts of flexibility and change are principally required to allow production levelling, using tools like SMED, but have their analogues in other processes such as research and development (R&D). The flexibility and ability to change are within bounds and not open-ended and therefore often not expensive capability requirements. More importantly, all of these concepts have to be understood, appreciated, and embraced by the actual employees who build the products and therefore own the processes that deliver the value. The cultural and managerial aspects of Lean are just as important as, and possibly more important than, the actual tools or methodologies of production itself. There are many examples of Lean tool implementation without sustained benefit and these are often blamed on weak understanding of Lean in the organization.

Lean aims to make the work simple enough to understand, to do and to manage. To achieve these three at once there is a belief held by some that Toyota's mentoring process, is one of the best ways to foster Lean Thinking up and down the organizational structure. This is the process undertaken by Toyota as it helps its suppliers to improve their own production. The closest equivalent to Toyota's mentoring process is the concept of ―Lean Sensei‖, which encourages companies, organizations, and teams to seek out outside, third-party experts, who can provide unbiased advice and coaching, (see Womack et al, Lean Thinking, 1998). There have been recent attempts to link Lean to Service Management, perhaps one of the most recent and spectacular of which was London Heathrow Airport's Terminal 5. This particular case provides a graphic example of how care should be taken in translating successful practices from one context (production) to another (services), expecting the same results. In this case the public perception is more of a spectacular failure, than a spectacular success, resulting in potentially, an unfair tainting of the lean manufacturing philosophies.

5.3 A BRIEF HISTORY OF WASTE REDUCTION THINKING

The avoidance and then latterly removal of waste has a long history and as such is not the history of Lean but is its motivator. In fact many of the concepts now seen as key to lean have been discovered and rediscovered over the years by others in their search to reduce waste. Lean has developed as an approach and style that has been demonstrated to be effective.

Pre-20th century Most of the basic goals of lean manufacturing are common sense and documented examples can be seen back to at least Benjamin Franklin. Who says of wasted time, ―He that idly loses 5s worth of time, loses 5s., and might as prudently throw 5s. into the river. He added that avoiding unnecessary costs could be more profitable than increasing sales: ―A penny saved is two pence clear. A pin a-day is a groat a-year. Save and have.

Again Franklin's The Way to Wealth says the following about carrying unnecessary inventory. ―You call them goods; but, if you do not take care, they will prove evils to some of you. You expect they will be sold cheap, and, perhaps, they may [be bought] for less than they cost; but, if you have no occasion for them, they must be dear to you. Remember what Poor Richard says, 'Buy what thou hast no need of, and ere long thou shalt sell thy necessaries.' In another place he says, 'Many have been ruined by buying good penny worths'.‖ Henry Ford cited Franklin as a major influence on his own business practices, which included Just-in-time manufacturing. The concept of waste being built into jobs and then taken for granted was noticed by motion efficiency expert Frank Gilbreth, who saw that masons bent over to pick up bricks from the ground. The bricklayer was therefore lowering and raising his entire upper body to pick up a 2.3 kg (5 lb.) brick, and this inefficiency had been built into the job through long practice. Introduction of a non-stooping scaffold, which delivered the bricks at waist level, allowed masons to work about three times as quickly, and with less effort.

20th century Frederick Winslow Taylor, the father of scientific management, introduced what are now called standardization and best practice deployment. In his Principles of Scientific Management (1911), Taylor said: ―And whenever a workman proposes an improvement, it should be the policy of the management to make a careful analysis of the new method, and if necessary conduct a series of experiments to determine accurately the relative merit of the new suggestion and of the old standard. And whenever the new method is found to be markedly superior to the old, it should be adopted as the standard for the whole establishment.

Taylor also warned explicitly against cutting piece rates (or, by implication, cutting wages or discharging workers) when efficiency improvements reduce the need for raw labour: ―…after a workman has had the price per piece of the work he is doing lowered two or three times as a result of his having worked harder and increased his output, he is likely entirely to lose sight of his employer's side of the case and become imbued with a grim determination to have no more cuts if soldiering [marking time, just doing what he is told] can prevent it.‖ Shigeo Shingo, the best-known exponent of single minute exchange of die (SMED) and error-proofing or poka-yoke, cites Principles of Scientific Management as his inspiration. American industrialists recognized the threat of cheap offshore labour to American workers during the 1910s, and explicitly stated the goal of what is now called lean manufacturing as a countermeasure. Henry Towne, past President of the American Society of Mechanical Engineers, wrote in the Foreword to Frederick Winslow Taylor's Shop Management (1911), ―We are justly proud of the high wage rates which prevail throughout our country, and jealous of any interference with them by the products of the cheaper labour of other countries. To maintain this condition, to strengthen our control of home markets, and, above all, to broaden our opportunities in foreign markets where we must compete with the products of other industrial nations, we should welcome and encourage every influence tending to increase the efficiency of our productive processes.‖

Ford starts the ball rolling Henry Ford continued this focus on waste while developing his mass assembly manufacturing system. Charles Buxton Going wrote in 1915:

Ford's success has startled the country, almost the world, financially, industrially, mechanically. It exhibits in higher degree than most persons would have thought possible the seemingly contradictory requirements of true efficiency, which are: constant increase of quality, great increase of pay to the workers, repeated reduction in cost to the consumer. And with these appears, as at once cause and effect, an absolutely incredible enlargement of output reaching something like one hundredfold in less than ten years, and an enormous profit to the manufacturer.

Ford, in My Life and Work (1922), provided a single-paragraph description that encompasses the entire concept of waste:

I believe that the average farmer puts to a really useful purpose only about 5%. of the energy he expends.... Not only is everything done by hand, but seldom is a thought given to a logical arrangement. A farmer doing his chores will walk up and down a rickety ladder a dozen times. He will carry water for years instead of putting in a few lengths of pipe. His whole idea, when there is extra work to do, is to hire extra men. He thinks of putting money into improvements as an expense.... It is waste motion— waste effort— that makes farm prices high and profits low.

Poor arrangement of the workplace—a major focus of the modern kaizen—and doing a job inefficiently out of habit—are major forms of waste even in modern workplaces. Ford also pointed out how easy it was to overlook material waste. A former employee, Harry Bennett, wrote:

One day when Mr Ford and I were together he spotted some rust in the slag that ballasted the right of way of the D. T. & I [railroad]. This slag had been dumped there from our own furnaces. 'You know,' Mr Ford said to me, 'there's iron in that slag. You make the crane crews who put it out there sort it over, and take it back to the plant.'

In other words, Ford saw the rust and realized that the steel plant was not recovering all of the iron.

Design for Manufacture (DFM) also is a Ford concept. Ford said (in My Life and Work) ...entirely useless parts [may be]—a shoe, a dress, a house, a piece of machinery, a railroad, a steamship, an airplane. As we cut out useless parts and simplify necessary ones, we also cut down the cost of making. ... But also it is to be remembered that all the parts are designed so that they can be most easily made.

The same reference describes just in time manufacturing very explicitly.

While Ford is renowned for his production line it is often not recognized how much effort he put into removing the fitters' work in order to make the production line possible. Until Ford, a car's components always had to be fitted or reshaped by a skilled engineer at the point of use, so that they would connect properly. By enforcing very strict specification and quality criteria on component manufacture, he eliminated this work almost entirely, reducing manufacturing effort by between 6090%. However, Ford's mass production system failed to incorporate the notion of ―pull production‖ and thus often suffered from over-production.

Toyota develops TPS Toyota's development of ideas that later became Lean may have started at the turn of the 20th century with Sakichi Toyoda, in a textile factory with looms that stopped themselves when a thread broke, this became the seed of automation. Toyota's journey with JIT may have started back in 1934 when it moved from textiles to produce its first car. Kiichiro Toyoda, founder of Toyota, directed the engine casting

work and discovered many problems in their manufacture. He decided he must stop the repairing of poor quality by intense study of each stage of the process. In 1936, when Toyota won its first truck contract with the Japanese government, his processes hit new problems and he developed the ―Kaizen‖ improvement teams.

Levels of demand in the Post War economy of Japan were low and the focus of mass production on lowest cost per item via economies of scale therefore had little application. Having visited and seen supermarkets in the USA, Taiichi Ohno recognised the scheduling of work should not be driven by sales or production targets but by actual sales. Given the financial situation during this period overproduction had to be avoided and thus the notion of Pull (build to order rather than target driven Push) came to underpin production scheduling.

It was with Taiichi Ohno at Toyota that these themes came together. He built on the already existing internal schools of thought and spread their breadth and use into what has now become the Toyota Production System (TPS). It is principally from the TPS, but now including many other sources, that Lean production is developing. Norman Bodek wrote the following in his foreword to a reprint of Ford's Today and Tomorrow:

I was first introduced to the concepts of just-in-time (JIT) and the Toyota production system in 1980. Subsequently I had the opportunity to witness its actual application at Toyota on one of our numerous Japanese study missions. There I met Mr Taiichi Ohno, the system's creator. When bombarded with questions from our group on what inspired his thinking, he just laughed and said he learned it all from Henry Ford's book.‖ It is the scale, rigour and continuous learning aspects of the TPS which have made it a core of Lean.

5.4 TYPES OF WASTES

While the elimination of waste may seem like a simple and clear subject it is noticeable that waste is often very conservatively identified. This then hugely reduces the potential of such an aim. The elimination of waste is the goal of Lean, and Toyota defined three broad types of waste: muda, Muri and mura; it should be noted that for many Lean implementations this list shrinks to the last waste type only with corresponding benefits decrease.

To illustrate the state of this thinking Shigeo Shingo observed that only the last turn of a bolt tightens it—the rest is just movement. This ever finer clarification of waste is key to establishing distinctions between value-adding activity, waste and non-value-adding work. Non-value adding work is waste that must be done under the present work conditions. One key is to measure, or estimate, the size of these wastes, in order to demonstrate the effect of the changes achieved and therefore the movement towards the goal.

The ―flow (or smoothness) based approach aims to achieve JIT, by removing the variation caused by work scheduling and thereby provide a driver, rationale or target and priorities for implementation, using a variety of techniques. The effort to achieve JIT exposes many quality problems that are hidden by buffer stocks; by forcing

smooth flow of only value-adding steps, these problems become visible and must be dealt with explicitly.

Muri is all the unreasonable work that management imposes on workers and machines because of poor organization, such as carrying heavy weights, moving things around, dangerous tasks, even working significantly faster than usual. It is pushing a person or a machine beyond its natural limits. This may simply be asking a greater level of performance from a process than it can handle without taking shortcuts and informally modifying decision criteria. Unreasonable work is almost always a cause of multiple variations.

To link these three concepts is simple in TPS and thus Lean. Firstly, Muri focuses on the preparation and planning of the process, or what work can be avoided proactively by design. Next, Mura then focuses on how the work design is implemented and the elimination of fluctuation at the scheduling or operations level, such as quality and volume. Muda is then discovered after the process is in place and is dealt with reactively. It is seen through variation in output. It is the role of management to examine the muda, in the processes and eliminate the deeper causes by considering the connections to the Muri and mura of the system. The muda and mura inconsistencies must be fed back to the Muri, or planning, stage for the next project.

A typical example of the interplay of these wastes is the corporate behaviour of ―making the numbers‖ as the end of a reporting period approaches. Demand is raised in order to 'make plan', increasing (mura), when the ―numbers‖ are low which causes production to try to squeeze extra capacity from the process which causes routines and standards to be modified or stretched. This stretch and improvisation leads to Muri-style waste which leads to downtime, mistakes and backflows and waiting, thus the muda of waiting, correction and movement.

The original seven muda are: Transportation (moving products that is not actually required to perform the processing) Inventory (all components, work-in-progress and finished product not being processed) Motion (people or equipment moving or walking more than is required to perform the processing) Waiting (waiting for the next production step) Overproduction (production ahead of demand) Over Processing (due to poor tool or product design creating activity) Defects (the effort involved in inspecting for and fixing defects)

Some of these definitions may seem rather idealistic, but this tough definition is seen as important and they drove the success of TPS. The clear identification of nonviable-adding work, as distinct from wasted work, is critical to identifying the assumptions behind the current work process and to challenging them in due course. Breakthroughs in SMED and other process changing techniques rely upon clear identification of where untapped opportunities may lie if the processing assumptions are challenged.

5.5 LEAN IMPLEMENTATION DEVELOPS FROM TPS

The discipline required to implement Lean and the disciplines it seems to require are so often counter-cultural that they have made successful implementation of Lean a major challenge. Some would say that it was a major challenge in its manufacturing 'heartland' as well. Implementations under the Lean label are numerous and whether they are Lean and whether any success or failure can be laid at Lean's door is often debatable. Individual examples of success and failure exist in almost all spheres of business and activity and therefore cannot be taken as indications of whether Lean is particularly applicable to a specific sector of activity. It seems clear from the ―successes‖ that no sector is immune from beneficial possibility.]

System engineering Lean is about more than just cutting costs in the factory. One crucial insight is that most costs are assigned when a product is designed, (see Genichi Taguchi). Often an engineer will specify familiar, safe materials and processes rather than inexpensive, efficient ones. This reduces project risk, that is, the cost to the engineer, while increasing financial risks, and decreasing profits. Good organizations develop and review checklists to review product designs.

Companies must often look beyond the shop-floor to find opportunities for improving overall company cost and performance. At the system engineering level, requirements are reviewed with marketing and customer representatives to eliminate those requirements which are costly. Shared modules may be developed, such as multipurpose power supplies or shared mechanical components or fasteners. Requirements are assigned to the cheapest discipline. For example, adjustments may be moved into software, and measurements away from a mechanical solution to an electronic solution. Another approach is to choose connection or power-transport methods that are cheap or that used standardized components that become available in a competitive market.

In summary, an example of a lean implementation programme could be:

With a tools-based approach: Senior management to agree and discuss their lean vision Management brainstorm to identify project leader and set objectives Communicate plan and vision to the workforce Ask for volunteers to form the Lean Implementation team (5-7 works best, all from different departments) Appoint members of the Lean Manufacturing Implementation Team Train the Implementation Team in the various lean tools - make a point of trying to visit other non-competing businesses which have implemented lean Select a Pilot Project to implement – 5S is a good place to start Run the pilot for 2–3 months - evaluate, review and learn from your mistakes Roll out pilot to other factory areas Evaluate results, encourage feedback Stabilize the positive results by teaching supervisors how to train the new standards you've developed with TWI methodology (Training Within Industry)

With a muri or flow based approach (as used in the TPS with suppliers): Sort out as many of the visible quality problems as you can, as well as downtime and other instability problems, and get the internal scrap acknowledged and its management started. Make the flow of parts through the system or process as continuous as possible using work cells and market locations where necessary and avoiding variations in the operators work cycle Introduce standard work and stabilise the work pace through the system Start pulling work through the system, look at the production scheduling and move towards daily orders with kanban cards Even out the production flow by reducing batch sizes, increase delivery frequency internally and if possible externally, level internal demand Improve exposed quality issues using the tools Remove some people and go through this work again (the Oh No !! moment)

Once you are satisfied that you have a habitual programme, consider introducing the next lean tool. Select the one which will give you the biggest return for your business.

Lean leadership The role of the leaders within the organization is the fundamental element of sustaining the progress of lean thinking. Experienced kaizen members at Toyota, for example, often bring up the concepts because they strongly feel that transferring of Toyota culture down and across the Toyota can only happen when more experienced Toyota Sensei continuously coach and guide the less experienced lean champions. Unfortunately, most lean practitioners in North America focus on the tools and methodologies of lean, versus the philosophy and culture of lean. Some exceptions include Shingijitsu Consulting out of Japan, which is made up of ex-Toyota managers, and Lean Sensei International based in North America, which coaches lean through Toyota-style cultural experience.

