INTRODUCTION TO PRODUCTION AND OPERATIONS MANAGEMENT

POMA

- Previously called Production Management
- Then Production and Operations Management
- Often called Operations Management
- Should not be confused with Operations Research or Production Management which are the domain of Mechanical and Industrial Engineering.

THE COURSE CONTENT

Tentative Course Content Units of Learning wise

- Unit I (Introduction and Productivity, Strategy and Competitiveness)
- Unit II (Forecasting)
- Unit III (Design of Production Systems)
- Unit III (Quality)
- Unit V (Operating and Controlling the System)

Tentative Course Content Lecture wise

- Unit I (5 Lectures)
- Unit II (3 Lectures)
- Unit III (12 Lectures)
- Unit III (10 Lectures)
- Unit V (15 Lectures)

History of Management

- Frederick Taylor and Gilbreths (Lillian and Frank Gilbreth) are pioneers of transforming management to scientific domain.
- Borrows a lot of information from Engineering and Management to give an overall bigger picture of operating and managing any organization.

Difference between Operations Management and Research

- OR relies on mathematical modeling and OM relies on practical scenarios/industrial cases.
- OR domain and tool of Engineers while OM is considered to be one of the critical tools of Managers.
- OR considered more powerful to improve the whole system where as OM can be applied to a part of the system.

- OR relies on mathematical modeling while OM relies on practical scenarios/industrial cases.

Why Study OPERATIONS MANAGEMENT

- Operations Management form core of any organization's senior leadership.
- What are organizations
- An organization is a business entity that can work for profit or non profit purposes to generate a value added product or service for its customers.
- Whether profit or non profit, the role of an OPERATIONS MANAGER is to sustain, protect, and project the company's operations side.

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- Why Operations Manager
- Every organization must manage processes and operations by which processes are performed.
- An operations Manager controls the processes by which value is added from conversion of inputs to outputs.
- Why Operations Manager
- Inputs include materials, inventory, services, land, and energy, human and capital resources.

Bridge between Management and Engineering

- Two Islands named Engineering and Management
- Operations management uses foundations of both Engineering and Management.
- Bridge Basics , Extension of road from both ends till they meet at the centre and fuse to give strength and allow the foundations to give added strength to the bridge
- Bridge between Management and Engineering. The primary responsibility of an Operations Manager working at any level, for production or service based organization, is to help and facilitate the building of walls. It's a demanding job but at the time takes the same amount of time required by people who are creating hurdles and end up building walls in stead of bridges.
- Also, it is important at this point in time to understand that the Strength of the Chain is equal to the strength of the weakest Link, so if your analysis, as an operations manager consists of both Engineering and Management Links. Any weakness of analysis in Engineering or Management Link would lead to an overall weak analysis. A balanced approach would be to make best use of the strength and overcome the weaknesses. As a rule of thumb, problem solving and decision making through Production and Operations Management would entail that both Engineering and Management aspects should be utilized to aim for the powerful systems (over all big picture) approach.

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INTRODUCTION TO PRODUCTION AND OPERATIONS MANAGEMENT (Contd.)

RECAP OF 1ST Lecture

- Course Content, Midterm and Final Exam
- Organization Definition
- Finance, Marketing and Operations
- Productive systems, Production and Service Systems
- Operations Management (The management of systems or processes that *create goods and/or provide services*)
- Operation Function (Consists of all activities directly related to producing goods or providing services)

Manufacturing and Service Definitions

- Manufacturing is the transformation of raw materials into finished goods for sale, or intermediate processes involving the production or finishing of semi-manufactures.
- It is a large branch of industry and of secondary production. Some industries, like semiconductor and steel manufacturer's use the term fabrication.
- Service is defined as either as

Services are deeds, processes, and performances.

OR

A service is a time-perishable, intangible experience performed for a customer acting in the role of a co-producer

Definition of Service Firms

Service enterprises are organizations that facilitate the production and distribution of goods, support other firms in meeting their goals, and *add value* to our personal lives.

Role of Services in an Economy

Production and Services Growth in Pakistan

Can be attributed to the following sectors

- Private
- Public
- Public Private
- Government

Key Areas of Responsibility for an Operations Manager

Operations Managers job responsibility includes but is not limited to:

- Forecasting
- Capacity planning

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- Scheduling
- Inventory Management
- Quality Assurance and Control
- Motivating employees
- Deciding where to locate facilities

Key Decision Areas for Operations Managers 5W2H Approach

- What : What resources/what amounts
- Why: The work is needed to be done
- When: Needed/ scheduled/ordered
- Where: Work to be done
- How much: Quantity to be produced or served,
- How: Designed/capacity planning
- Who: To do the work

Decision Making

Operations Manager spends most of their routine hours in making decisions under certainty or uncertainty. The various tools available to an Operations Manager include

1. Models
2. Quantitative approaches
3. Analysis of trade-offs
4. Systems approach

Applications of Models in Operations Management

Models Are Beneficial and effective to an Operations Manager primarily because of the following reasons

- Easy to use, less expensive
- Require users to organize
- Systematic approach to problem solving
- Increase understanding of the problem
- Enable "what if" questions
- Specific objectives
- Consistent tool
- Power of mathematics
- Standardized format

Historical Development of OM

- JIT and TQC
- Manufacturing Strategy Paradigm
- Service Quality and Productivity
- Total Quality Management and Quality Certification
- Historical Development of OM (cont'd)
- Business Process Reengineering
- Supply Chain Management
- Electronic Commerce