One of the dissociative effects of Lean is in the area of key performance indicators (KPI). The KPIs by which plant/facility are judged will often be driving behaviour, because the KPIs themselves assume a particular approach to the work being done. This can be an issue where, for example a truly Lean, Fixed Repeating Schedule (FRS) and JIT approach is adopted, because these KPIs will no longer reflect performance, as the assumptions on which they are based become invalid. It is a key leadership challenge to manage the impact of this

KPI chaos within the organization. A set of performance metrics which is considered to fit well in a Lean environment is Overall Equipment Effectiveness, or OEE.

Similarly, commonly used accounting systems developed to support mass production are no longer appropriate for companies pursuing Lean. Lean Accounting provides truly Lean approaches to business management and financial reporting.

Key focus areas for leaders are PDCA thinking Genchi Genbutsu ―go and see‖ philosophy Process confirmation

Differences from TPS Whilst Lean is seen by many as a generalization of the Toyota Production System into other industries and contexts there are some acknowledged differences that seem to have developed in implementation.

Seeking profit is a relentless focus for Toyota exemplified by the profit maximization principle (Price – Cost = Profit) and the need, therefore, to practice systematic cost reduction (through TPS or otherwise) in order to realize benefit. Lean implementations can tend to de-emphasise this key measure and thus become fixated with the implementation of improvement concepts of ―flow‖ or ―pull.

Tool orientation is a tendency in many programmes to elevate mere tools (standardized work, value stream mapping, visual control, etc.) to an unhealthy status beyond their pragmatic intent. The tools are just different ways to work around certain types of problems but they do not solve them for you or always highlight the underlying cause of many types of problems. The tools employed at Toyota are often used to expose particular problems that are then dealt with, as each tool's limitations or blind spots are perhaps better understood. So, for example, Value Stream Mapping focuses upon material and information flow problems (a title built into the Toyota title for this activity) but is not strong on Metrics, Man or Method. Internally they well know the limits of the tool and understood that it was never intended as the best way to see and analyse every waste or every problem related to quality, downtime, personnel development, cross training related issues, capacity bottlenecks, or anything to do with profits, safety, metrics or morale, etc. No one tool can do all of that. For surfacing these issues other tools are much more widely and effectively used.

Management technique rather than change agents has been a principle in Toyota from the early 1950s when they started emphasizing the development of the production manager's and supervisors' skills set in guiding natural work teams and did not rely upon staff-level change agents to drive improvements. This can manifest itself as a ―Push‖ implementation of Lean rather than ―Pull‖ by the team itself. This area of skills development is not that of the change agent specialist, but that of the natural operations work team leader. Although less prestigious than the TPS specialists, development of work team supervisors in Toyota is considered an equally, if not more important, topic merely because there are tens of thousands of these individuals. Specifically, it is these manufacturing leaders that are the main focus of training efforts in Toyota since they lead the daily work areas, and they directly and dramatically affect quality, cost, productivity, safety, and morale of the team environment. In many companies implementing Lean the reverse set of priorities is true. Emphasis is put on developing the specialist, while the supervisor skill level is expected to somehow develop over time on its own.

5.6 LEAN SERVICES

Lean, as a concept or brand, has captured the imagination of many in different spheres of activity. Examples of these from many sectors are listed below.

Lean principles have been successfully applied to call centre services to improve live agent call handling. By combining Agent-assisted Voice Solutions and Lean's waste reduction practices, a company reduced handle time, reduced between agent variability, reduced accent barriers, and attained near perfect process adherence.

A study conducted on behalf of the Scottish Executive, by Warwick University, in 2005/06 found that Lean methods were applicable to the public sector, but that most results had been achieved using a much more restricted range of techniques than Lean provides.

The challenge in moving Lean to services is the lack of widely available reference implementations to allow people to see how it can work and the impact it does have. This makes it more difficult to build the level of belief seen as necessary for strong implementation. It is also the case that the manufacturing examples of 'techniques' or 'tools' need to be 'translated' into a service context which has not yet received the level of work or publicity that would give starting points for implementers. The upshot of this is that each implementation often 'feels its way' along as must the early industrial engineers of Toyota. This places huge importance upon sponsorship to encourage and protect these experimental developments.

Discussion

1. What is meant by the term lean manufacturing?

2. What are the origins of the concept of lean manufacturing?

3. What types of wastes does it principally address?

4. What are the benefits of utilizing a lean approach to production and operating practices in business?

5. In the light of your experience of business practices in your country, do you think there is a need for a lean approach to business?

UNIT 6

JUST-IN-TIME (BUSINESS)

The sixth unit is about the just-in-time approach to production and operation management.

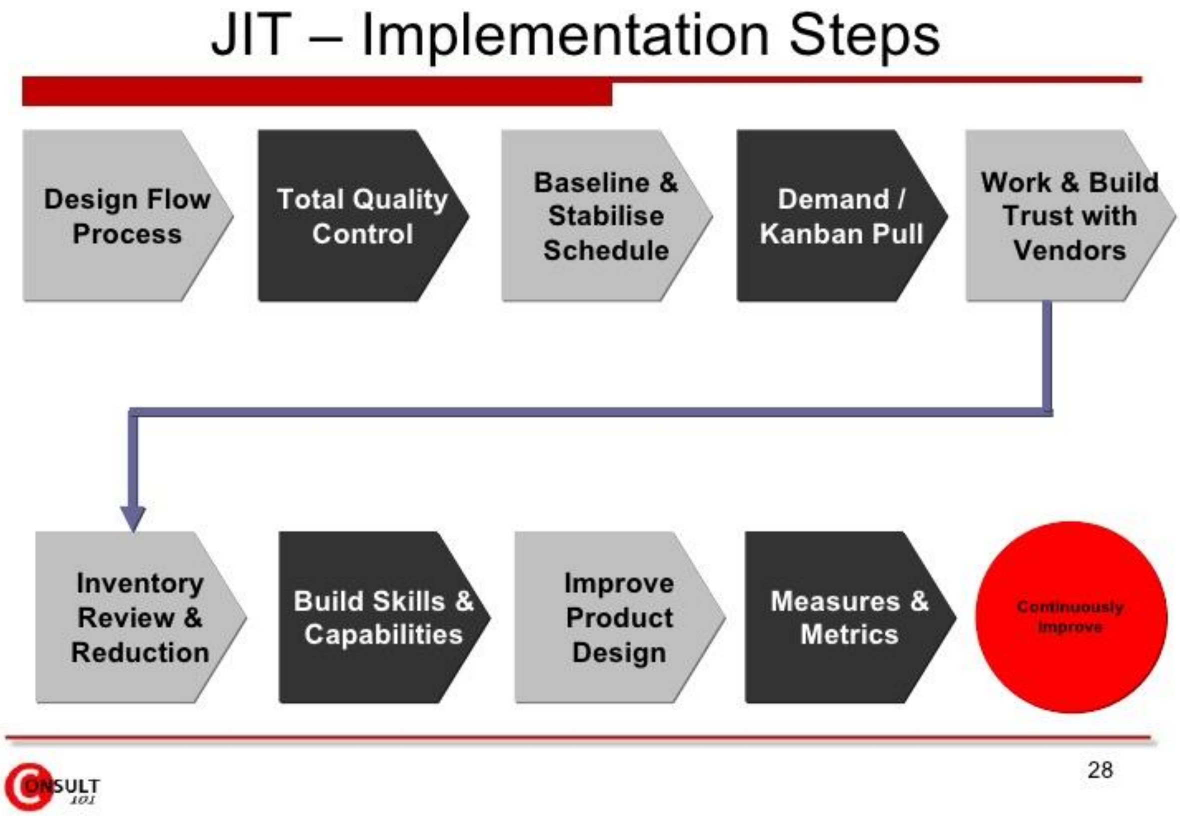
Learning Outcomes

By the end of this unit students should be able to;

- see what is the philosophy behind Jit
- Identify the advantages over the traditional approach to maintaining an inventory or stock.
- implement such an approach
- Identify the chief differences between a vender-managed inventory and a customer managed inventory.

6.1 INTRODUCTION

Just-in-time (JIT) is an inventory strategy implemented to improve the return on investment of a business by reducing in-process inventory and its associated carrying costs. In order to achieve JIT the process must have signals of what is going on elsewhere within the process. This means that the process is often driven by a series of signals, which can be Kanban that tell production processes when to make the next part. Kanban are usually 'tickets' but can be simple visual signals, such as the presence or absence of a part on a shelf. When implemented correctly, JIT can lead to dramatic improvements in a manufacturing organization's return on investment , quality, and efficiency. Some have suggested that "Just on Time" would be a more appropriate name since it emphasizes that production should create items that arrive when needed and neither earlier nor later.



Quick communication of the consumption of old stock which triggers new stock to be ordered is key to JIT and inventory reduction. This saves warehouse space and costs. However since stock levels are determined by historical demand, any sudden demand rises above the historical average demand, the firm will deplete inventory faster than usual and cause customer service issues. Some have suggested that recycling Kanban faster can also help flex the system by as much as 10-30%. In recent years manufacturers have touted a trailing 13 week average as a better predictor for JIT planning than most forecasters could provide.

6.2 HISTORY

The technique was first used by the Ford Motor Company as described explicitly by Henry Ford's My Life and Work (1923): "We have found in buying materials that it is not worthwhile to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry any stock whatsoever. The carloads of raw materials would arrive on schedule and in the planned order and amounts, and go from the railway cars into production. That would save a great deal of money, for it would give a very rapid turnover and thus decrease the amount of money tied up in materials. With bad transportation one has to carry larger stocks." This statement also describes the concept of "dock to factory floor" in which incoming materials are not even stored or warehoused before going into production. The concept needed an effective freight management system (FMS); Ford's Today and Tomorrow (1926) describes one.

The technique was subsequently adopted and publicized by Toyota Motor Corporation of Japan as part of its Toyota Production System (TPS). However, Toyota famously did not adopt the procedure from Ford, but from Piggly Wiggly. Although Toyota visited Ford as part of its tour of American businesses, Ford had not fully adopted the Just-In-Time system, and Toyota executives were appalled at the piles of inventory laying around and the uneven work schedule of the employees of Ford. Toyota also visited Piggly Wiggly, and it was there that Toyota executives first observed a fully functioning and successful Just-In-Time system, and modelled TPS after it.

It is hard for Japanese corporations to warehouse finished products and parts, due to the limited amount of land available for them. Before the 1950s, this was thought to be a disadvantage because it forced the production lot size below the economic lot size. (An economic lot size is the number of identical products that should be produced, given the cost of changing the production process over to another product.) The undesirable result was poor return on investment for a factory.

The chief engineer at Toyota in the 1950s, Taiichi Ohno, examined accounting assumptions and realized that another method was possible. The factory could implement JIT which would require it to be made more flexible and reduce the overhead costs of retooling and thereby reduce the economic lot size to fit the available warehouse space. JIT is now regarded by Ohno as one of the two 'pillars' of the Toyota Production System.

Therefore over a period of several years, Toyota engineers redesigned car models for commonality of tooling for such production processes as paint-spraying and welding. Toyota was one of the first to apply flexible robotic systems for these tasks. Some of the changes were as simple as standardizing the hole sizes used to hang parts on hooks. The number and types of fasteners were reduced in order to standardize assembly steps and tools. In some cases, identical sub-assemblies could be used in several models.

Toyota engineers then determined that the remaining critical bottleneck in the retooling process was the time required to change the stamping dies used for body parts. These were adjusted by hand, using crowbars and wrenches. It sometimes took as long as several days to install a large, multi-ton die set and adjust it for acceptable quality. Further, these were usually installed one at a time by a team of experts, so that the line was down for several weeks.

So Toyota implemented a strategy now called Single Minute Exchange of Die (SMED), developed with Shigeo Shingo. With very simple fixtures, measurements were substituted for adjustments. Almost immediately, die change times fell to hours instead of days. At the same time, quality of the stampings became controlled by a written recipe, reducing the skill level required for the change. Further analysis showed that a lot of the remaining time was used to search for hand tools and move dies. Procedural changes (such as moving the new die in place with the line in operation) and dedicated tool-racks reduced the die-change times to as little as 40 seconds. Today dies are changed in a ripple through the factory as a new product begins flowing.

After SMED, economic lot sizes fell to as little as one vehicle in some Toyota plants. Carrying the process into parts-storage made it possible to store as little as one part in each assembly station. When a part disappeared, that was used as a signal (Kanban) to produce or order a replacement.

6.3 PHILOSOPHY

The philosophy of JIT is simple - inventory is defined to be waste. JIT inventory systems expose the hidden causes of inventory keeping and are therefore not a simple solution a company can adopt; there is a whole new way of working the company must follow in order to manage its consequences. The ideas in this way of working come from many different disciplines including statistics, industrial engineering, production management and behavioural science. In the JIT inventory philosophy there are views with respect to how inventory is looked upon, what it says about the management within the company, and the main principle behind JIT. Inventory is seen as incurring costs, or waste, instead of adding and storing value, contrary to traditional accounting. This does not mean to say JIT is implemented without awareness that removing inventory exposes pre-existing manufacturing issues. With this way of working, businesses are encouraged to eliminate inventory that does not compensate for manufacturing process issues, and then to constantly improve those processes so that less inventory can be kept. Secondly, allowing any stock habituates the management to stock keeping and it can then be a bit like a narcotic. Management are then tempted to keep stock there to hide problems within the production system. These problems include backups at work centres, machine reliability, and process variability, lack of flexibility of employees and equipment, and inadequate capacity among other things.

In short, the just-in-time inventory system is all about having ―the right material, at the right time, at the right place, and in the exact amount‖, without the safety net of inventory. The JIT system has implications of which are broad for the implementors.

Stocks JIT emphasises inventory as one of the seven wastes (overproduction, waiting time, transportation, inventory, processing, motion and product defect), and as such its practice involves the philosophical aim of reducing input buffer inventory to zero. Zero buffer inventory means that production is not protected from exogenous (external) shocks. As a result, exogenous shocks reducing the supply of input can easily slow or stop production with significant negative consequences. For example, Toyota suffered a major supplier failure as a result of the 1997 Aisin fire which rendered one of its suppliers incapable of fulfilling Toyota's orders. In the U.S., the 1992 railway strikes resulted in General Motors having to idle a 75,000-worker plant because they had no supplies coming in.

Transaction cost approach; JIT reduces inventory in a firm. However, unless it is used throughout the supply chain, it can be hypothesized that firms are simply outsourcing their input inventory to suppliers (Naj 1993). This effect was investigated by Newman (1993), who found, on average, suppliers in Japan charged JIT customers a 5% price premium.

Environmental concerns; During the birth of JIT, multiple daily deliveries were often made by bicycle; with increases in scale has come the adoption of vans and lorries (trucks) for these deliveries. Cusumano (1994) has highlighted the potential and actual problems this causes with regard to gridlock and the burning of fossil fuels. This violates three JIT wastes: 1. Time; wasted in traffic jams 2. Inventory; specifically pipeline (in transport) inventory and 3. Scrap; with respect to petrol or diesel burned while not physically moving.

Price volatility JIT implicitly assumes a level of input price stability such that it is desirable to inventory inputs at today's prices. Where input prices are expected to rise storing inputs may be desirable.

Quality volatility JIT implicitly assumes the quality of available inputs remains constant over time. If not, firms may benefit from hoarding high quality inputs.

Demand stability Karmarker (1989) highlights the importance of relatively stable demand which can help ensure efficient capital utilisation rates. Karmarker argues without a significant stable component of demand, JIT becomes untenable in high capital cost production. In the U.S., the 1992 railway strikes resulted in General Motors having to idle a 75,000-worker plant because they had no supplies coming in.

6.4 JIT IMPLEMENTATION DESIGN

Step 1: Awareness Revolution

It means giving up old concept of managing and adopting JIT way of thinking. There are 10 principles for improvement:

1. Abolish old tradition concepts.

2. Assume that new method will work.

3. No excuses is accepted.

4. It is not seeking for perfection, absolutely zero-defect process, few defects is acceptable.

5. Correct mistakes immediately.

6. Do not spend money on improvement.

7. Use you brain to solve problem.

8. Repeat to ask yourself 5 times before any decision.

9. Gather information from several people, more is better!

10. Remember that improvement has no limits. (Hirano, 18)

The idea of giving up old concept was especially for the large lot production, The lot production was felt that "having fewer changeover was better", but it was no longer true. Whereas JIT is a one-piece flow manufacturing;. To compare the two, Hirano had this idea:

Lot production: "Unneeded goods...In unneeded quantities...At unneeded times..." (20) JIT: "Needed goods...In needed quantities...At needed times..." (21)

The main point here is to have an awareness of the need of throwing out old system and adopting a new one.

Step 2: 5S's For Workplace Improvement (Hirano, 2008)

The 5S's stand for:

Seiri - Proper Arrangement

Seiton - Orderliness

Seiso - Cleanliness

Seiketsu - Clean-up

Shitsuke - Discipline

This 5S's should be implemented company-wide and this should be part of a total improvement program.

Seiri - Proper Arrangement means sorting what you have, identifying the needs and throwing out those unnecessary.

One example is using red-tags. This is a little red-bordered paper saying what the production is, how many are accumulated and then stick these red tags onto every box of inventory . It enhances the easiness to know the inventory status and can reduce cost.

Seiton - Orderliness means making thing in order. Examples include keeping shelves in order, keeping storage areas in order, keeping workplace in order, keeping worktables in order and keeping the office in order.

Seiso - Cleanliness means having a clean workplace, equipment, etc.

Seiketsu - Cleanup mean maintaining equipment and tools.

Shitsuke - Discipline means following the rules and making them a habit.

Step 3: Flow Manufacturing (Hirano, 2008)

Flow manufacturing means producing one single piece of product at a time but multi-handling which follows the process sequence.

There are several main points concerning flow manufacturing:

1. Arrange machines in sequence.
2. U-shaped production line (Cellular Manufacturing).
3. Produce one-piece at a time.
4. Train workers to be multi-skilled.
5. Follow the cycle time.
6. Let the workers standing and walking around while working.
7. Use small and dedicated machines.

Discussion

Discuss Hirano's differences between Lot Production and Flow Manufacturing and present a tabulation of the differences.

Step 4: Standard Operations (Hirano, 2008)

Standard Operation means to produce quality safely and less expensively through efficient rules and methods of arranging people, products and machines.

The bases of standard operations are:

1. Cycle time It means how long it would take to "carry out part all the way through the cell". (Hirano,) Following are the equations for calculating cycle time. (Hirano,)

Daily Quantity Required = Monthly Quantity Needed / Working Days per month

Cycle Time = Working Hours per day / Daily Quantity Required

2. Work sequence

3. Standard stock-on-hand

4. Use operation charts

Step 5: Multi-Process Handling

Multi-process handling means one worker is responsible for several processes in a cell. (Hirano,)

Some points that should be aware: (Hirano,)

· Clearly assign jobs to machines and workers.

· Make a good use of U-shaped cell manufacturing.

· Multi-skilled workers

· Operation should be able to perform multi-machine handling and multi process handling.

Multi-machine handling - a worker should handle several machines at once, this is also called "horizontal handling". (Hirano,)

Multi-process handling - a worker should handle several different processes at once, this is also called "vertical handling" and this is the basis for JIT production. (Hirano,)

· Uses casters extensively As author written, "Floor bolts are our enemies! Machines must be movable." (Hirano,)

The above 5 steps are the basis for introducing JIT. Only after these are completed can JIT be implemented.

Some of the initial results at Toyota were horrible, but in contrast to that a huge amount of cash appeared, apparently from nowhere, as in-process inventory was built out and sold. This by itself generated tremendous enthusiasm in upper management.

Another surprising effect was that the response time of the factory fell to about a day. This improved customer satisfaction by providing vehicles usually within a day or two of the minimum economic shipping delay.

Also, many vehicles began to be built to order, completely eliminating the risk they would not be sold. This dramatically improved the company's return on equity by eliminating a major source of risk.

Since assemblers no longer had a choice of which part to use, every part had to fit perfectly. The result was a severe quality assurance crisis, and a dramatic improvement in product quality. Eventually, Toyota redesigned every part of its vehicles to eliminate or widen tolerances, while simultaneously implementing careful statistical controls for quality control. Toyota had to test and train suppliers of parts in order to assure quality and delivery. In some cases, the company eliminated multiple suppliers.

When a process problem or bad parts surfaced on the production line, the entire production line had to be slowed or even stopped. No inventory meant that a line could not operate from in-process inventory while a production problem was fixed.

Many people in Toyota confidently predicted that the initiative would be abandoned for this reason. In the first week, line stops occurred almost hourly. But by the end of the first month, the rate had fallen to a few line stops per day. After six months, line stops had so little economic effect that Toyota installed an overhead pull-line, similar to a bus bell-pull, that permitted any worker on the production line to order a line stop for a process or quality problem. Even with this, line stops fell to a few per week.

The result was a factory that eventually became the envy of the industrialized world, and has since been widely emulated.

The just-in-time philosophy was also applied to other segments of the supply chain in several types of industries. In the commercial sector, it meant eliminating one or all of the warehouses in the link between a factory and a retail establishment.

Benefits As most companies use an inventory system best suited for their company, the Just In-Time Inventory System (JIT) can have many benefits resulting from it. The main benefits of JIT are listed below.

1. Set up times are significantly reduced in the factory. Cutting down the set up time to be more productive will allow the company to improve their bottom line to look more efficient and focus time spent on other areas that may need improvement. This allows the reduction or elimination of the inventory held to cover the "changeover" time, the tool used here is SMED. 2. The flows of goods from warehouse to shelves are improved. Having employees

focused on specific areas of the system will allow them to process goods faster instead of having them vulnerable to fatigue from doing too many jobs at once and simplifies the tasks at hand. Small or individual piece lot sizes reduce lot delay inventories which simplifies inventory flow and its management. 3. Employees who possess multiple skills are utilized more efficiently. Having employees trained to work on different parts of the inventory cycle system will allow companies to use workers in situations where they are needed when there is a shortage of workers and a high demand for a particular product. 4. Better consistency of scheduling and consistency of employee work hours. If there is no demand for a product at the time, workers don‘t have to be working. This can save the company money by not having to pay workers for a job not completed or could have them focus on other jobs around the warehouse that would not necessarily be done on a normal day. 5. Increased emphasis on supplier relationships. No company wants a break in their inventory system that would create a shortage of supplies while not having inventory sit on shelves. Having a trusting supplier relationship means that you can rely on goods being there when you need them in order to satisfy the company and keep the company name in good standing with the public. 6. Supplies continue around the clock keeping workers productive and businesses focused on turnover. Having management focused on meeting deadlines will make employees work hard to meet the company goals to see benefits in terms of job satisfaction, promotion or even higher pay.

Problems

1. Within a JIT system; the major problem with just-in-time operation is that it leaves the supplier and downstream consumers open to supply shocks and large supply or demand changes. For internal reasons, this was seen as a feature rather than a bug by Ohno, who used the analogy of lowering the level of water in a river in order to expose the rocks to explain how removing inventory showed where flow of production was interrupted. Once the barriers were exposed, they could be removed; since one of the main barriers was rework, lowering inventory forced each shop to improve its own quality or cause a holdup in the next downstream area. One of the other key tools to manage this weakness is production levelling to remove these variations. Just-in time is a means to improving performance of the system, not an end.

With very low stock levels meaning that there are shipments of the same part coming in sometimes several times per day, Toyota is especially susceptible to an interruption in the flow. For that reason, Toyota is careful to use two suppliers for most assemblies. As noted in Liker (2003), there was an exception to this rule that put the entire company at risk by the 1997 Aisin fire. However, since Toyota also makes a point of maintaining high quality relations with its entire supplier network, several other suppliers immediately took up production of the Aisin-built parts by using existing capability and documentation. Thus, a strong, long-term relationship with a few suppliers is preferred to short-term, price-based relationships with competing suppliers. This long-term relationship has also been used by Toyota to send Toyota staff into their suppliers to improve their suppliers' processes. These interventions have now been going on for twenty years and result in improved margins for Toyota and the supplier as well as lower final customer costs and a more reliable supply chain. Toyota encourages their suppliers to duplicate this work with their own suppliers.

2. Within a raw material stream As noted by Liker (2003) and Womack and Jones (2003), it would ultimately be desirable to introduce synchronised flow and linked JIT all the way back through the supply stream. However, none followed this in detail all the way back through the processes to the raw materials. With present technology, for example, an ear of corn cannot be grown and delivered to order. The same is true of most raw materials, which must be discovered and/or grown through natural processes that require time and must account for natural variability in weather and discovery. The part of this currently viewed as impossible is the synchronised part of flow and the linked part of JIT. It is for the reasons stated raw materials companies decouple their supply chain from their clients' demand by carrying large 'finished goods' stocks. Both flow and JIT can be implemented in isolated process islands within the raw materials stream. The challenge then becomes to achieve that isolation by some means other than the huge stocks they carry to achieve it today.

It should be noted that the advent of the mini mill steelmaking facility is starting to challenge how far back JIT can be implemented, as the electric arc furnaces at the heart of many mini-mills can be started and stopped quickly, and steel grades changed rapidly.

3. Oil It has been frequently charged that the oil industry has been influenced by JIT. The argument is presented as follows:

The number of refineries in the United States has fallen from 279 in 1975 to 205 in 1990 and further to 149 in 2004. As a result, the industry is susceptible to supply shocks, which cause spikes in prices and subsequently reduction in domestic manufacturing output. The effects of hurricanes Katrina and Rita are given as an example: in 2005, Katrina caused the shutdown of 9 refineries in Louisiana and 6 more in Mississippi, and a large number of oil production and transfer facilities, resulting in the loss of 20% of the US domestic refinery output. Rita subsequently shut down refineries in Texas, further reducing output. The GDP figures for the third and fourth quarters showed a slowdown from 3.5% to 1.2% growth. Similar arguments were made in earlier crises.

Besides the obvious point that prices went up because of the reduction in supply and not for anything to do with the practice of JIT, JIT students and even oil & gas industry analysts question whether JIT as it has been developed by Ohno, Goldratt, and others is used by the petroleum industry. Companies routinely shut down facilities for reasons other than the application of JIT. One of those reasons may be economic rationalization: when the benefits of operating no longer outweigh the costs, including opportunity costs, the plant may be economically inefficient. JIT has never subscribed to such considerations directly; following Waddel and Bodek (2005), this ROI-based thinking conforms more to Brown-style accounting and Sloan management. Further, and more significantly, JIT calls for a reduction in inventory capacity, not production capacity. From 1975 to 1990 to 2005, the annual average stocks of gasoline have fallen by only 8.5% from 228,331 to 222,903 bbls to 208,986 (Energy Information Administration data). Stocks fluctuate seasonally by as much as 20,000 bbls. During the 2005 hurricane season, stocks never fell below 194,000 thousand bbls, while the low for the period 1990 to 2006 was 187,017 thousand bbls in 1997. This shows that while industry storage capacity has decreased in the last 30 years, it hasn't been drastically reduced as JIT practitioners would prefer.

Finally, as shown in a pair of articles in the Oil & Gas Journal, JIT does not seem to have been a goal of the industry. In Waguespack and Cantor (1996), the authors point out that JIT would require a significant change in the supplier/refiner relationship, but the changes in inventories in the oil industry exhibit none of those tendencies. Specifically, the relationships remain cost-driven among many competing suppliers rather than quality-based among a select few long-term relationships. They find that a large part of the shift came about because of the availability of short-haul crudes from Latin America. In the follow-up editorial, the Oil & Gas Journal claimed that "casually adopting popular business terminology that doesn't apply" had provided a "rhetorical bogey" to industry critics. Confessing that they had been as guilty as other media sources, they confirmed that "It also happens not to be accurate."

Summary

BUSINESS MODELS FOLLOWING SIMILAR APPROACH

Vendor Managed Inventory (VMI) employs the same principles as those of JIT inventory however the responsibilities of managing inventory is placed with the vendor in a vendor/customer relationship. Whether it‘s a manufacturer who is managing inventory for a distributor, or a distributor managing inventory for their customers; the role of managing inventory is given to the vendor.

The primary advantage of this business model is that the vendor has industry experience and expertise which enables them to better anticipate demand and inventory needs. The inventory planning and controlling is facilitated by the use of applications that allow vendors to have access to the inventory picture of its customer.

Third party applications offer vendors the benefit afforded by a quick implementation time. Further, such companies hold valuable inventory management knowledge and expertise that helps organizations immensely.

Customer Managed Inventory; With Customer Managed Inventory (CMI), the customer as opposed to the vendor in a VMI model is given the responsibility of making all inventory decisions. This is similar to the concepts employed by JIT inventory. With a clear picture of their inventory and that of their supplier‘s, the customer is able to anticipate fluctuations in demand and make inventory replenishment decisions accordingly.

Discussion

1. Where did the just-in-time approach to production and operation management come from?

2. What is the philosophy behind it?

3. How would one begin to implement such an approach?

4. What are the chief differences between a vender-managed inventory and a customer-managed inventory?

UNIT 7

TOYOTA: A CASE STUDY

The seventh unit considers, in some detail, the case of Toyota. Not only is it now the largest car company in the world but it is regarded as owing much of its success to its innovative approach to production and operations management techniques.

Learning Outcomes

By the end of this unit students should be able to;

- Articulate a brief history of Toyota, before considering what is meant by the Toyota Way
- Finally consider some of the main tenets of the Toyota production system.

7.1 INTRODUCTION

Toyota Motor Corporation,; a multinational corporation headquartered in Japan, is the world's largest automaker. As of 2008, Toyota employs approximately 316,000 people around the world in comparison to second ranked automaker General Motors' 266,000 employees. Toyota ranks as the World's fifth largest publicly traded company, ahead of ninth ranked competitor General Motors, according to Fortune Magazine's Global 500.

In 1934, while still a department of Toyota Industries, it created its first product Type A engine and in 1936 its first passenger car the Toyota AA. The company was eventually founded by Kiichiro Toyoda in 1937 as a spinoff from his father's company Toyota Industries to create automobiles. Toyota currently owns and operates Lexus and Scion brands and has a majority shareholding stake in Daihatsu Motors, and minority shareholdings in Fuji Heavy Industries Isuzu Motors, and Yamaha Motors. The company includes 522 subsidiaries.

Toyota is headquartered in Toyota City and Nagoya (both in Aichi), and in Tokyo. In addition to manufacturing automobiles, Toyota provides financial services through its division Toyota Financial Services and also creates robots. Toyota Industries and Finance divisions form the bulk of the Toyota Group, one of the largest conglomerates in the world.

History In 1933, Toyoda Automatic Loom Works created a new division devoted to the production of automobiles under the direction of the founder's son, Kiichiro Toyoda. Kiichiro Toyoda had travelled to Europe and the United States in 1929 to investigate automobile production and had begun researching gasoline-powered engines in 1930. Toyoda Automatic Loom Works was encouraged to develop automobile production by the Japanese government, which needed domestic vehicle production partly due to the worldwide money shortage and partly due to the war with China. In 1934, the division produced its first Type A Engine, which was used in the first Model A1 passenger car in May 1935 and the G1 truck in August 1935. Production of the Model AA passenger car started in 1936. Early vehicles bear a striking resemblance to the Dodge Power Wagon and Chevrolet, with some parts actually interchanging with their American originals.