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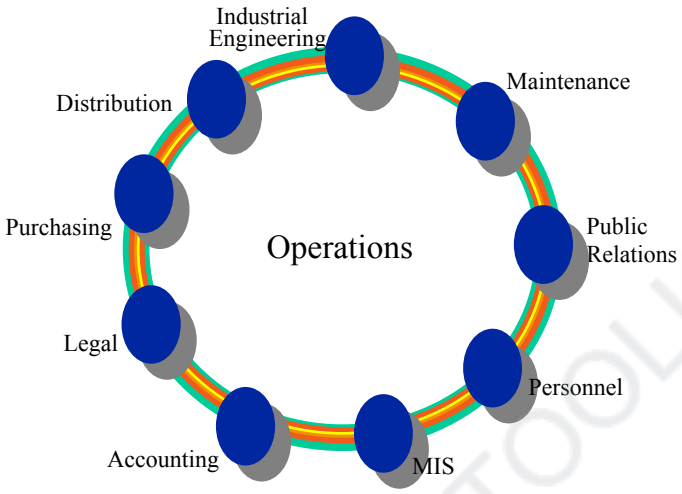
Current Trends in Business

Trends in Business in general and Operations Management which have shaped the industry and the technological support to the industry include the following:-

1. The Internet, e-commerce, e-business
2. Management technology
3. Globalization
4. Management of supply chains
5. Agility

Production and Operations Management as Nucleus in the Organizations

Operations occupy the central figure in any service or manufacturing organization. A small decision as it may seem can serious effect the workings and performance output in other units.



Current Issues in OM

The recent wave of telecom sector infrastructure consolidation and deregulation has led to a lot of foreign investors aggressively seeking new Pakistani partners. With the aid of operation management studies we can foresee the following current issues in Pakistan. These issues have already been addressed in Pakistan as well as in other countries.

1. Effectively consolidating the operations resulting from mergers
2. Developing flexible supply chains to enable mass customization of products and services
3. Managing global supplier, production and distribution networks
4. Increased "commoditization" of suppliers
5. Current Issues in OM (cont'd)
6. Achieving the "Service Factory"
7. Enhancing value added services
8. Making efficient use of Internet technology
9. Achieving good service from service firms

What is a Production and Productive System?

A productive system is defined as a user of resources to transform inputs into some desired outputs (products as well as services) where as production system refers specifically to only desired output in the form of products or manufactured goods.
It is important to understand that productive system reflects both production as well as services systems.

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We also need to understand the important transformations through which a raw material is converted a value added end product or service.

- Physical--manufacturing
- Location--transportation
- Exchange--retailing
- Storage--warehousing
- Physiological--health care
- Informational--telecommunications

Our discussion throughout the semester would focus on what is a Service and what is a Good? In our course of discussion, we will collect numerous examples to better understand that Workers working for creation of a product, manufacturing units are simultaneously working to create a service? So the statement that Services never include goods and goods never include services can never be true.

Production of Goods vs. Delivery of Services

- Production of goods – tangible output
- Delivery of services – an action and reaction between the provider /deliverer of services and the demander of services, bank teller, hair stylist.
- Service job categories
  - Government
  - Wholesale/retail
  - Financial services
  - Healthcare
  - Personal services
  - Business services
  - Education

Percent Service Employment for Selected Nations

Percent Service Employment for Selected Nations (Source not Authenticated)

Country	1980	1987	1993	2000
United States	67.1	71.0	74.3	74.2
Canada	67.2	70.8	74.8	74.1
Pakistan	**13.3**	**16.0**	**18.0**	**23.9**
Japan	54.5	58.8	59.9	72.7
France	56.9	63.6	66.4	70.8
Italy	48.7	57.7	60.2	62.8
Brazil	46.2	50.0	51.9	56.5
China	13.1	17.8	21.2	40.6

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Stages of Economic Development in Pakistan

Society	Pre-dominant activity	Use of human labor	Unit of social life	Standard of living measure	Structure	Technology
Pre-Industrial (1947 to 1960)I	Agriculture Mining (coal. Salt)	Raw muscle power	Extended household (Joint Families)	Survival	Routine Traditional Authoritative	Simple hand tools
Industrial (1960 – todate)	Goods production	Machine tending	Individual	Quantity of goods	Bureaucratic Hierarchical	Machines
Post-industrial (Future)	Services	Artistic Creative Intellectual	Community	Quality of life in terms of health, education, recreation	Inter-dependent Global	Information

Source of Service Sector Growth

Pakistan is slowly but surely facing a change in its demographics, economics and more important social norms. This shift has often proven to be the source of service sector growth.

Innovation

- Push and Pull theory e.g. Cash Management
- Services derived from products e.g. CD/Automobile/Video Rental
- Information driven services like finance brokerage services.

Social Trends

- Aging of the population
- Increase in Life expectancy
- Two-income families, both the males and females of the family are working
- Growth in number of single people.

Home as sanctuary

Functions with in an Organization

- The Operations function consists of all activities that are directly related to production of a good or service.
- Operations function exist in services like healthcare, Police, Traffic, transportation, consultancy, food handling, restaurants etc.
- Operations function forms the core of all businesses.

Operations and Marketing

- Value addition refers to conversion of raw materials to finished goods or services.
- Value added often refers to the difference between the cost of the raw material and the price of the finished good.
- The revenues from selling goods is used in betterment of existing product or service or R &D, investment in new facilities and equipments
- Weeding out or eliminating non value adding operations. E.g. storage of goods which have been produced ahead of scheduled production, increases storage and inventory costs. reducing storage cost would reduce transformation cost and thus increase value addition
- Marketing relates to selling of a good or service of the organization through advertising and pricing decisions.

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- Marketing department assesses the customer's needs and communicate it to the operations people on short term and design people on the long term basis.

- Operations people need information about demand over a short range in order to purchase raw materials or manage inventory or schedule production plan where as the design people need information to redesign or simply design new products or services.
- Marketing provides valuable information about the competitors customers needs and communicate it to the operations people on short term and design people on the long term basis.

Finance

- The finance function focuses on activities that relate to securing resources at favorable prices and then allocating these resources through out the organization.
- Finance and Operation Personnel exchange information and expertise in the following way.
- Budgets
- Economic analysis of investment proposals
- Provision of funds

Historical Evolution of Operations Management

- Industrial revolution (1770's)
- Scientific management (1911)
  - Mass production
  - Interchangeable parts
  - Division of labor
- Human relations movement (1920-60)
- Decision models (1915, 1960-70's)
- Influence of Japanese manufacturers

Simple Product Supply Chain

Supply Chain: A sequence of activities and organizations involved in producing and delivering a good or service. Let's apply the same concept to what we have on our breakfast table every morning, a simple loaf of bread.

Current Issues in OM

An operations manager needs to prepare himself or herself for the following issues in the years to come whether its Pakistan or outside Pakistan.

- Effectively consolidating the operations resulting from mergers
- Developing flexible supply chains to enable mass customization of products and services
- Managing global supplier, production and distribution networks
- Increased "commoditization" of suppliers
- Current Issues in OM (cont'd)
- Achieving the "Service Factory"
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COMPETITIVENESS, STRATEGY AND PRODUCTIVITY

Meanings of Competitiveness, Strategy and Productivity

We are already familiar with these three terms, for the sake of easy reference, let us revisit their definitions

1. **Competitiveness** refers to an aggressive willingness to compete
2. **Strategy** is an elaborate and systematic plan of action with defined resources **and**
3. **Productivity** refers to the ratio of the quantity and quality of units produced to the labor per unit of time or simply ratio of output to input.

How Organization Compete against each other

Businesses since the beginning of time have competed against each other. On the basis of competition, various types of market exist for nearly all lines of products and services. We already know that absolute monopoly and perfect competition type of markets are not that pervasive, yet businesses try to avoid perfect competition and strive to go for absolute monopoly so they can enjoy no competition and exploit the customer sentiments for buying. We can identify the following common and widespread ways in which organizations can compete against other organizations.

1. Price: In our day to day routine observations, we often see that a lower price would attract more customers provided the product or service fulfils its intended use. Lower price helps an organization to increase its customer base.
2. Quality is an important dimension by which superior raw materials as well as high Skillman ship would ensure that product manufactured or service developed is offered to the customer with something extra. That something extra is nothing else but Quality. Quality is always offered free of cost, we will discuss this when we study in details Quality Management and Total Quality Management.
3. Product Differentiation refers to special features that make the product or service look more suitable to the customers like an automobile manufacturer decides to provide GPS system to selected customer at an additional price etc.
4. Flexibility is the ability to respond to changes. It may refer to changes in target sales, product feature like adding GPS device to all automobiles
5. Time refers to the period required to provide a product or service to a customer from the moment the order is booked to the delivery, also time required to rectify a shortcoming or mistake

A. Competitiveness

Competitiveness is how effectively an organization meets the needs and requirements of customers relative to other (Competitors) organizations that offer similar goods or services

The key to successfully competing against the organizations competitors or rivals is to answer these two questions diligently

I. What do the Customers Want?
II. How can our business deliver the required Value to the customers?

The first question begets a natural and logical answer which is that the customers want Value. Similarly the second question also asks for a logical answer which is the way organizations would deliver value to the customer as per the understanding of the organization. If an organization can understand that Value is always the tradeoff between performance and cost then it can adopt various means to provide value to the customer.

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Mathematically speaking value equals the performance (of the product or service) divided by cost. Most organizations have different measurement rules attached in measurement of quality, speed and flexibility.

Value= Performance/Cost= (Quality +Speed+ Flexibility)/Cost_____ Eq. 1

The equation above also captures the product differentiation concept, which in reality is an important dimension of quality. The concept of quality would be covered at a later stage, towards the middle of the semester.

We can also say that, the customer is measuring performance with the help of Quality, Speed and Flexibility for the price or cost he is willing to pay.

The point worth noting is that in most of the cases the three factors of performance would not be weighed equally in some cases, quality would be more important than speed or flexibility etc. We can thus make use of an important concept of assigning weights so the equation changes to

Value= (w1 x Quality + w2 x Speed+ w3 X Flexibility) / Cost_____Eq.2

Where w1, w2 and w 3 are different weights and if they all have same value then equation 2 reduces to equation 1 again. IN other words, equation 2 is not only generic but more reflective of performance measurement of an organization.

Different organizations assign different means to obtain the value of these weights by developing in-house or a consultant derived Performance Measurement Model (PMM). This can be used to obtain an overall performance score by measuring the success of a manufacturing company in its operational activities. The developed PMM measures a company's level of performance in critical dimensions and combines these performance scores to obtain a ranking score. A set of critical dimensions and their sub-components is fully defined, and performance scorecards are developed to guide the assignment of performance scores. Performance scores are assigned according to the level of intensity of a manufacturing company's investments, practices, actions or infrastructures in the critical dimensions.

How Organizations can gain Competitive Advantage

As Students of Organization Management, we can look at value in terms of the three important functions of any organization to see how organizations can gain competitive advantage

1. Marketing
2. Finance
3. Operations

A. Businesses Gain Competitive Advantage by using Market based strategies

1. Identifying consumer wants and needs
2. Pricing
3. Advertising and promotion

B. Businesses Gain Competitive Advantage by using Finance based strategies

1. Identifying sources of funds and applications of funds.
2. Capital and Financial Investments.
3. Financial Leverage (Debt to Equity) and
4. Capital structure.

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C. Businesses Gain Competitive Advantage by using Operations based strategies

1. Product and service design. The design is not only the starting point but allows certain features to be added which makes your product or service favorable to the customer.
2. Cost or Cost Leadership, offers the product or service at an economical price
3. Location refers to the Convenient point of sales, it can be a petrol pump (services) with an attached convenience store
4. Quality should always match the price and service.
5. Quick response aka Also known as Agility and an organization on this basis is often known as Agile Organization)
6. Flexibility. Flexibility change the car model from sedan to coupe based on your marketing divisions inputs.
7. Inventory management. Maintain safety stocks and critical spares.
8. Supply chain management. Develop and sustain an active and strong chain between suppliers and end customers.
9. Service .After sales service, owning the customers issue as your own, a concept which has failed PK in its quest for foreign market penetration.