Although the Toyota Group is best known today for its cars, it is still in the textile business and still makes automatic looms, which are now computerized and electric sewing machines which are available worldwide.

Toyota Motor Co. was established as an independent and separate company in 1937. During the Pacific War (World War II) the company was dedicated to truck production for the Imperial Japanese Army. Because of severe shortages in Japan, military trucks were kept as simple as possible. For example, the trucks had only one headlight on the center of the hood. The war ended shortly before a scheduled Allied bombing run on the Toyota factories in Aichi.

After the war, commercial passenger car production started in 1947 with the model SA. In 1950, a separate sales company, Toyota Motor Sales Co., was established (which lasted until July 1982). In April 1956, the Toyo-pet dealer chain was established. The following year, the Crown became the first Japanese car to be exported to the United States and Toyota's American and Brazilian divisions, Toyota Motor Sales Inc. and Toyota do Brazil S.A., were also established.

Toyota began to expand in the 1960s with a new research and development facility, a presence in Thailand was established, the 10 millionth model was produced, a Deming Prize and partnerships with Hino Motors and Daihatsu were also established. The first Toyota built outside Japan was in April 1963, at Port Melbourne in Australia. By the end of the decade, Toyota had established a worldwide presence, as the company had exported its one-millionth unit.

With high petrol prices and a weak US economy in the summer of 2008, Toyota reported a double-digit decline in sales for the month of June, similar to figures reported by the Detroit Big Three. For Toyota, these were attributed mainly to slow sales of its Tundra pickup, as well as shortages of its fuel-efficient vehicles such as the Prius, Corolla and Yaris. In response, the company has announced plans to idle its truck plants, while shifting production at other facilities to manufacture in-demand vehicles.

Company overview The Toyota Motor Company was awarded its first Japanese Quality Control Award at the start 1980s and began participating in a wide variety of Motorsports. Due to the 1973 oil crisis consumers in the lucrative U.S. market began turning to small cars with better fuel economy. American car manufacturers had considered small economy cars to be an ―entry level‖ product, and their small vehicles were made to a low level of quality in order to keep the price low. Japanese customers, however, had a long-standing tradition of demanding small fuel-efficient cars that were manufactured to a high level of quality. Because of this, companies like Toyota, Honda, and Nissan established a growing presence in North America in the 1970s.

In 1982, the Toyota Motor Company and Toyota Motor Sales merged into one company, the Toyota Motor Corporation. Two years later, Toyota entered into a joint venture with GM called NUMMI, the New United Motor Manufacturing, Inc., operating an automobile manufacturing plant in Fremont, California. The factory was an old General Motors plant that had been closed for several years. Toyota then started to establish new brands at the end of the 1980s, with the launch of their luxury division Lexus in 1989.

In the 1990s Toyota began to branch out from producing mostly compact cars by adding many larger and more luxurious vehicles to its line-up, including a full sized pickup, the T100 (and later the Tundra), several lines of SUVs, a sport version of the Camry, known as the Camry Solara, and the Scion brand, a group of several affordable, yet sporty, automobiles targeted specifically to young adults. Toyota also began production of the world's best-selling hybrid car, the Prius, in 1997. With a major presence with Europe, due to the success of Toyota Team Europe, the corporation decided to set up TMME, Toyota Motor Europe Marketing & Engineering, to help market vehicles in the continent. Two years later, Toyota set up a base in the United Kingdom, TMUK, as the company's cars had become very popular among British drivers. Bases in Indiana, Virginia and Tianjin were also set up. In 1999, the company decided to list itself on the New York and London Stock Exchange.

In 2001, Toyota's Toyo Trust and Banking merged to form the UFJ, United Financials of Japan, which was accused of corruption by the Japan's government for making bad loans to alleged Yakuza crime syndicates with executives accused of blocking Financial Service Agency inspections. The UFJ was listed among Fortune Magazine's largest money-losing corporations in the world, with Toyota's chairman serving as a director. At the time, the UFJ was one of the largest shareholders of Toyota. As a result of Japan's banking crisis, the UFJ was merged again to become Mitsubishi UFJ Financial Group.

In 2002, Toyota managed to enter a Formula One works team and establish joint ventures with French motoring companies Citroën and Peugeot, a year after Toyota started producing cars in France.

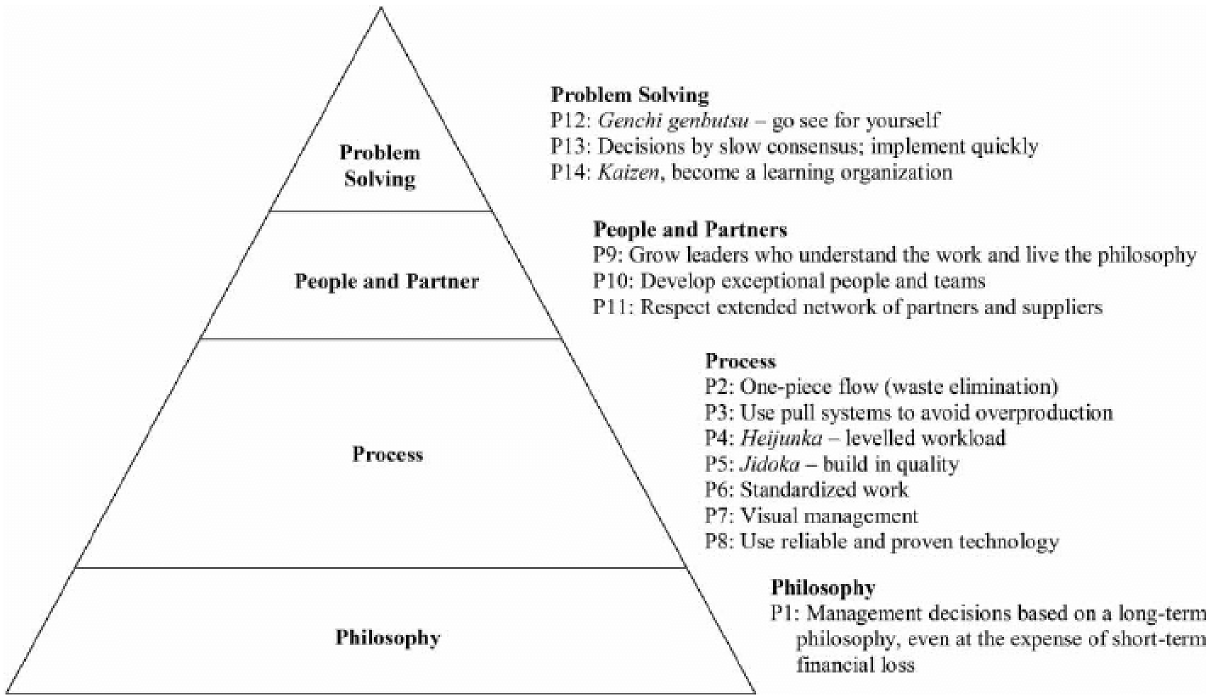
Toyota ranked eight on Forbes 2000 list of world's leading companies for the year 2005. The company was number one in global automobile sales for the first quarter of 2008.

On December 7, 2004, a U.S. press release was issued stating that Toyota would be offering Sirius Satellite Radios. However, as late as Jan. 27, 2007, Sirius Satellite Radio and XM Satellite radio kits were not available for Toyota factory radios. While the press release enumerated nine models, only limited availability existed at the dealer level in the U.S. As of 2008, all Toyota and Scion models have either standard or available XM radio kits. Major Lexus dealerships have been offering satellite radio kits for Lexus vehicles since 2005, in addition to factory-equipped satellite radio models.

In 2007, Toyota released an update of its full size truck, the Tundra, produced in two American factories, one in Texas and one in Indiana. ―Motor Trend‖ named the Tundra ―Truck of the Year,‖ and the 2007 Toyota Camry ―Car of the Year‖ for 2007. It also began the construction of two new factories, one to build the RAV4 in Woodstock, Ontario and the other to build the Toyota Prius in Blue Springs, Mississippi. This plant was originally intended to build the Toyota Highlander, but Toyota decided to use the plant in Princeton, Indiana instead. The company has also found recent success with its smaller models - the Corolla and Yaris - as petrol prices have risen rapidly in the last few years.

7.2 THE TOYOTA WAY

The 14 Principles of the Toyota Way is a management philosophy used by the Toyota corporation that includes the Toyota Production System. The main ideas are to base management decisions on a ―philosophical sense of purpose‖, to think long term, to have a process for solving problems, to add value to the organization by developing its people, and to recognize that continuously solving root problems drives organizational learning.



Since the 1980s, Toyota and Lexus vehicles have been recognized for their quality and are consistently ranked higher than other car makes in owner satisfaction surveys, due in large part (according to Jeffrey Liker, a University of Michigan professor of industrial engineering) to the business philosophy that underlies its system of production.

The 14 Principles The Toyota Way has been called ―a system designed to provide the tools for people to continually improve their work‖ The 14 principles of The Toyota Way are organized in four sections: 1) Long-Term Philosophy, 2) The Right Process Will Produce the Right Results, 3) Add Value to the Organization by Developing Your People, and 4) Continuously Solving Root Problems Drives Organizational Learning. The principles are set out and briefly described below:

Section I — Long-Term Philosophy

Principle 1 Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals. People need purpose to find motivation and establish goals.

Section **II** — The Right Process Will Produce the Right Results

Principle 2 Create a continuous process flow to bring problems to the surface. Work processes are redesigned to eliminate waste (muda) through the process of continuous improvement — kaizen. The eight types of muda are: 1. Overproduction 2. Waiting (time on hand) 3. Unnecessary transport or conveyance 4. Over processing or incorrect processing 5. Excess inventory 6. Unnecessary movement 7. Defects 8. Unused employee creativity

Principle 3 Use “pull” systems to avoid overproduction. A method where a process signals its predecessor that more material is needed. The pull system produces only the required material after the subsequent operation signals a need for it. This process is necessary to reduce overproduction.

Principle 4 Level out the workload (Heijunka). (Work like the tortoise, not the hare). This helps achieve the goal of minimizing waste (muda), not overburdening people or the equipment (muri), and not creating uneven production levels (Mura).

Principle 5 Build a culture of stopping to fix problems, to get quality right the first time. Quality takes precedence (Jidoka). Any employee in the Toyota Production System has the authority to stop the process to signal a quality issue.

Principle 6 Standardized tasks and processes are the foundation for continuous improvement and employee empowerment. Although Toyota has a bureaucratic system, the way that it is implemented allows for continuous improvement (kaizen) from the people affected by that system. It empowers the employee to aid in the growth and improvement of the company.

Principle 7 Use visual control so no problems are hidden. Included in this principle is the 5S Program - steps that are used to make all work spaces efficient and productive, help people share work stations, reduce time looking for needed tools and improve the work environment. Sort: Sort out unneeded items Straighten: Have a place for everything Shine: Keep the area clean Standardize: Create rules and standard operating procedures Sustain: Maintain the system and continue to improve it

Principle 8 Use only reliable, thoroughly tested technology that serves your people and processes. Technology is pulled by manufacturing, not pushed to manufacturing.

Section **III** — Add Value to the Organization by Developing Your People

Principle 9 Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others. Without constant attention, the principles will fade. The principles have to be ingrained; it must be the way one thinks. Employees must be educated and trained: they have to maintain a learning organization.

Principle 10 Develop exceptional people and teams who follow your company's philosophy. Teams should consist of 4-5 people and numerous management tiers. Success is based on the team, not the individual.

Principle 11 Respect your extended network of partners and suppliers by challenging them and helping them improve. Toyota treats suppliers much like they treat their employees, challenging them to do better and helping them to achieve it. Toyota provides cross functional teams to help suppliers discover and fix problems so that they can become a stronger, better supplier.

Section IV: Continuously Solving Root Problems Drives Organizational Learning

Principle 12 Go and see for yourself to thoroughly understand the situation (Genchi Genbutsu). Toyota managers are expected to ―go-and-see‖ operations. Without experiencing the situation first hand, managers will not have an understanding of how it can be improved. Furthermore, managers use Tadashi Yamashima's (President, Toyota Technical Centre (TCC)) ten management principles as a guideline: 1. Always keep the final target in mind. 2. Clearly assign tasks to yourself and others. 3. Think and speak on verified, proven information and data. 4. Take full advantage of the wisdom and experiences of others to send, gather or discuss information. 5. Share information with others in a timely fashion. 6. Always report, inform and consult in a timely manner. 7. Analyse and understand shortcomings in your capabilities in a measurable way. 8. Relentlessly strive to conduct kaizen activities. 9. Think ―outside the box,‖ or beyond common sense and standard rules. 10. Always be mindful of protecting your safety and health.

Principle 13 Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi). The following are decision parameters: 1. Find what is really going on (go-and-see) to test 2. Determine the underlying cause 3. Consider a broad range of alternatives 4. Build consensus on the resolution 5. Use efficient communication tools

Principle 14 Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen). The process of becoming a learning organization involves criticizing every aspect of what one does. The general problem solving technique to determine the root cause of a problem includes: 1. Initial problem perception 2. Clarify the problem 3. Locate area/point of cause 4. Investigate root cause (5 whys) 5. Counter measure 6. Evaluate 7. Standardize

Translating the principles There is a question of uptake of the principles now that Toyota has production operations in many different countries around the world. As a New York Times article notes, while the corporate culture may have been easily disseminated by word of mouth when Toyota manufacturing was only in Japan, with worldwide production, many different cultures must be taken into account. Concepts such as ―mutual ownership of problems,‖ or ―Genchi Genbutsu,‖ (solving problems at the source instead of behind desks), and the ―kaizen mind,‖ (an unending sense of crisis behind the company‘s constant drive to improve), may be unfamiliar to North Americans and people of other cultures. A recent increase in vehicle recalls may be due, in part, to ―a failure by Toyota to spread its obsession for craftsmanship among its growing ranks of overseas factory workers and managers.‖ Toyota is attempting to address these needs by establishing training institutes in the United States and in Thailand.

Discussion

Apply the ten management principles to other business industries expanding upon how they can be implemented on said industries and businesses.

7.3 TOYOTA PRODUCTION SYSTEM

The Toyota Production System (TPS) refers to an integrated socio-technical system, developed by Toyota, that comprises its management philosophy and practices. The TPS organizes manufacturing and logistics for the automobile manufacturer, including interaction with suppliers and customers. The system is a major precursor of the more generic ―Lean manufacturing.‖. The system was developed between 1948 and 1975.

Originally called ―Just In Time Production,‖ it builds on the approach created by the founder of Toyota, Sakichi Toyoda, his son Kiichiro Toyoda, and the engineer Taiichi Ohno. The founders of Toyota drew heavily on the work of W. Edwards Deming and the writings of Henry Ford. When these men came to the United States to observe the assembly line and mass production that had made Ford rich, they were unimpressed. While shopping in a supermarket they observed the simple idea of an automatic drink resupplied; when the customer wants a drink, he takes one, and another replaces it. The principles underlying the TPS are embodied in The Toyota Way.

Goals The main objectives of the TPS are to design out overburden and inconsistency, and to eliminate waste. The most significant effects on process value delivery are achieved by designing a process capable of delivering the required results smoothly; by designing out 'mura'. It is also crucial to ensure that the process is as flexible as necessary without stress or 'muri' since this generates 'muda'. Finally the tactical improvements of waste reduction or the elimination of 'muda' are very valuable.

There are seven kinds of muda that are addressed in the TPS: 1. over-production 2. Motion (of operator or machine) 3. Waiting (of operator or machine) 4. Conveyance 5. Processing itself 6. Inventory (raw material) 7. Corrections (reworks and scrap)

The elimination of 'muda' has come to dominate the thinking of many when they look at the effects of the TPS because it is the most familiar of the three to implement. In the TPS many initiatives are triggered by 'Mura' or 'Muri' reduction which drives out 'Muda' without specific focus on its reduction.