Throughout the semester our aim would be to identify and understand different types of strategies which have been exploited to the fullest by various organizations and adopted religiously as their actual Operational strategies companies. This has helped these organizations to gain competitive advantage over their counterparts.

Common Reasons why Organizations Fail

We can identify certain familiar reasons why Organizations fail to achieve a competitive advantage and end up loosing out to their competitors. These reasons are universal in nature and find the same footing in Pakistan as well as any other place in the world.

1. Too much emphasis on short-term financial performance. Quite often, cost cutting, profit maximizing at the cost of social responsibility or employee motivation is a failed strategy pursued by organizations, which just hastens their status to oblivion.
2. Failing to take advantage of strengths and opportunities. This is in reality failing to hold on to proven successful strategies or core competencies. Sometimes a change in leadership leads to change in strategy, where just for the sake of glory and high profits, organizations forget their core competence and opt for strategies and tactic which cause their downfall.
3. Failing to recognize competitive threats. This reason is the exact opposite of failure to make use of the organizations strengths. Quite often organizations decide to pursue status quo and ends up bringing no new product or service or even no innovation in its existing product or service line leading to lack of customer satisfaction, decline in profits and finally being declared a failure.
4. Neglecting operations strategy. This is definitely the most important reason of failure; organizations often end up employing non productive techniques which lead to inconsistent and failed operations. Absence of an Operations Strategy leads to
5. Too much emphasis in product and service design and not enough on improvement. Differentiation in terms of service and product, American companies in 1980s did that they never introduced incremental refinements rather went for big changes and thus lost to Japanese competitors.
6. Neglecting investments in capital and human resources. A total disregard to use the best resource. Capital and human resources in the long run make or break an organization.
7. Failing to establish good internal communications. Matrix organizations or hierarchy or such a strong structure that often the structure does not allow communication.

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8. Failing to consider customer wants and needs. This is actually indicative of an organizations lack of marketing research skills. This also shows that there is no respect to Customer Relationship Management Concept and certainly no respect to the customer.

Mission/Strategy/Tactics

Most of the organizations tend to answer the question that how does mission, strategies and tactics relate to their decision making and attaining distinctive competencies? Organizations over the years have mastered the art and technique of developing a vision and a mission statement, which helps them to come with functional strategies and practical tactics by which they can make judicious decisions and attain distinctive competencies

2. Strategy

1. Strategies are Plans for achieving organizational goals
   - Mission is the reason for existence for an organization
   - Mission Statement answers the question "What business are we in?"
   - Goals provide detail and scope of mission
   - Tactics are the methods and actions taken to accomplish strategies

2. Concept of Strategy for a Pakistani Automobile manufacturer
   - Strategies are plans for achieving organizational goals
   - Mission is to provide BEST AUTOMOBILES to individuals as well as BUSINESS organizations of Pakistan
   - Mission Statement is to give you safe wheels to move around"
   - Goals are to provide utility, and heavy equipment mobiles.
   - Tactics consist of employing TQM methods to accomplish strategies

Planning and Decision Making

Planning and decision making concepts make use of setting a mission, goal, strategy and achieving the end result through some effective and practical tactic. In hierarchical order the organization first makes or develops a mission and employ tactics by developing operational procedures.

Strategy Example

You are a business student at Virtual University of Pakistan. You would like to have a career in business, have a good job, and earn enough income to live comfortably

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Mission:	Live a good life
•Goal:	Successful career, good income
•Strategy:	Obtain a Business Degree from VU.
•Tactics:	Select a business field of your interest and high market value
•Operations:	Register, buy books, take courses, Study, graduate, apply & get job

Examples of Strategies

1. Low cost (Cost Leadership/Economical)
2. Scale-based strategies (Critical Value)
3. Specialization (Specific characteristics)
4. Flexible operations (To change production design of products on the same infrastructure)
5. High quality (exceeds customer requirements and satisfactions)
6. Service (meets minimum standard specifications)

The special attributes or abilities that give an organization a competitive edge.

1. Price
2. Quality
3. Time
4. Flexibility
5. Service
6. Location

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DISTINCTIVE COMPETENCIES

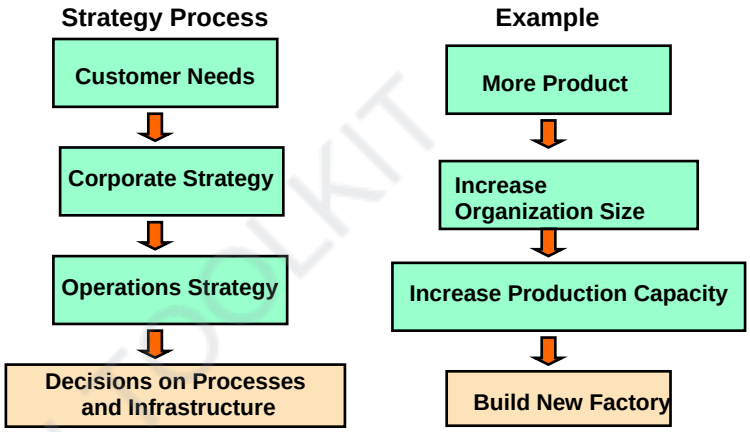
The special attributes or abilities that give an organization a competitive edge.

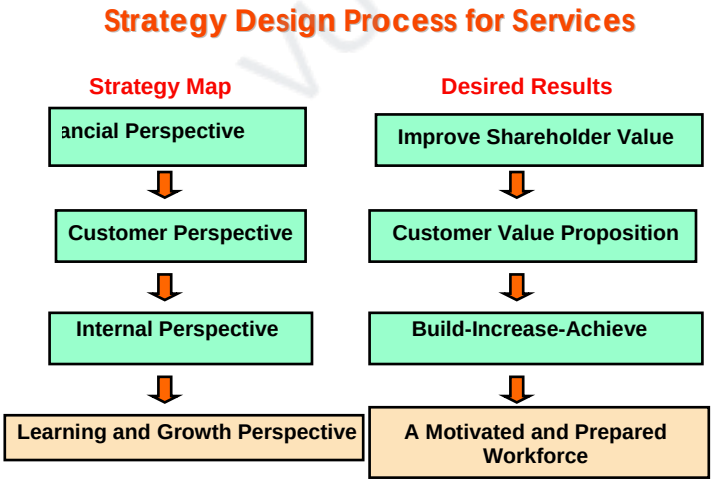
1. Price
2. Quality
3. Time
4. Flexibility
5. Service
6. Location

A. Operations Strategy

•Operations strategy – The approach, consistent with organization strategy that is used to guide the operations function. We first study strategy design process with example for manufacturing and Services.

Strategy Design Process





Relationship between Operations and Organizational Strategy

•Organizational strategy is

- An over all big picture for the whole organization.
- Longer in time horizon
- Less detailed and broader in scope.

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•Operational Strategy is

- Narrower in scope and in more detail
- Prepared by middle management.
- Should be in line with the Organization strategy

•Operational Strategy if

- Designed and implemented successfully can make an organization more successful.
- Organizations started focusing on operational strategies in early 1990s before that organizations focused on financial and marketing strategies.
- Operational strategies mostly function on two dimensions of **quality management** and **service/manufacturing strategy**.

An operations Manager should avoid SUBOPTIMIZATION meaning his operational strategy for the department and divisions goals should not harm the overall Organizational strategy. He should opt for systems approach or a big picture approach or strictly base his operations strategy on Organizational strategy.

Operations Strategy for Service Organizations

Service Organizations in Pakistan function with a very detailed and elaborative Operations Strategy. It is important to identify the Strategy Design Process and able to recognize the concepts associated with Strategy Formulation. Service Organizations are no exceptions and work diligently to identify, nurture and protect their distinctive competencies. Service Organizations are busy carrying out detailed environmental scanning and also periodically carryout SWOT Analysis.

As operations manager of a service based organization, one should be able to understand the importance of both Order qualifiers and Order winners. Order qualifiers
are those significant characteristics that service customers perceive as minimum standards of acceptability to be considered as a potential purchase while order winners
are the characteristics of an organization's services that cause it to be perceived as better than the competitors services. A bank offering 10 percent return on customers' holdings would be an order qualifier but if the same service has an additional characteristic of some added feature like availability of interest free loans for purchase of car or building of homes, then the banks service becomes order winner.

Steps in Developing a Manufacturing/Service Strategy

1. Segment the market according to the product/Service group (A person interested in buying a sedan car would rarely show interest in buying an SUV car, the market segmentation should be just and judicious)
2. Identify product/Service requirements, demand patterns, and profit margins of each group (Your Market research department should be able to capture these with the help of MIS systems)
3. Determine order qualifiers and winners for each group (Order Qualifiers would meet customer requirements and Order Winners would satisfy customers)
4. Convert order winners into specific performance requirements (Continuous improvement always helps and it is what the Japanese has perfected through KAIZEN)

Key External Factors

1. Economic conditions should include both Micro and Macro Economics.
2. Political conditions require the organization to carryout PEST analysis.
3. Legal environment relates to government regulations for investor protection.
4. Technology .Gap Analysis focusing market leaders in the respective field.
5. Competition so as to expect no free lunches or no monopolies.
6. Markets are always free markets till proven otherwise

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Key Internal Factors

1. Human Resources include Trained, skilled and qualified employees.
2. Facilities and equipment are a good source for motivation, and obtaining competitive advantage over your competitors.
3. Financial resources. A higher Free cash flow makes a company outperform its competitors.
4. Customers include repeat customers, as well as customer relationship Management.
5. Products and services relates to how does the organization values itself whether it provides products or services that add value)
6. Technology .Legacy Systems or Technology that is competitive and has the potential to gain competitive advantage.
7. Suppliers .Companies have taken care of the supplier issue by making use of effective Supply Chain Management Strategies or use vertical or horizontal integration techniques.

Strategic Service Vision

Service Concept includes

- Service Levels refer to the important elements of the service to be provided, usually stated in terms of results produced for customers.
- Perception corresponds to the elements perceived by the target market segment, by the market in general, by employees, & by others. How do customers perceive the service concept?
- Delivery focuses on the efforts in terms of the manner in which the service is designed, delivered, marketed.
- Strategic Service Vision.

Operating Strategy

- Focus Area includes important elements of the strategy: operations, financing, marketing, organization, human resources, and control. Also the central service area along with the location of investments (human resource or Technology).
- Central Operations to control quality and costs, improve measures, incentives, rewards. The expected results should be evaluated in terms of, quality of service, cost profile, productivity, morale/loyalty of servers.

Service Delivery System

The important features of the service delivery system include role of people, technology, equipment, layout, procedures

- The capacity it has to provide at peak levels
- The extent to which it should help to insure quality standards, differentiate the service from competition, provide barriers to entry by competitors.
- Relatively Low (as compared to manufacturing) Overall Entry Barriers
- Economies of Scale Limited (not always but most of the time)
- High Transportation Costs
- Erratic Sales Fluctuations
- No Power Dealing with Buyers or Suppliers
- Product Substitutions for Service
- High Customer Loyalty
- Exit Barriers

Competitive Service Strategies (Overall Cost Leadership)

- Seeking Out Low-cost Customers
- Standardizing a Custom Service
- Reducing the Personal Element in Service Delivery (promote self-service)

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- Reducing Network Costs (hub and spoke)
- Taking Service Operations Off-line

Competitive Service Strategies (Differentiation)

- Making the Intangible Tangible (memorable)
- Customizing the Standard Product
- Reducing Perceived Risk
- Giving Attention to Personnel Training
- Controlling Quality

Note: Differentiation in service means being unique in brand image, technology use, features, or reputation for customer service.