Origins

This system, more than any other aspect of the company, is responsible for having made Toyota the company it is today. Toyota has long been recognized as a leader in the automotive manufacturing and production industry.

It may be surprising that Toyota received their inspiration for part of their production system in the United States, but not from its automotive production process. This occurred when a delegation from Toyota visited the United States to study its commercial enterprises. They first visited several Ford Motor Company automotive plants in Michigan, but despite Ford being the industry leader at that time, found many of the methods in use to be not very effective. They were mainly appalled by the large amounts of inventory on site and by how the amount of work being performed in various departments within the factory was uneven on most days. However, on their visit to a Piggly Wiggly, an American supermarket, the delegation was inspired by how the supermarket only reordered and restocked goods once they‘d been bought by customers.

Toyota applied the lesson from Piggly Wiggly by reducing the amount of inventory they would hold only to a level that its employees would need for a small period of time, and then subsequently reorder. This is highly representative of a Just-in-Time (JIT) inventory system.

While low inventory levels are a key outcome of the Toyota Production System, an important element of the philosophy behind its system is to work intelligently and eliminate waste so that inventory is no longer needed. Many American businesses, having observed Toyota's factories, set out to attack high inventory levels directly without understanding what made these reductions possible. The act of imitating without understanding the underlying concept or motivation may have led to the failure of those projects.

The Toyota production system has been compared to squeezing water from a dry towel. What this means is that it is a system for thorough waste elimination. Here, waste refers to anything which does not advance the process, everything that does not increase added value. Many people settle for eliminating the waste that everyone recognises as waste. But much remains that simply has not yet been recognised as waste or that people are willing to tolerate.

People had resigned themselves to certain problems, had become hostage to routine and abandoned the practice of problem-solving. This going back to basics, exposing the real significance of problems and then making fundamental improvements, can be witnessed throughout the Toyota Production System,

Summary

Results Toyota was able to greatly reduce lead time and cost using the TPS, while improving quality. This enabled it to become one of the ten largest companies in the world. It is currently as profitable as all the other car companies combined and became the largest car manufacturer in 2007. It has been proposed that the TPS is the most prominent example of the 'correlation', or middle, stage in a science, with material requirements planning and other data gathering systems representing the 'classification' or first stage. A science in this stage can see correlations between events and can propose some procedures that allow some predictions of the future. Due to the success of the production philosophy's predictions many of these methods have been copied by other manufacturing companies, although mostly unsuccessfully.

Discussion

1. After reading the brief history of Toyota, what would you say are the principal reasons for its success?

2. What is meant by the Toyota Way?

3. List the main tenets of the Toyota production system.

UNIT 8

PRODUCT DEVELOPMENT IN A TQM ENVIRONMENT

The eighth, and final unit, serves to encapsulate the key points of the module by presenting an overview of production and operations management within the framework of Total Quality Management‘, or TQM for short.

Learning Outcomes

By the end of this unit students should be able to;

- Explain what is meant by total quality management
- Consider what its main drivers today.
- State the fifteen principles of production of operations management within the framework of TQM.

8.1 TOTAL QUALITY MANAGEMENT (TQM)

Total Quality Management is an approach to the art of management that originated in Japanese industry in the 1950's and has become steadily more popular in the West since the early 1980's. Total Quality is a description of the culture, attitude and organization of a company that aims to provide, and continue to provide, its customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with things being done right first time, and defects and waste eradicated from operations.

Many companies have difficulties in implementing TQM. Surveys by consulting firms have found that only 20-36% of companies that have undertaken TQM have achieved either significant or even tangible improvements in quality, productivity, competitiveness or financial return. As a result many people are sceptical about TQM. However, when you look at successful companies you find a much higher percentage of successful TQM implementation.

Some useful messages from results of TQM implementations: if you want to be a first-rate company, don't focus on the second-rate companies who can't handle TQM, look at the world-class companies that have adopted it the most effective way to spend TQM introduction funds is by training top management, people involved in new product development, and people involved with customers it's much easier to introduce EDM/PDM in a company with a TQM culture than in one without TQM. People in companies that have implemented TQM are more likely to have the basic understanding necessary for implementing EDM/PDM. For example, they are more likely to view EDM/PDM as an information and workflow management system supporting the entire product life cycle then as a departmental solution for the management of CAD data

Important aspects of TQM include customer-driven quality, top management leadership and commitment, continuous improvement, fast response, actions based on facts, employee participation, and a TQM culture.

8.2 CUSTOMER-DRIVEN QUALITY

TQM has a customer-first orientation. The customer, not internal activities and constraints, comes first. Customer satisfaction is seen as the company's highest priority. The company believes it will only be successful if customers are satisfied. The TQM company is sensitive to customer requirements and responds rapidly to them. In the TQM context, `being sensitive to customer requirements' goes beyond defect and error reduction, and merely meeting specifications or reducing customer complaints. The concept of requirements is expanded to take in not only product and service attributes that meet basic requirements, but also those that enhance and differentiate them for competitive advantage.

Each part of the company is involved in Total Quality, operating as a customer to some functions and as a supplier to others. The Engineering Department is a supplier to downstream functions such as Manufacturing and Field Service, and has to treat these internal customers with the same sensitivity and responsiveness as it would external customers.

8.3 TQM LEADERSHIP FROM TOP MANAGEMENT

TQM is a way of life for a company. It has to be introduced and led by top management. This is a key point. Attempts to implement TQM often fail because top management doesn't lead and get committed - instead it delegates and pays lip service. Commitment and personal involvement is required from top management in creating and deploying clear quality values and goals consistent with the objectives of the company, and in creating and deploying well defined systems, methods and performance measures for achieving those goals. These systems and methods guide all quality activities and encourage participation by all employees. The development and use of performance indicators is linked, directly or indirectly, to customer requirements and satisfaction, and to management and employee remuneration.

8.4 CONTINUOUS IMPROVEMENT

Continuous improvement of all operations and activities is at the heart of TQM. Once it is recognized that customer satisfaction can only be obtained by providing a high-quality product, continuous improvement of the quality of the product is seen as the only way to maintain a high level of customer satisfaction. As well as recognizing the link between product quality and customer satisfaction, TQM also recognizes that product quality is the result of process quality. As a result, there is a focus on continuous improvement of the company's processes. This will lead to an improvement in process quality. In turn this will lead to an improvement in product quality, and to an increase in customer satisfaction. Improvement cycles are encouraged for all the company's activities such as product development, use of EDM/PDM, and the way customer relationships are managed. This implies that all activities include measurement and monitoring of cycle time and responsiveness as a basis for seeking opportunities for improvement.

Elimination of waste is a major component of the continuous improvement approach. There is also a strong emphasis on prevention rather than detection, and an emphasis on quality at the design stage. The customer-driven approach helps to prevent errors and achieve defect-free production. When problems do occur within the product development process, they are generally discovered and resolved before they can get to the next internal customer.

8.5 FAST RESPONSE

To achieve customer satisfaction, the company has to respond rapidly to customer needs. This implies short product and service introduction cycles. These can be achieved with customer-driven and process-oriented product development because the resulting simplicity and efficiency greatly reduce the time involved. Simplicity is gained through concurrent product and process development. Efficiencies are realized from the elimination of non-value-adding effort such as re-design. The result is a dramatic improvement in the elapsed time from product concept to first shipment.

8.6 ACTIONS BASED ON FACTS

The statistical analysis of engineering and manufacturing facts is an important part of TQM. Facts and analysis provide the basis for planning, review and performance tracking, improvement of operations, and comparison of performance with competitors. The TQM approach is based on the use of objective data, and provides a rational rather than an emotional basis for decision making. The statistical approach to process management in both engineering and manufacturing recognizes that most problems are system-related, and are not caused by particular employees. In practice, data is collected and put in the hands of the people who are in the best position to analyse it and then take the appropriate action to reduce costs and prevent non-conformance. Usually these people are not managers but workers in the process. If the right information is not available, then the analysis, whether it be of shop floor data, or engineering test results, can't take place, errors can't be identified, and so errors can't be corrected.

8.7 EMPLOYEE PARTICIPATION

A successful TQM environment requires a committed and well-trained work force that participates fully in quality improvement activities. Such participation is reinforced by reward and recognition systems which emphasize the achievement of quality objectives. On-going education and training of all employees supports the drive for quality. Employees are encouraged to take more responsibility, communicate more effectively, act creatively, and innovate. As people behave the way they are measured and remunerated, TQM links remuneration to customer satisfaction metrics.

8.8 A TQM CULTURE

It's not easy to introduce TQM. An open, cooperative culture has to be created by management. Employees have to be made to feel that they are responsible for customer satisfaction. They are not going to feel this if they are excluded from the development of visions, strategies, and plans. It's important they participate in these activities. They are unlikely to behave in a responsible way if they see management behaving irresponsibly - saying one thing and doing the opposite.

8.9 PRODUCT DEVELOPMENT IN A TQM ENVIRONMENT

Product development in a TQM environment is very different to product development in a non-TQM environment. Without a TQM approach, product development is usually carried on in a conflictual atmosphere where each department acts independently. Short-term results drive behaviour so scrap, changes, work-around, waste, and rework are normal practice. Management focuses on supervising individuals, and fire-fighting is necessary and rewarded.

Product development in a TQM environment is customer-driven and focused on quality. Teams are process-oriented, and interact with their internal customers to deliver the required results. Management's focus is on controlling the overall process, and rewarding teamwork.

15 Principles Of Good Product Development

The following fifteen principles provide a sound basis for good Engineering and product development:

1. Quality is a must - TQM approach
2. A bias for cycle time reduction
3. A bias for innovation
4. Coherent vision, strategy, plan and metrics
5. A product-family oriented business unit

6. Listening to the voice of the customer

7. A clearly defined and well-organized development process

8. Cross-functional product development teams

9. Supplier involvement early in the development process

10. A development methodology

11. Highly skilled, well-trained people

12. Computer aided design systems

13. Digital product models controlled by edm and pdm systems

14. Simulation and rapid prototyping

15. Best practice techniques

Discussion

Provide a critic of the principles and the potential short comings they may have.

An outline of the principles is provided below.

1. QUALITY IS A MUST - TQM APPROACH Total Quality Management (TQM) is an approach to the art of management that has become steadily more popular in the West since the early 1980's. In a couple of sentences, Total Quality can be summarized as a description of the culture, attitude and organization of a company that aims to provide, and continue to provide, its customers with products and services that satisfy their needs. The culture requires quality in all aspects of the company's operations, with things being done right first time, and defects and waste eradicated from operations. The key points of TQM include: □ customer-driven quality □ TQM leadership from top management □ continuous improvement □ fast response to customer requirements □ actions based on data and analysis □ participation by all employees □ a TQM culture

TQM has a customer-first orientation. Customer satisfaction is seen as the company's highest priority. This demands constant sensitivity to customers and fast response to their requirements. Each part of the company is involved in Total Quality, operating as a customer to some functions and as a supplier to others. Vendors are seen as partners in the process of providing customer satisfaction.

Top management commitment and involvement is required in creating and deploying clear quality values and goals consistent with the objectives of the company, and in creating and deploying well defined systems, methods and performance measures for achieving those goals. Such systems and methods guide all quality activities and encourage participation by all employees. The development and use of performance indicators is linked, directly or indirectly, to customer requirements and satisfaction, and to employee remuneration.

Continuous improvement of all operations and activities is at the heart of TQM. Because customer satisfaction can only be achieved by providing a high-quality product, continuous improvement of the quality of the product is seen as the only way to maintain a high level of customer satisfaction. As well as recognizing the link between product quality and customer satisfaction, TQM also recognizes that product quality is the result of process quality. As a result, there is a focus on continuous improvement of the company's processes. This will lead to an improvement in process quality. In turn this will lead to an improvement in product quality, and to an increase in customer satisfaction. Improvement cycles are encouraged for all activities from design and development of products, through routine support and administrative services, to customer relationship management. To achieve continuous improvement the company has to measure and analyse its own performance and that of other companies.

Elimination of waste is a major component of the quality improvement approach. There is also a strong emphasis on prevention rather than detection, hence an emphasis on quality at the design stage. The customer-driven process helps to prevent errors and get closer to defect-free production. When problems do occur within the product development process, the aim is to identify and solve them rather than hide them. As a result, they are generally discovered and resolved before they can get to the next internal customer.

Fast response is required in the form of ever shorter product and service introduction cycles and more rapid response to customer needs. This means that all activities should include measurement and monitoring of cycle time and responsiveness as a basis for identifying opportunities for improvement. Among the main benefits of customer-driven and process-oriented product development are the resulting simplicity and efficiency that greatly reduce the time involved. Simplicity is gained through the concurrent efforts of design teams, and efficiencies are realized from the elimination of non-value-added effort such as re-design. The result is a dramatic reduction in the elapsed time from product concept until first shipment.

At the heart of TQM is the statistical analysis of engineering and manufacturing information. Facts, data and analysis support the planning, review and tracking of performance, improvement of operations, and comparisons of quality performance with competitors. TQM is based on the use of objective data, and provides a rational rather than an emotional basis for decision making. The statistical approach to process management recognizes that most problems are system-related, and are not caused by particular employees. The approach ensures that data is collected and placed in the hands of the people who are in the best position to analyse it, and then take the appropriate action to reduce costs and prevent non-conformance. If the right information is not available, then the analysis, whether it be of shop floor data, or engineering test results, cannot take place, errors cannot be identified, and consequently errors cannot be corrected.

A successful TQM environment requires a committed and well-trained workforce that participates in quality improvement activities. Such participation is reinforced by reward and recognition systems emphasizing the achievement of quality objectives. On-going education and training of all employees supports the drive for quality. Employees are encouraged to take more responsibility, communicate more effectively, act creatively, and innovate. Their knowledge and skills are respected by management.

Without a TQM approach, Engineering and product development are usually carried out in a conflictual atmosphere with individual departments reacting to problems. Changes, scrap, delays, work-around, waste, and rework are seen as normal behaviour. Management focuses on supervising individuals. Fire-fighting is necessary and rewarded.

In a TQM environment, Engineering and product development are customer-driven. They are focused on quality and on preventing problems rather than reacting to them. Teams are process-oriented, and interact with their internal customers to deliver the required results. Management's focus is on controlling the overall process, and rewarding teamwork.

2. A BIAS FOR CYCLE TIME REDUCTION Customers' requirements and competitive pressures will result in the need for companies to decrease product development costs and overall product costs, reduce product development cycle time, and improve quality. This will have a major effect on business. Companies will be forced to organize themselves in such a way that high quality products can be developed very quickly in response to customer requirements.

In fast-evolving technological environments, products become obsolete sooner. The reduced time between product launch and product retirement erodes sales revenues. Since this phenomenon depends on factors beyond a company's control, the only way it can lengthen a product's life is to get it to the market earlier.

Bringing products to market quickly means that product offerings will be fresher and the latest technology can be included because less time passes between definition of the product and its arrival on the market. Less time in development means less labour and less cost. The company responds quicker to customers, gets more sales, and sets the pace of innovation.

A company which is good at developing new products can use this advantage to gain market share. While competitors are busy developing the same abilities, the leading company introduces new products and features faster, and also develops new abilities. When a competitor reaches its targeted level of competence, the leader is ready with a newly developed advantage and the competitor is again behind - spending money to build competence which does not provide the needed return on implementation, because the environment has changed.

The culmination of a good product development strategy is achievement of a position where products conform closely to validated customer requirements and exceed competitors' products in features, cost, quality, and lead time. There is significant competitive value in shortening design and development lead time, as has been demonstrated by companies such as Hewlett-Packard, Toshiba and Chrysler. Short time to market for a new product permits a quick response to emerging customer requirements, and provides an opportunity to gather a bigger share of the market by being first.

3. A BIAS FOR INNOVATION ; Innovation is the prime corporate strategy for the first decade of the twenty-first century. It is important to find out if your organization has taken the right steps to be highly innovative. The following questions are taken from our Innovation Status Survey.

If your organization has taken the right steps you should be able to answer 'Yes' to all the questions. Has one person in the organisation been given the mission to promote innovation? Has the organisation's innovation strategy been defined?

 Has management set objectives for the annual number and percentage of innovative products, processes and services? Has a specific set of ROI criteria been developed for innovation projects? Are resources (people, finance, time) specifically assigned to innovation? Has the innovation process been documented in the Quality Manual? Are computer systems recognized as a key resource to support innovation? Has the organization agreed on a definition of innovation that is communicated and understood by everyone? Are people willing to discuss new ideas with people in other parts of the organization? Does everyone receive training about innovation each year?

4. COHERENT VISION, STRATEGY, PLAN AND METRICS An Engineering vision is a high-level conceptual picture of the way the Engineering function should look some time in the future if it is to be able to perform successfully and continue to perform successfully. The reason for having, and sharing this vision, is to make it easier to achieve the Engineering objectives. The vision will guide people through strategy setting and planning, and help them with their everyday work.

The Engineering objectives should be quantitative and the units of measure in which they are expressed should become key metrics for the Engineering organization. The Engineering vision describes the overall desired state in mainly qualitative terms, and it helps achieve the Engineering objectives - which are probably set at the corporate or top management level. Once the objectives and the vision have been agreed, the next step will be to select a suitable strategy to achieve them. Once the strategy has been defined, it will be possible to start planning the detailed activities and resources needed to meet the objectives and vision.

There will be a close link between Engineering objectives, Engineering vision, Engineering strategy, Engineering plan, implementation of the plan, and Engineering metrics.

Much in the same way that implementation of unconnected computer systems will lead to Islands of Automation, and a failure to achieve the expected productivity gains, the introduction of unconnected vision, strategy and metrics will also fail to give the desired results.

5. A PRODUCT-FAMILY ORIENTED BUSINESS UNIT The major attraction of a Product Family oriented Business Unit (PFOBU) is the time and cost performance achieved by targeting a relatively small, well-defined, highly focused set of products and processes and a well-defined group of customers. PFOBUs are fairly small in size (the actual size depending on the product and market) and focused so they are fairly easy to manage.

PFOBUs don't have the features of large monolithic corporations (such as numerous layers of hierarchy, large staff groups, multiple product lines, departmental fiefdoms, managers supplying conflicting information) that make it impossible for their corporate management to understand what is happening or what actions will lead to improved performance.

The clear focus on a limited range of activities makes it easy to develop a coherent Engineering vision, strategy and plan for a PFOBU. It's almost obvious which metrics should be used and which targets should be set. It's relatively easy to introduce TQM because the organization is by definition clearly focused on a particular set of customers, and it's very clear what has to be done to satisfy them.

A PFOBU focuses on a single product family. Within the family there may be several product lines, but all the products are basically similar. This means there are similarities between the specifications, parts, drawings, manufacturing processes, assembly techniques, and distribution channels.

At any given time, two, three or even more generations of the family may be under development. Once the first generation of the family has been developed, the cost and time to develop succeeding products will decrease. The second generation may re-use 75% of the parts used in the first generation, so there is a tremendous reduction in design work, process design, and verification. There is no need to reinvent the wheel for each new product.

A PFOBU focuses on a single product family, so it can also focus on a single product development process. This results in a better understanding of the process, how it can be improved and where most value can be added. The parts of the process where the PFOBU does not, for some reason, want to carry out all activities internally can be outsourced - probably to world-class suppliers. The process can be continuously improved. The PFOBU gets more and more competitive, closer and closer to customer requirements.

Because they focus on one product family, the people in the PFOBU get to know their product in depth. They don't run the risk of being transferred to projects on completely different products with completely different requirements. Instead, through training and experience they learn how to make a valuable contribution to their product line. Everyone learns about the process. They know who does what, what has to be done, where everything is, and how things are organized.

Successful PFOBUs make use of concurrent engineering, product development teams, a phased development process and a well-defined development methodology. At each stage of the process - concept, feasibility, development, production, launch, support and recycling - cross-functional team members work together for the good of the family. The milestones and goals of each phase are defined in advance, and it is only when everyone agrees they have been attained that the next phase is started.

Because PFOBUs focus on one product family, the best equipment, such as machines and computer systems can be purchased, installed and optimized. It can be cost justified over several generations of the product family, not just on one project.

Because PFOBUs focus on one product family, planning and scheduling is much easier. There is no longer the need to continually switch resources between projects on completely different products. It's easier to plan to have the right resources available when they are needed. It's easier to plan ahead, since so much is already known about the next generation of the product.

In a PFOBU, people want to make use of existing parts. An Engineering Data Management / Product Data Management (EDM/PDM) system will provide information, ranging from specifications to user documentation, about existing products, parts and processes. It will allow people to re-use or make small changes to an existing part rather than design a completely new one. It will allow them to see what problems have occurred in the past, and will help them to avoid repeating them.

In a PFOBU, information is shared among team members. An EDM/PDM system makes information available according to their rights to access and modify it. In a global PFOBU, people may work on the same project in different countries, maintaining close contact with customers throughout the world. It is difficult to maintain control over concurrent processes and information use in multiple locations. An EDM/PDM system makes it possible to support global information usage and international workflow.

6. LISTENING TO THE VOICE OF THE CUSTOMER. In the last few years some companies have come to understand that they only exist because their customers buy their services or products. At the other extreme, there are many more companies who have an almost Soviet planning approach to product development. They still produce a product or service according to the command of their internal planning committees and expect people to buy it.

Until 10 or 15 years ago this method worked - even in the industrialized West. Demand was so high and unquestioning that most companies providing products and services didn't think seriously of listening to customer opinion. Instead they defined their corporate markets and plan, their engineers defined their product, and their plants then went ahead and produced products to plan. Customers were not involved in the process. It was assumed they would be grateful for the products produced for them.

Things have changed a lot in recent years, thanks to Japanese manufacturers and increased competition. However, there are still quite a lot of Western manufacturers and service companies who haven't caught on. Often the problem is that they are run by people who spent much of their career in the 'age of production' when the customer's opinion was not sought. Some airlines still treat their passengers as if the airline was doing passengers a favor by letting them fly on their dirty old planes with unfriendly crews. These airlines still haven't understood that passengers have, or will have, a choice - flying with a competitor. Where there is already a competitor on the route, maybe the competitor will have cut overhead costs, smartened up its planes and sent its crews on training courses to learn how to behave with customers - people who have paid good money to buy the airline's service. In other cases, there may not be a competitor yet - but the opportunity (and the threat) is there.

For many years, similar problems bedevilled the Western automobile manufacturers. They couldn't understand that, given a choice, many people would rather buy a nicely-styled, up-to-date, inexpensive, reliable, cheap-to-run car from Japan than an expensive-to-buy, expensive-to-run, likely-to-breakdown dinosaur from Detroit. At last it looks as if most of them are beginning to get the message - but you have to wonder why it has taken so long.

You might think that what happens to airlines and giant automotive manufacturers isn't relevant to your product development process - but it is. It is important to listen to the customer, to take account of what the customer is saying about your product or service, to take account of what a potential customer is saying about your competitors' products and services. If you show some interest in your potential customer's needs and wishes when you develop your product or service, then when that person comes to spend hard-earned money, they may buy your product or service rather than that of your competitor.

It's important that many customers do choose your product rather than your competitor's. The end result of having enough customers buy your product is that at the end of the financial year your company's revenues exceed its costs. If this isn't the case, then before long you may find yourself 'surpluses'. You might think this is unlikely to happen, but look around. There are quite a few companies that forgot the simple habit of listening to the customer. They can be found in almost every industry - steel, automobile, computer, consumer electronics, airline - and, as international competition and deregulation spread, other industries such as telecommunications and utilities will be affected.

It's important for you and your company to listen to the customer, and make sure that the customer's demands, expectations, requirements and wishes are reflected in the product you offer. Listening to the customer is a key part of the product development process. The customer provides a lot, if not most, of the product specification. Of course, in some cases, a new product is invented and so the specifications come from the mind of the inventor or researcher. In most cases though, a customer isn't going to buy an invention - a customer buys a product or service that incorporates the invention. If the product or service doesn't meet customer requirements then the invention - however brilliant - falls by the wayside. The same is true for the brilliant ideas that engineers like to add on to a product - unless the customer wants them then they are more likely to do harm than good.

How can product development organizations listen to customers and find out what they want? Strangely enough one way is actually by sitting down and talking with customers. Another - even stranger for those product development organizations that try to keep away from customers - is to involve customer representatives in the development process. In both these cases, the contact is direct. It's not via a sales rep who talks to someone from Marketing in a bar one evening - who then tells the Marketing VP at the next monthly meeting - who mentions it to the Engineering VP - who suggests someone works on it when they have some time.

The advantage of close relationships with the customer is that they help ensure that the product being developed really meets customer requirements. Most of the time, such relationships also prevent errors occurring. Now and again, some errors may occur, but they will be seen and corrected before they can cause too much trouble. These relationships save time because people only work on what is required to add value, rather than on non-value-adding activities. Similarly, money is saved by cutting out unnecessary activities and eliminating changes and rework.

7. A CLEARLY DEFINED AND WELL-ORGANIZED DEVELOPMENT PROCESS A clearly defined and well-organized product development process lies at the heart of an effective Engineering environment, yet only a few companies have taken advantage of the potential advantages it offers. Instead, most companies continue with a traditional, ineffective product development process - so find that development costs are too high, development cycles are too long and products don't correspond to customer perceptions of quality. If they improved the product development process, they would overcome these difficulties.

The product development process is made up of a number of inter-related tasks. The aim of the first set of tasks is to produce the information that defines the product and the information that defines the processes that are used to make and support the product. Then, other tasks are carried out to make and support the product.

The process of defining and making a product can be very complex, expensive and time-consuming. For example, it can take several years to define and make products such as cars, microprocessors, and even cameras. The process may contain several thousand tasks. These may be carried out by many different companies working in different places round the world. Hundreds, or even thousands, of people may be directly involved in these tasks.

Of course, not all products are the result of such complex processes. Sometimes there may only be a few people involved in the process and they may all be on one site. They may be able to carry out all the activities such as specification, design, analysis, documentation, test and production in a few weeks. In such cases, the process is generally well-organized and the people involved in the process have a very good understanding of the overall process as well as their own roles and tasks.

In product development processes that involve hundreds or thousands of people and tasks, it is not uncommon to find that no one person understands the overall process. Each person has a detailed understanding of their own role and tasks, but no-one is able to describe the overall process in any detail. Although no-one understands the overall process, it does exist. It is made up of certain tasks carried out in a certain order. The process works, it has worked in the past, and it is expected that it will work in the future.

The individuals in the process try to bring about improvement by improving the way that their particular tasks are carried out. For example, a design engineer might believe that a new CAD system would help improve the productivity of a particular design task. As nobody is responsible for the overall process, nobody checks to see that the productivity of the overall process is increased by the new system. In fact, it might decrease. The interfaces between the new CAD system and other parts of the process might not exist - with the result that new tasks are needed in other parts of the process.

In another part of the process, another person may decide to improve productivity by transferring a task currently carried out on a mainframe computer to a PC. They may get a much better response time from the PC, but unless it is on a network they may be creating a break in the information flow that will lead to transcription errors and a longer development cycle. An apparent improvement in local productivity may lead to a decrease in overall productivity.

The process is very closely linked to the other components of the engineering environment such as people, information, and computer systems. People carry out the tasks that make up the process. Information plays a key role in the product development process. It is used and communicated throughout the process. Information is used by people and tasks. Information flows through the process.

Computer systems support the tasks and information flows in the process. Engineers are trained in the techniques and practices that correspond to tasks in the process.

Any changes to the process are likely to affect the other components of the engineering environment. For example, if some tasks are to be removed and others carried out in parallel, some people may lose their jobs and others may have to learn new skills. Many tasks in the process exist to produce information that will define the product and the manufacturing and support activities. Many tasks involve creating, accessing, using, recalling and modifying information. Changes to the process and to tasks will lead to changes in the use of information. Information flows will change and computer systems may have to be replaced. The effect of process change on the other components means that it has to be carried out with great care.

Processes that are not properly defined and organized, but are the result of past activities and uncoordinated improvements, may, by chance, be effective. It is more likely that they will not be. With fast-changing products, systems, and practices, it's unlikely that a process that has grown without being planned is going to be the most effective. It's unlikely that it's going to be the quickest, cheapest and highest quality way of combining the necessary tasks to meet the development objective.

A company should aim for use of the best process. Unless the overall process has been analysed in detail it's unlikely to be the best. More likely it's going to be uncompetitive. It's going to be lengthy, costly, error-ridden, and full of non-value adding, uncoordinated and time-wasting tasks.

To make improvements, the process has to be analysed and understood in detail. A new, fast, waste-free, low-cost process has to be defined and then implemented. Probably many existing tasks will have to be removed, some new ones added, and the overall organization of the process will change significantly.

8. CROSS-FUNCTIONAL PRODUCT DEVELOPMENT TEAMS ; In a cross-functional product development team, product developers from different functions work together and in parallel. Team members come from functions such as marketing, design, service, quality, manufacturing engineering, test and purchasing. Often, key suppliers are included in the team. Sometimes, representatives of the customer are also included in the team, allowing the Voice of the Customer to be heard throughout the development process. Team members work together, sharing information and knowledge, and producing better results faster than they would have done if operating in a traditional product development mode. The end result is that products get to market faster, costs are reduced and quality is improved.

If cross-functional product development teams are not used, the product development process is likely to be serial, with each group of specialists working one after the other on successive phases of the development. Once a group has finished its work it passes it on to the next group. For one reason or another this group may not like what it gets, so sends it back with a request for modification. By the time the first group gets the request for modification, it is working on something else, so can't respond immediately. Often the first group doesn't like the requested change, so comes up with another alternative. Although the group does its best to provide a good alternative, it may not understand all the reasons behind the request for change, so the new alternative may still not meet the requirements.

This serial, to-and-fro approach to product development tends to be slow, costly and low-quality, leading to a lot of engineering changes and a product that is less competitive than expected.

Other problems with the semi-independent groups of specialists arise because each group has its own specialist vocabulary, its own computer systems and applications, and its own data definitions and structures. When groups exchange information there are often misunderstandings in terminology, data conversion errors and incompatible data definitions. As a result, the information each group works with is often incomplete and erroneous.

There are many advantages to the cross-functional product development team approach. One is that people with a mix of skills working together are much better at coming up with a solution to an overall problem than individuals with limited specialist knowledge. A cross-functional product development team's composite knowledge of design, processes, materials, manufacturing, quality, and customer requirements can be applied to develop the best definition of the product and its manufacturing, support and disposal processes.

Working together, the members of the team will tend to use a common, shared vocabulary and standardized data definitions. Common tools can be used, thereby reducing data exchange problems. In cases where it is not possible to use common tools, use of a limited set of tools can be agreed by the team, and the exchange of information between them can be standardized. Information will be shared, so information access becomes quicker. Understanding of information improves because team members are available to explain the meaning of information. Functional specialists are not allowed to develop unsuitable solutions without being rapidly brought back to reality by the rest of the team.

The improved communication resulting from team membership helps reduce changes to specifications. It helps increase downstream awareness early in the development process. Team members from upstream functions get a better understanding of downstream reality, resulting in a reduction in problems for downstream functions. The reduction in changes results in less rework and in a reduction in the overall product development cycle. The reduction in changes also takes the burden off the engineering change system, allowing the remaining changes to be handled more effectively.