Customer Criteria for Selecting an online Banking Service Provider in Pakistan

We can apply our concepts of service to an online banking service provider in Pakistan. We investigate the service being provided by the bank by checking for availability, convenience, dependability, personalization, price, quality, reputation, safety and speed. This should help us understand the strength of service industry in a competitive environment especially in our country of Pakistan.

CHARACTERISTIC	REMARKS
Availability	24 hour ATM or online financial transaction
Convenience	Site location from any internet equipped computer in and out of Pakistan
Dependability	On-time performance and correct information
Personalization	Know customer's name and ID
Price	The fee a customer pays for online service
Quality	Reflected in service.
Reputation	Word-of-mouth and audited and examined by neutral bodies.
Safety	Customers online data is safe and inaccessible to others and hackers
Speed	Avoid excessive waiting in website loading and data available online.

Online banking service providers are often checked for:

- Anti-competitiveness i.e. whether are not allowing other online banking service providers to enter the market by constructing barriers to entry
- Fairness indicates the concept of Yield management. Meaning whether the bank is actually providing the same return as it had promised to the customer
- Invasion of Privacy. Calling people through telephones or visiting offices thus making use of Micro-marketing concepts, which often makes the patron and customer feel that his privacy has been compromised.
- Data Security. Banks make it a point that the financial records of the customers are not accessed by unauthorized personnel.
- Reliability. Banks always strive that their service is reliable and considered safe and usable by its customers. Most online banking service providers allow its customers to access their account statement, free of cost.

Service Purchase Decision

In order to understand further we evaluate the service organizations in terms of Purchase Decision.

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- *Service Qualifier*: To be taken seriously a certain level must be attained on the competitive dimension, as defined by other market players. Examples are cleanliness for a fast food restaurant or safe aircraft for an airline.
- *Service Winner*: The competitive dimension used to make the final choice among competitors. Example is price of airline ticket or bus fare.
- *Service Loser*: Failure to deliver at or above the expected level for a competitive dimension. Examples are failure to repair auto (dependability), rude treatment (personalization) or late delivery of package (speed).

Using Information to Categorize Customers (For Call Centers in Pakistan)

- Coding grades customers on how profitable their business is.
- Routing is used by call centers to place customers in different queues based on customer code.
- Targeting allows choice customers to have fees waived and get other hidden discounts.
- Sharing data about your transaction history with other firms is a source of revenue.

Quality and Time Strategies

•Quality-based strategies

- Focuses on maintaining or improving the quality of an organization's products or services
- Quality at the source

•Time-based strategies

- Focuses on reduction of time needed to accomplish tasks
- Time Based Strategies: Organizations have registered reduction in time by employing the following "6" time based strategies. There are 6 time based strategies namely:-

1. Planning Time The time required to react to a competitive threat, or to adopt new technologies, or to approve changes to an existing facility
2. Products/Service Design Time The time needed to develop or market new or redesigned products or services
3. Processing Time The time required to produce goods or services, includes repairing equipment, quality training, inventory etc
4. Changeover Time is the time needed to change from producing one type of product or service to another. New model, new insurance /health service.
5. Delivery Time is the time needed to fill orders.
6. Response Time for complaints is the required to improve the model or service features according to customer inputs and improving employee working conditions.

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PRODUCTIVITY

Productivity

Productivity is a measure of the effective use of resources, usually expressed as the ratio of output to input .Also called Efficiency at times

•Productivity ratios are used for

- Planning workforce requirements
- Scheduling equipment
- Financial analysis

Productivity

- Partial measures is output/(single input)
- Multi-factor measures is output/(multiple inputs)
- Total measure is the output/(total inputs)

Productivity Growth = Current Period Productivity – Previous Period Productivity
Previous Period Productivity

Productivity Growth = Unit less Quantity

Partial measures: Output/Labor; Output/Machine; Output/Capital; Output/Energy

Multifactor measures: Output/(Labor + Machine); Output/(Labor + Capital + Energy)

Total measure = Goods or Services Produced / All inputs used to produce them

Labor Productivity	Units of output per labor hour Units of output per shift Value-added per labor hour
Machine Productivity	Units of output per machine hour
Capital Productivity	Units of output per Rs. input Dollar value of output per Rs. input
Energy Productivity	Units of output per kilowatt-hour Rupee value of output per kilowatt-hour

Example

What is the multifactor productivity "MFP"? if 7500 Units Produced and Sold for Rs.10/unit with Cost of labor of Rs.10,000, Cost of materials: Rs.5,000 and Cost of overhead: Rs.20,000.

Solution $$MFP = \frac{\text{Output}}{\text{Labor + Materials + Overhead}}$$

$$MFP = \frac{(7500 \text{ units})*(10)}{10{,}000 + 5{,}000 + 20{,}000}$$

$$MFP = \frac{(750{,}00)}{35{,}000}$$

MFP = 2.1420

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Factors Affecting Productivity

Productivity stands tall on four important pillars of Capital, Quality, Management and Technology. These pillars are also responsible for positively as well as negatively affecting the Productivity of the Organization.

1. CAPITAL An existing machine or facility if it is not functioning up to full capacity or turning out products which are not acceptable can lower productivity. A new machine or repair of existing machine would require capital input.
2. QUALITY Poor quality products would not meet customer requirements and would need repairs and reworks on the product to meet the standards.
3. MANAGEMENT With better scheduling, planning, coordinating and controlling activities of management the machine operations can be carried to improve productivity.
4. TECHNOLOGY Technological improvements have increased productivity. A machine of today would outperform machine of yesterday but may not withstand machines of tomorrow.

CAUTION: Without careful planning technology can reduce productivity as it often leads to increased costs, inflexibility or mismatched operations. All leads to reduction in value.

Other Factors Affecting Productivity

- **Standardization** We live in a world where for the sake of convenience, reliability and safety, majority of the products and services have been standardized. If for a moment any process whether it relates to manufacturing or services is made standard less, the vital concept of compatibility would be lost. Think for a moment if there is a fire at a Montessori school or at a crowded stadium, if there is no standardization of fire hose attached to the fire truck and fire hydrant present at the site, no effort would succeed in putting out the fire and saving the lives of the people.
- **Use of Internet** .Use of Internet/Extranet especially for the services side, even though there are knowledge base applications available for the manufacturing side as well but primarily it has the been the services side which has been able to exploit the resourcefulness of the Internet.
- **Computer viruses**. A lot of time IT based services industry have fallen a prey to computer viruses and hackers.
- **Searching for lost or misplaced items**. This speaks low about the coordinating activities and can lead to loss in production time and increase in idle time. Often this also leads to increase in replacement costs
- **Scrap rates** Any aberration in the raw materials or processed product can lead to increase in scrap. The increase in scrap rate in fact can decrease the utilization of resources in general and raw material
- **New workers** Organizations spend millions of Rupees every year to train their employees. A trained workforce is not only reliable and dependable but also ensures good

Host of other Factors Affecting Productivity:

- Safety
- Shortage of IT Trained Workers
- Layoffs
- Labor turnover
- Design of the workspace
- Incentive plans that reward productivity

E. Bottleneck Operation

- Bottleneck is one process in a chain of processes, such that its limited capacity (increased time of completion, or increased labour requirement) reduces the capacity of the whole chain
- A related concept is critical path (see Project Management) and the Theory of Constraints (from the field of Industrial Engineering and Operations management).
- Theory of constraints (TOC) is a body of knowledge on the effective management of (mainly business) organizations, as systems.

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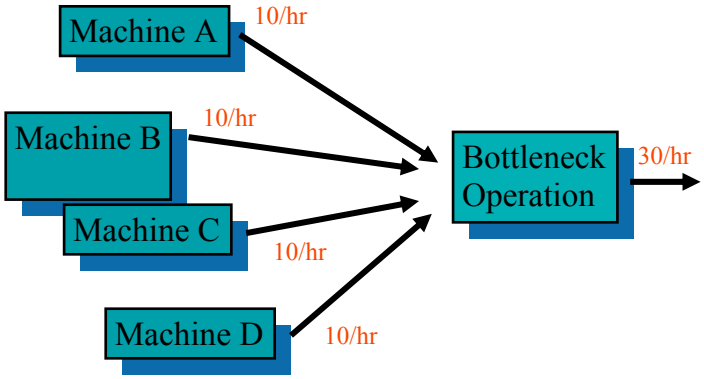
The figure below clearly shows that a machine requiring 12 hours to complete the job is the real bottleneck. A manufacturing bottle neck like this normally leads to delayed completion and extended time for job. Similar bottlenecks are observed in the Service side as well.



Develop productivity measures

- Determine and isolate critical (bottleneck) operations
- Develop methods for productivity improvements
- Establish reasonable goals
- Get management support
- Measure and publicize improvements
- Clearly differentiate between productivity and efficiency

Example of Productivity Measurement

You have just determined that your 20 Operations (Service) department employees have used a total of 2200 hours of labor this week to process 480 insurance forms. Last week the same crew used only 2000 hours of labor to process 400 forms.

- Which productivity measure should be used?
- Answer: Could be classified as a Total Measure or Partial Measure and Time/Labor productivity.
- Is productivity increasing or decreasing?

Answer: Last week's productivity = 400/2000 = 0.2, and this week's productivity is = 480/2200 = 0.22. So, productivity is increasing slightly.

Pakistani Productivity Example 1

Calculate the change in productivity of Pakistani Textile Industry between the years 2003-04 and 2004-05? (Installed Capacity)

Parameter	2003/4	2004/5	Change
Number of mills	399	426	6.77
Spindles (000)	9286.8	9815.5	5.69
Rotors(000)	145.6	151.6	4.12

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Pakistani Productivity Example2

Calculate the change in productivity of Pakistani Textile Industry between the years 2003-04 and 2004-05? (Working Capacity)

Parameter	2003/4	2004/5	% Change
Number of Looms(000)	4.3	4.9	13.95
Spindles (000)	7710.0	8531.0	10.65
Rotors(000)	67.3	75.1	11.59

Textile Productivity Example 3

Calculate the Productivity of Pakistani Textile Industry between the years 2003-04 and 2004-05? (Weaving Sector Capacity)

Parameter	**Installed I**	**Working W**	**% Effectiveness W/I**
Power Loom Sector	225258	220447	
Independent Weaving Unit	26034	25500	
Integrated Textile Unit	10249	4947	
Total	261541	220447	

Pakistan Automobile Industry

Calculate the Productivity Change for Pakistani Automobile Industry between the years 2003-04 and 2004-05?

Type	**2003-04**	**2004-05**	**% change in Productivity**
Cars	79,655	100,213	
Motorcycles	263,149	386,589	
Trucks	1,669	1,999	
Buses	1,151	1,503	
Tractors	28,583	35,308	

How countries/nations can improve productivity

As students of Operations Management in Pakistan we need to know and understand how the concepts of productivity can help nation improve its quality of life and economy.

- Increase capital formation by saying no to foreign goods. This would increase savings and decrease consumption. Foreign goods only make why to a market if there is high consumption. BE PAKISTANI BUY PAKISTANI
- Decrease in administrative (non productive) regulations of the government. Self explanatory.
- Right balance between Services and Manufacturing activities. In the city of Lahore, there is an availability of surplus services, which is often less productive than manufacturing operations
- An emphasis on both long term and short term objective based performance. (Closely monitor and audit the variances between planed and actual results).
- Exploit the inherent resources of domestic market .Let it be known to all that the best productive market for Pakistani Producer is Pakistani market.

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Summary

The important concepts of Productivity, Competitiveness and Strategy when considered in cohesion enhance the overall performance of any service based or manufacturing organization. Organizations formulate operational and organizational strategies to achieve competitive advantage over its competitors. Different types of competencies allow organizations to formulate time or quality based strategies to achieve competitive
Advantage and increase their revenues. The same concepts find equal application for a country to gain competitive advantage over other countries.