The amount of formal communication (e.g. official sign-offs) can be reduced because information can be communicated informally within the team. The number of administrative documents can be reduced. Many of the documents previously required during a design phase are no longer needed as all the information is with the team, and there is less need to communicate with other people.

The team has a much clearer view of the status of the product's development than a manager of a development in a serial environment in which activity is spread over a number of semi-independent, uncommunicative groups. The team environment provides a very open, visible environment.

Whereas in the serial process each group can behave and make modifications that are hard for other groups to identify and understand, in the cross-functional team it's much more difficult for someone to do something, such as make a change, without the rest of the team being immediately aware of it.

Within the team, all functions are more or less equal, so there is less chance of one function being completely out of touch with customer requirements yet having the political strength to impose its desires.

Another advantage of the team approach is that re-use of existing parts and processes is likely to increase. It's much more likely that one of the team members will remember the existence of a similar part or process than an individual working alone.

The result of all these improvements is a reduction in overhead costs, a reduction in the development cycle and an improvement in quality.

The reduction in the development cycle usually also results in a reduction in the number of development hours. This has a direct effect on development costs. The team approach also tends to prevent development cost overrun as it focuses attention on the early identification and resolution of problems. The team approach also improves product quality. The early involvement of downstream functions reduces the risk of potential problems.

9. SUPPLIER INVOLVEMENT EARLY IN THE DEVELOPMENT PROCESS; In the coming years, companies will have to get products to market much faster. To do this they will make many changes. They will, for example, reduce the number of levels of management, adopt teamwork, ensure departments cooperate, provide equal opportunities for female engineers, get work done with a flexible and skilled workforce (rather than by weight of numbers) and buy in specialized services from outside rather than trying to do everything in-house. For many companies, the cost of purchased materials accounts for more than half of their expenses, so it's a good place to try to reduce costs. As well as increased use of suppliers, the future will also see them being involved earlier in the product development process.

In the past, suppliers weren't involved early in the process. The activities of the product development process were carried out in series, and suppliers were only involved near the end of the process. A typical product would go through many activities - it might start life in the marketing function, and then go through conceptual design, engineering design and analysis, testing, detailed design, manufacturing engineering, process planning, tooling, NC programming, production planning, purchasing, machining, assembly, testing, packaging, installation and maintenance.

Often, suppliers would only be involved in manufacturing some of the parts. They wouldn't be involved at the design stage, and often their work only started when they received the released design documentation. Usually they would raise good questions about some aspect of the design. The resulting change process wasted time, led to the introduction of new problems, and often resulted in the product getting to market late.

As well as having a negative impact on performance, this way of working with suppliers didn't take advantage of their knowledge and experience. A particular supplier might be a world-class producer of a particular component, yet not be consulted on initial specifications and design, just expected to produce to a plan produced by people with much less relevant know-how.

In some cases, suppliers were only brought into the process to compete against each other on pricing. As a result the company finished up working with a large number of suppliers, and even with different suppliers on similar products. It was impossible to build up the stable, long-term quality-generating relationships that lead to client satisfaction.

To respond to the need to get products to market faster, to reduce the cost of developing products and to make sure the product provides customer satisfaction, the product development process needs to be re-organized. There are many possible approaches to re-organization. Many of them will increase the reliance on suppliers. Companies that focus on upstream product specification and design activities where they can best use their resources will want to outsource downstream activities where they are not cost-effective (e.g. in detailed drafting) or are less competent than specialized organizations (e.g. in parts manufacture), so suppliers will have a greater role to play in these areas.

In team-oriented companies, people from different functions will work together on the upstream activities, effectively taking the major decisions about the entire product development process in the initial design phase. The team will need to know in detail at an early stage about the different parts of the product, and the way the parts fit together. The team will want to make the best possible use of suppliers with the aim of getting a customer-satisfying product to market as quickly as possible. This will probably mean involving the supplier right at the beginning of the process, when the major modules of the product are being defined. The supplier will then be given the job of designing and manufacturing a complete sub-assembly.

In the re-organized process, suppliers will be expected to respond quickly, to be responsible and to be reliable. They will be expected to have excellent skills, knowledge and experience concerning particular parts or activities. The company will want to have long-term relationships with a small group of highly competent, knowledgeable and trusted suppliers.

In companies that don't have early supplier involvement, improvement initiatives in the Engineering Department will only provide some of the expected improvements in the performance of the product development process and in engineering productivity. Each time a supplier is involved in the process, all the traditional problems of wasted time and money mentioned above will appear, and prevent the benefits coming through. The fault won't be that of the supplier, but of the organizational structure. 10. A DEVELOPMENT METHODOLOGY Product development is a complex process involving many poorly understood variables, relationships and abstractions. It addresses a wide range of types of problem, and is carried out by a wide variety of people, using a wide range of practices, methods and systems, working in a wide variety of environments. Converting a concept into a complex multi-technology product under these conditions is not easy. It requires a lot of effort, definition, analysis, investigation of physical processes, verification, trade-offs and other decisions. It's not easy, but it's not impossible if it's properly organized.

In many companies, the product development process is not commonly agreed, written down or formalized. It's vague. Everyone has a different idea of it - based on their knowledge and habits resulting from past experience. In this confused situation, whatever process is actually used is unlikely to correspond to the best way for the company to develop its products - which means the company is wasting time or losing money or running the risks of quality problems.

In coming years, product development performance must improve. It has to become faster, cheaper and better. Companies with undefined, ineffective development processes and methodologies will be uncompetitive. They will have to identify the best process and define their development methodology. Once these have been formalized and communicated, everyone in the development process will need to follow them - otherwise they'll run the risk of wasting company resources.

A well-defined product development methodology lets everybody in the process know exactly what is happening in the process at all times, and tells them what they should be doing. It defines the major phases of the process and explains what has to be done in each phase. It shows how the process fits with the company organization and structure. It shows the objectives and deliverables at the end of each phase, and the way phases connect together. It shows which processes, systems, methods, techniques, practices and methodologies should be used at which time in each phase. It shows the human resources that are needed - the people, skills and knowledge - and their organization. It shows the role and responsibilities of each engineer and the role of teams. It shows the role of management, project managers, functional reviewers, approvers, and others. It describes the major management milestones and commitments. It describes the metrics used in the process.

Companies without a well-defined product development methodology are likely to suffer from quality problems and projects finishing late and over-budget. The people in the company won't share a common view of the way they should be developing a product. The company will have problems with long cycle times, too many iterations of the design cycle, and too many engineering changes. It will always be trailing behind market-leading companies with regard to quality, cost and time-to-market of new and improved products. Often, such companies don't even realize they have problems until they've lost significant market share.

Companies without a well-defined product development process and product development methodology won't get the benefits they expect from initiatives to improve Engineering performance. Their spontaneous, haphazard approach will prevent them from defining and optimizing the process, so they won't be able to tailor the initiative to fit the process. Without a clearly defined methodology, it's not known which systems and practices are most appropriate - so the necessary integration of an initiative will be difficult to carry out. Any gains that come from use of an initiative in one place are likely to be lost in another place because a coherent solution hasn't been prepared.

Product development is becoming the fundamental differentiator for both the speed and cost with which new and improved products are brought to market. It's the activity where competitive advantage can be gained in quality and performance. Companies that understand this and put in place a clear product development process supported by a well-defined development methodology have every chance of becoming market leaders. They can use the methodology as the basis for involving people at all levels and in all functions in defining, designing, and producing the best product and getting it to market fastest. They'll improve profitability and competitiveness. During development of products they'll see ways to improve the process and the methodology. The continual improvement of new design methods, and changes in response to customer feedback, will keep them ahead of competitors who are forced to copy their methods, play catch-up, and condemn themselves to second place.

Many companies use a phased product development process is which the main steps are: definition of customer needs and product performance requirements planning for product evolution planning for design and manufacturing product design manufacturing process design production

Converting a concept into a complex, multi-technology product involves many steps of refinement. Companies that design successfully have carefully crafted product development processes that extend over all phases of product development from initial planning to customer follow-up.

11. HIGHLY SKILLED, WELL-TRAINED PEOPLE The Engineering workforce is a key factor in achieving better performance levels. Even though use of computers will increase, and down-sizing will reduce headcount, people will still be needed. Engineering organizations will be looking for highly skilled and adaptable engineers. Such people will be in short supply, so organizations will have difficulty in finding them, and will need to treat them well if they are going to retain them.

Organizations will be looking for people with different types of skills for different activities. Even though teamwork will be common, people with very specialized skills will still be needed. For example, certain types of analysis can only be carried out by people with in-depth knowledge of a subject and long experience in interpreting results. Even a large team of generalists without this specialized knowledge, skills and experience can not carry out such analysis. This should not be taken to mean that specialists will not need to work in teams, only that specialized skills will still be needed in the team environment. Alongside the need for specialists will be a growing need for generalists - people with skills in several areas. Generalists will participate in or lead teams, act as an interface between specialists, and provide links to customers and suppliers.

Everyone, specialists as well as generalists, will need to be skilled in the systems, practices and techniques of the organization. They will need to understand the tools the company has chosen to work with so that they can make best use of them and so that they can understand what their colleagues are doing. People will also need softer skills, such as the ability to work in a team, the ability to communicate well with their colleagues, and the ability to work with people who come from other functional, cultural and national backgrounds. They will have to be adaptable, and open to new ways of working. Engineering organizations that don't have a skilled, trained workforce will find it very difficult to improve performance. After all, without competent people, how can change occur? Additional computer systems will not improve performance unless people understand them and are able to use them. The same is true for new techniques, practices and technologies. Without appropriate people, the potential benefits will not be achieved. Without good people, the company's product development performance will not change. It will continue to be too slow and too expensive, and the company will continue to suffer from quality problems. As time goes on, the organization will become less and less competitive. It will be difficult to modify organizational structures to meet market requirements. Without people with the basic skills it won't be possible to take advantage of advanced systems and practices, so the company will slip further behind.

Engineering organizations that have skilled, trained people will find it easy to improve performance. Their people will be trained in the techniques of working together effectively. Teams will be formed to improve the product development process. Best practices will be introduced and the corresponding training given. Training will be given to ensure that everybody understands and benefits from the computer systems they are using. Cycle times and product costs will be reduced, and product quality improved.

12. COMPUTER AIDED DESIGN SYSTEMS CAD is an ideal tool for companies that want to improve quality and reduce development cycles and costs. A design built with CAD should be of higher quality than one made by traditional means. The geometric model in the computer is accurate and unambiguous. Many things can be done with it that are not possible or would take far too long to carry out manually. A 3D CAD model of a part can be displayed on a PC or workstation so the designer can see what it really looks like. The model can be rotated, viewed from different angles, and magnified so the designer sees the details on the screen. Any errors can be corrected immediately. Analysis can be carried out while the model is still in the computer - there is no need to wait for a physical prototype before testing starts.

It is cheaper to design with CAD than with traditional means. Although it may cost as much to develop the initial design, everything after that is much cheaper. For example, instead of paying people to build physical prototypes, it may be possible to simulate all the necessary tests on the computer model. If a physical prototype is really necessary it can be produced directly from the CAD model by rapid prototyping - again avoiding all the traditional costs of model-making.

CAD is much faster than manual techniques. As with the cost, there may not be much difference on the initial design, but after that everything goes much faster. Once a model has been built it can be used throughout the development process. People don't have to re-develop it for each task. With traditional design methods there is always the danger that people in downstream functions may re-design the part to fit the way they work. With CAD, there is no need for this - they can work with the as-designed CAD model, saving time and avoiding re-design. Another way in which CAD saves time compared to manual techniques is in the opportunities it offers for re-use. Once a part has been developed and released it is available for use on other products. It may be possible to use it on another product in exactly the

Same form or perhaps with a slight modification. In either case, much less work is needed than in developing a completely new design, so a lot of time will be saved.

There are still some companies that don't use CAD. There are still many companies where CAD is not used in all the areas where it could be used. In areas of these companies where CAD is not used, all the usual problems of use of manual design continue to occur. There may be quality problems because the design on paper is not an exact representation of the part. When the paper design is handed to another group there may be errors due to misunderstanding what the design is meant to represent. Transcription errors may occur as design details are copied from one task to another. Time may be wasted as people carry out tasks -such as technical calculations and data communication - that would be carried out much faster by computers. Between tasks, time may be wasted as people wait for drawings to come by internal mail.

As well as being a source of quality problems and wasted time, manual techniques are much more costly. People have to be paid to do them. It's cheaper and more accurate to get a computer to carry out a calculation or draw a straight line than to get a person to do it.

Those companies that do use CAD should have a faster product development cycle than those that don't. Their development process should be cheaper and of higher quality. They will find it easier to get closer to customers. For example, the customer can be brought in and shown the design on a workstation and asked if it satisfies requirements. If it doesn't, changes can be made much quicker than they would if it was necessary to wait for a physical prototype to be built before the client could be involved. Once the design is agreed, it can be communicated immediately to the team responsible for the next phase of the development cycle. They can get working right away and as soon as they are finished, the next phase can start. Time will not be lost through the transcription and communication delays so typical of manual development. By getting their products to market faster companies using CAD should increase market share and profit.

13. DIGITAL PRODUCT MODELS CONTROLLED BY EDM AND PDM SYSTEMS In coming years, the product development process has to get faster, it has to cost less, and it has to be higher quality. Having digital product models under the control of EDM and PDM systems will help attain these objectives in several ways. It should be much quicker to access and retrieve computer-based product data than it is to get paper documents. It should also be much cheaper - once the information is in the system it can be displayed on a screen. There's no need to pay someone to get the document. There's no need to make a physical copy. The quality should be much better - the information shown on the screen will be the information in the computer. It won't get torn, it won't be a faint copy, it won't be mislaid, it won't be the wrong version - and the information can be shown on the screen in 3D, which should mean less confusion.

Provided the computer is up and running, the information will be available almost immediately. There'll be no need to wait for a document until someone gets back from lunch, or recovers from being sick. There'll be no need to wait while someone who recently joined the company asks his or her boss where a particular document can be found. Then of course, there are all the other problems that will be avoided - someone else has the document, or someone modified the document but didn't tell anyone, or someone modified the entity described in the document but didn't modify the document.

For most of the product development process, information is all-important. It's all people can work with when the product doesn't physically exist. Yet strangely enough, in most organizations information is not managed the same way as other company assets. In most companies, there's no high-level manager responsible for the information describing the product and the processes that are used to develop, manufacture and support it. Some of this information will be under the control of the 'Document Store' - often a low-level organization located in a basement.

The rest of the information is distributed round the company, and is under the control of the people who use it, or maybe the people who create it - it's not always very clear. The detailed ownership and procedures for each piece of information are difficult to resolve, and there may be many cases where they are not resolved. As a result, people do their own thing. If they are to be held responsible for a task using certain information, they want the information to be under their control. As most information is used by people in several departments, each of whom is held responsible for tasks using that same information, several people want the same information to be under their control. Each one invents their own rules on how the information is managed, structured, stored, and used.

Problems occur at the interface between each pair of departments. Each department is responsible for its own work. When it comes to information, this means that each department structures the information the way that is most suitable for its own needs, uses the terminology that is most appropriate for its discipline, stores information on the medium that it finds to be most effective, and defines the information elements as a function of its own needs. This leads to the department working in the most effective way for its own needs, but creates problems when the information is transferred to another department.

The result of this approach to using and managing information is that the product development process is slow and expensive and riddled with errors. All along the process, time is wasted as information is converted and transferred, unnecessary overhead cost is added, and there is a lot of non-value-adding translation of information. Problems occur as paper is shuffled from one desk to another and from one department to another. On the shop floor, the result is expensive rework and scrap as the wrong parts are produced.

Access to information is slow, and there is always the chance that data will be lost. Copies of the same information differ, and a lot of time is lost in discussions trying to reconcile differences. Due to all the time lost with information problems, projects overrun. People can't find existing information, so there is little reuse of information - instead money and time are wasted as people continually reinvent the wheel. As the departments use different formats and structures of information, it is often simplest for them to put the information on paper before transferring it to another department. Once on paper it can be destroyed, lost, or mislaid.

In future product development organizations, engineering information will be a strategic resource, and its management a key issue. Effective use, and re-use, of

Engineering information will play a key role in differentiating world-class companies from others.

World-class product development organizations will want to control their information, and achieve the maximum benefit from it. They will only be able to do this if it is all available electronically. As a result, all relevant information will be converted to a computer-controllable electronic form. Paper documents will be converted to electronic form. Discussions will be recorded on electronic media. Products and processes will be videotaped. All relevant product and process information will be made available on electronic media as an electronic corporate memory. EDM and PDM systems will manage this data. They will include cross-functional data dictionaries so that people from all functions can understand what they contain.

14. SIMULATION AND RAPID PROTOTYPING In the coming years, there will be a lot of pressure on companies to improve their product development performance. They will have to develop products faster, at a lower cost, and with better quality. Simulation and rapid prototyping will help them meet these objectives.

Simulation is carried out to study the performance of a system, product or process before it has been physically built or implemented. It involves the development and testing of a computer-based model of a part or product.

Rapid prototyping is the production of a physical prototype directly from a computer based model of a part or product.

Simulation has been used for many decades. It involves the development of a computer-based model of a part or product, the development of a computer-based model of the environment in which the part or product will be used, the testing of the part under different conditions of the environment, analysis of the behaviour of the part, and modification of the model of the part to improve its behaviour. The models of the part and the environment may be built graphically using a CAD system or they may be input in the form of equations. Computer-based simulation is cheap and effective. It makes it easier to evaluate before implementing. It allows errors to be identified and corrected before they are implemented. Models can be built, tested and compared for different concepts. 'What-if' analysis can be carried out. Recommendations for improvement can be made.

Simulation helps meets the objective of developing products faster because it does not require the time-consuming activities of building physical models of the part and the environment. Instead it uses the models designed in the computer which would normally be the basis for building the physical models. Time is saved because it is not necessary to build the 'physical' model. In addition, even more time is saved as modifications are made to the computer-based model and the simulation is repeated. Simulation is cheaper than the traditional methods of building and testing a physical model. There are savings in reduced material costs. There are savings because all the activities of defining the process for making the prototype and then building it and testing it are no longer needed. Quality is improved because it is possible to define and test many more potential designs using a computer-based model of the part than when using physical prototypes.

Rapid prototyping is used to produce an accurate 3D model directly from a CAD model. There are several rapid prototyping technologies such as stereo lithography, instant slice curing, and selective laser sintering. Whereas one of the benefits of simulation is that a physical prototype is not needed, for some products there are nevertheless benefits of having a physical prototype. A physical prototype is a good visualization and communication tool for people unaccustomed, unable, or unwilling to work with an image on the screen. It provides a common language for people from different functions and eliminates misunderstanding. The parts produced can be used as fit and function models. They can be used as design verification tools, and patterns for other manufacturing processes. They can be used to check interference, and to test ease of assembly and maintenance.

The benefits of simulation come from use of computer-based models. The benefits of rapid prototyping come from use of physical models produced directly from computer-based models.

The activity prior to rapid prototyping is the development of a computer-based model of a part or product. This is the normal CAD design activity. It has to be carried out whether a prototype is going to be produced by rapid prototyping or traditional means. Once the CAD model exists, a physical model can be produced directly by one of the rapid prototyping technologies, whereas with traditional means, drawings of the CAD model would be produced, manufacturing engineers would decide how to produce it, and then it would be manufactured. Rapid prototyping cuts out these steps - so it saves the time associated with them, it saves their cost and it eliminates the possibility of transcription errors and misinterpretation.

Companies that don't use simulation and rapid prototyping will find their product development cycles are longer, and their development costs higher, than those of companies that do use them. Companies that don't have rapid prototyping and simulation should investigate how they would benefit from their use. Both practices offer the advantages of reducing development costs and cycles and improving quality. Some costs are involved in acquiring simulation and rapid prototyping systems, and in training people to use them. The balance between costs and benefits will change from one company to another, so each company has to look at its particular requirements in detail.

15. BEST PRACTICE TECHNIQUES Different people have different understandings of the term 'Best Practice Techniques'. In the context of our overview, 'Best Practices Techniques' includes many relatively modern ways of working. Some of these have been in existence for years but still appear as modern compared to the very traditional techniques used by many Engineering organizations. They include techniques such as Benchmarking, Design for Assembly (DFA), Failure Modes Effects and Criticality Analysis (FMECA), Activity Based Costing (ABC) and Taguchi techniques. Here are a few words and references about each of these.

Benchmarking is the continuous process of measuring products, services, and practices against a product development organization's toughest competitors or those renowned as industry leaders. If the other organizations are found to have more effective operations, then the product development organization can work out why they are better, then start to improve its own operations.

DFA techniques aim to reduce the cost and time of assembly by simplifying the product and process through such means as reducing the number of parts, combining two or more parts into one, simplifying assembly operations, designing for parts handling, selecting fasteners for ease of assembly and ensuring that products are easy to test. Design for Manufacture (DFM) techniques are closely linked to DFA techniques, but are more oriented to individual parts and components rather than to DFA's sub-assemblies, assemblies, and products. DFM aims to eliminate the unnecessary features of a part that make it difficult and expensive to manufacture.

FMECA, a quality tool which can be applied to systems, products, manufacturing processes and equipment is used to identify the possible ways in which failure can occur, the corresponding causes of failure, and the corresponding effects of failure.

Discussion

1. What is meant by total quality management?

2. Why is customer-driven quality such an important issue in today‘s world of business?

3. Do you think fast response is part and parcel of the business philosophy in your country? State the reasons for your opinion.

4. Why is meant by the phrase: actions based on facts?

5. How would you begin to instigate a TQM culture?

6. Take an example of a company that you have some experience of. Look at the 15 principles related

to product and operations management from a TQM perspective. Which ones would you start with if you wanted to improve the overall quality of service of management?

APPENDIX

PRODUCTION THEORY BASICS

In microeconomics, production is quite simply the conversion of inputs into outputs. It is an economic process that uses resources to create a commodity that is suitable for exchange. This can include manufacturing, storing, shipping and packaging. Some economists define production broadly as all economic activity other than consumption. They see every commercial activity other than the final purchase as some form of production.

Production is a process, and as such it occurs through time and space. Because it is a flow concept, production is measured as a ―rate of output per period of time‖. There are three aspects to production processes: the quantity of the commodity produced, the form of the good created, the temporal and spatial distribution of the commodity produced.

A production process can be defined as any activity that increases the similarity between the pattern of demand for goods, and the quantity, form, and distribution of these goods available to the market place.

EFFICIENCY AND CROSS-EFFICIENCY

A production process is efficient if a given quantity of outputs cannot be produced with any less inputs. It is said to be inefficient when there exists another feasible process that, for any given output, uses less inputs. Some economists (in particular Eisenstein) use the term Efficiency to indicate that production processes tend to be inherently inefficient due to satisficing behaviour. The ―rate of efficiency‖ is simply the amount of (or value of) outputs divided by the amount of (or value of) inputs. If a production process uses 50 units of input (or $5000 worth of inputs) to produce one unit of output it is more efficient than a process that uses 55 units of input (or $5500 worth of inputs) to produce the same level of output. It is said to be 10% more efficient ({55-50}/50=1/10=10%).

FACTORS OF PRODUCTION

The inputs or resources used in the production process are called factors of production by economists. The myriad of possible inputs are usually grouped into six categories. These factors are: Raw materials Machinery Labour services Capital goods Land Entrepreneur

In the ―long run‖, all of these factors of production can be adjusted by management. The ―short run‖, however, is defined as a period in which at least one of the factors of production is fixed.

A fixed factor of production is one whose quantity cannot readily be changed. Examples include major pieces of equipment, suitable factory space, and key managerial personnel.

A variable factor of production is one whose usage rate can be changed easily. Examples include electrical power consumption, transportation services, and most raw material inputs. In the short run, a firm‗s ―scale of operations‖ determines the maximum number of outputs that can be produced. In the long run, there are no scale limitations.

TOTAL, AVERAGE, AND MARGINAL PRODUCT

The total product (or total physical product) of a variable factor of production identifies what outputs are possible using various levels of the variable input. This can be displayed in either a chart that lists the output level corresponding to various levels of input, or a graph that summarizes the data into a ―total product curve‖. The diagram shows a typical total product curve. In this example, output increases as more inputs are employed up until point A. The maximum output possible with this production process is Qm. (If there are other inputs used in the process, they are assumed to be fixed.)

The average physical product is the total product divided by the number of units of variable input employed. It is the output of each unit of input. If there are 10 employees working on a production process that manufactures 50 units per day, then the average product of variable labour input is 5 units per day.

The average product typically varies as more of the input is employed, so this relationship can also be expressed as a chart or as a graph. A typical average physical product curve is shown (APP). It can be obtained by drawing a vector from the origin to various points on the total product curve and plotting the slopes of these vectors. The marginal physical product of a variable input is the change in total output due to a one unit change in the variable input (called the discrete marginal product) or alternatively the rate of change in total output due to an infinitesimally small change in the variable input (called the continuous marginal product). The discrete marginal product of capital is the additional output resulting from the use of an additional unit of capital (assuming all other factors are fixed). The continuous marginal product of a variable input can be calculated as the derivative of quantity produced with respect to variable input employed. The marginal physical product curve is shown (MPP). It can be obtained from the slope of the total product curve. Because the marginal product drives changes in the average product, we know that when the average physical product is falling, the marginal physical product must be less than the average. Likewise, when the average physical product is rising, it must be due to a marginal physical product greater than the average. For this reason, the marginal physical product curve must intersect the maximum point on the average physical product curve.

Notes: MPP keeps increasing until it reaches its maximum. Up until this point every additional unit has been adding more value to the total product than the previous one. From this point onwards, every additional unit adds less to the total product compared to the previous one – MPP is decreasing. But the average product is still increasing till MPP touches APP. At this point, an additional unit is adding the same value as the average product. From this point onwards, APP starts to reduce because every additional unit is adding less to APP than the average product. But the total product is still increasing because every additional unit is still contributing positively. Therefore, during this period, both, the average as well as marginal products, are decreasing, but the total product is still increasing. Finally we reach a point when MPP crosses the x-axis. At this point every additional unit starts to diminish the product of previous units, possibly by getting into their way. Therefore the total product starts to decrease at this point. This is point A on the total product curve. (Courtesy: Dr Shehzad Inayat Ali).

DIMINISHING RETURNS

Diminishing returns can be divided into three categories: a 1. Diminishing Total return, which implies reduction in total product with every additional unit of input. This occurs after point A in the graph. 2. Diminishing Average returns, which refers to the portion of the APP curve after its intersection with MPP curve. 3. Diminishing Marginal returns, refers to the point where the MPP curve starts to slope down and travels all the way down to the x-axis and beyond.

Putting it in a chronological order, at first the marginal returns start to diminish, then the average returns, followed finally by the total returns.

DIMINISHING MARGINAL RETURNS

These curves illustrate the principle of diminishing marginal returns to a variable input (not to be confused with diseconomies of scale which is a long term phenomenon in which all factors are allowed to change). This states that as you add more and more of a variable input, you will reach a point beyond which the resulting increase in output starts to diminish. This point is illustrated as the maximum point on the marginal physical product curve. It assumes that other factor inputs (if they are used in the process) are held constant. An example is the employment of labour in the use of trucks to transport goods. Assuming the number of available trucks (capital) is fixed, then the amount of the variable input labour could be varied and the resultant efficiency determined. At least one labourer (the driver) is necessary. Additional workers per vehicle could be productive in loading, unloading, navigation, or around the clock continuous driving. But at some point the returns to investment in labour will start to diminish and efficiency will decrease. The most efficient distribution of labour per piece of equipment will likely be one driver plus an additional worker for other tasks (2 workers per truck would be more efficient than 5 per truck).

Resource allocations and distributive efficiencies in the mix of capital and labour investment will vary per industry and according to available technology. Trains are able to transport much more in the way of goods with fewer ―drivers‖ but at the cost of greater investment in infrastructure. With the advent of mass production of motorized vehicles, the economic niche occupied by trains (compared with transport trucks) has become more specialized and limited to long haul delivery.

P.S.: There is an argument that if the theory is holding everything constant, the production method should not be changed, i.e., division of labour should not be practiced. However, the rise in marginal product means that the workers use other means of production method, such as in loading, unloading, navigation, or around the clock continuous driving. For this reason, some economists think that the ―keeping other things constant‖ should not be used in this theory.

MANY WAYS OF EXPRESSING THE PRODUCTION RELATIONSHIP

The total, average, and marginal physical product curves mentioned above are just one way of showing production relationships. They express the quantity of output relative to the amount of variable input employed while holding fixed inputs constant. Because they depict a short run relationship, they are sometimes called short run production functions. If all inputs are allowed to be varied, then the diagram would express outputs relative to total inputs, and the function would be a long run production function. If the mix of inputs is held constant, then output would be expressed relative to inputs of a fixed composition, and the function would indicate long run economies of scale.

Rather than comparing inputs to outputs, it is also possible to assess the mix of inputs employed in production. An isoquant (see below) relates the quantities of one input to the quantities of another input. It indicates all possible combinations of inputs that are capable of producing a given level of output.

Rather than looking at the inputs used in production, it is possible to look at the mix of outputs that are possible for any given production process. This is done with a production possibilities frontier. It indicates what combinations of outputs are possible given the available factor endowment and the prevailing production technology.

ISOQUANTS

There are many ways of producing a given level of output. You can use a lot of labour with a minimal amount of capital, or you could invest heavily in capital equipment that requires a minimal amount of labour to operate, or any combination in between. For most goods, there are more than just two inputs. For example in agriculture, the amount of land, water, and fertilizer can all be varied to produce different amounts of a crop. An isoquant, in the two input case, is a curve that shows all the ways of combining two inputs so as to produce a given level of output.

THE MARGINAL RATE OF TECHNICAL SUBSTITUTION

Isoquants are typically convex to the origin reflecting the fact that the two factors are substitutable for each other at varying rates. This rate of substitutability is called the ―marginal rate of technical substitution‖ (MRTS) or occasionally the ―marginal rate of substitution in production‖. It measures the reduction in one input per unit increase in the other input that is just sufficient to maintain a constant level of production. For example, the marginal rate of substitution of labour for capital gives the amount of capital that can be replaced by one unit of labour while keeping output unchanged.

Marginal Rate of Technical Substitution To move from point A to point B in the diagram, the amount of capital is reduced from Ka to Kb while the amount of labour is increased only from La to Lb. To move from point C to point D, the amount of capital is reduced from Kc to Kd while the amount of labour is increased from Lc to Ld. The marginal rate of technical substitution of labour for capital is equivalent to the absolute slope of the isoquant at that point (change in capital divided by change in labour). It is equal to 0 where the isoquant becomes horizontal, and equal to infinity where it becomes vertical.

The opposite is true when going in the other direction (from D to C to B to A). In this case we are looking at the marginal rate of technical substitution capital for labour (which is the reciprocal of the marginal rate of technical substitution labour for capital). It can also be shown that the marginal rate of substitution labour for capital is equal to the marginal physical product of labour divided by the marginal physical product of capital.

In the unusual case of two inputs that are perfect substitutes for each other in production, the isoquant would be linear (linear, a straight line, with a function y = a - bx). If, on the other hand, there is only one production process available, factor proportions would be fixed, and these zero-substitutability isoquants would be shown as horizontal or vertical lines.