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THE DECISION PROCESS

Learning Objectives

Decision Process is more or less the fundamental process of Management. Whether a person works in a manufacturing organization or a services side organization, he or she would be asked to carry out the decision process. Normally the decision making process involves the following six important steps

1. Specify Objectives and the Criteria for decision making
2. Develop Alternatives
3. Analyze and compare alternatives.
4. Select the best alternative.
5. Implement the chosen Alternative
6. Monitor the results to ensure the desired results are achieved.

Operations Manager identifies the criteria by which the proposed solutions will be judged. The common criteria often relates to costs, profits, return on investment, productivity, risk, company image, impact on demand, or similar variables. The management is interested that the Operations Manager should be able to focus on parameters that will increase or decrease? Ideally the aim is that

1. Costs should decrease and Profits should increase
2. Return on Investment should increase along with increase in Productivity.
3. Risk should decrease along with increase in Company image.
4. Demand should increase for the product or service.
5. Monitor the results to ensure the desired results are achieved.

The Decision Process Example

The CEO of ABC Corporation has asked you (the VP Operations) to help the BOD reach a decision whether to introduce a new automobile model. The new model would have the following effects on important decision making process. Certain Parameters will increase and decrease?

- Costs decrease by 15 %
- Profits increase by 2%
- Return on Investment stays the same
- Productivity decreases by 5%
- Risk increases by 5 %
- Company image may increase or decrease
- Demand may increase or decrease for the product or service.

Solution

Based on the above data, a Risk Averse Manager would forego the new project, A Risk taker would go for it. These factors alone do not present the overall big picture, most of the times in practical situations, the decision is based upon important factors like ROI, Productivity, Utilization of available resources, Profits and Costs in line with organizations operational and organizational strategy and the mapping of the organization with respect to its competitors and competitive environment..

Causes of Poor Decisions

Unforeseeable and uncertain circumstances , which in reality refers to a mistake or error in the decision making, remedial action is to have a STEERING COMMETIEE (comprising of senior management) to review the whole process and monitor the decision steps.

Decision Environments

There are three degrees of Certainty, Risk and Uncertainty.

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1. Certainty: Means that the relevant parameter such as costs, capacity and demand have known values.
2. Risk means that certain parameters have probabilistic outcomes.
3. Uncertainty means that the certain parameters have various possible future events.

Decision Environments often represent the same three scenarios of Certainty, Risk and Uncertainty. Let us consider the example where we are making a ball bearing which is to be used in ceiling fan and our marketing department comes with up three scenarios with different set of numbers. It costs us Rs 40 per unit to manufacture the ball bearing. The marketing department has through its market research noted that our organization can have a sale price of Rs. 90 per unit.

- Certainty: Profit per unit is Rs. 50. You have an order for 2000 units. The decision is under certainty as the Means that the relevant parameter such as costs, capacity and demand have known values.
- Risk There is a 25 % chance of demand of 2000 units, 50% chance of demand of 1000 units and 25 % chance of an order of 500 units.
- Uncertainty .There is no available data of demand forecasts means that the certain parameters necessary for decision making are absent.

DECISION THEORY

No discussion in Production Operation Management is complete without making a reference to Decision Theory. Decision Theory is in fact a general approach to decision making.

Decision theory consists of the following three elements.

1. A set of possible outcomes exist that will have a bearing on the results of the decision.
2. A list of alternatives to choose from.
3. A known payoff for each alternative under each possible future condition.

An operations manager would need to develop an understanding of decision theory knowledge and needs to employ the following.

1. Identify a set of possible future conditions called state of nature which includes the low, high, medium demand pattern and a working on the competitor's introduction of new product.
2. Develop a list of alternatives, one of which may be to do nothing.
3. Determine or estimate the payoff associated with each alternative for every possible future condition.
4. If possible estimate the likely hood of each possible future condition.
5. Evaluate alternatives according to some decision criterion e.g. maximize expected profit and select the best alternatives to choose from.

PAY OFF TABLE

•Payoff table summarizes the information of a decision and captures the expected payoffs under various possible states of nature.

•Let us consider an example, we are setting up a pharmaceutical factory and our state of nature indicates that If we built a small facility the return remains the same whether the demand is low or high, the medium facility indicates a constant return on moderate and high. If we build a large facility chances are that the return would only be good if we have a high demand or return.

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Alternatives	Possible Future Demands		
	Low	Moderate	High
Small Facility	Rs. 10 M	Rs. 10 M	Rs. 10 M
Medium	Rs. 5 M	Rs. 8 M	Rs. 12 M
Large	Rs. 1 M	Rs. 2 M	Rs. 15 M

The states of nature are very important, for our decision making.

Decision Making under Certainty

Decision making under certainly is always simple but never available to the managers.

Alternatives	Possible Future Demands		
	Low	Moderate	High
Small Facility	Rs. 10 M	Rs. 10 M	Rs. 10 M
Medium	Rs. 5 M	Rs. 8 M	Rs. 12 M
Large	Rs. 1 M	Rs. 2 M	Rs. 15 M

Decision Making under Certainty

- It is known with certainty that the demand will be low, moderate and high.
- In the example, we just select the best or highest payoff for all the states of nature.

Decision Making under Uncertainty

- In the absence of clear information, An Operations Manager would need to carryout decision making under uncertainty. This is the usual pattern when managers working at assembly plants, services, oil refineries or chemical processing plant end up facing a dilemma to evaluate the alternative of payoffs..

1. Maximin
2. Maximax
3. Minimax Regret
4. Laplace

Maximin

- Maximin determines the worst payoff for each alternative; the operations manager chooses the best worst alternative. Meaning the least (best) of the worst.
- It is a pessimistic approach.
- Ensures a guaranteed minimum.

Maximax

- Maximax determines
- the best possible outcome
- Choose the Alternative with the best possible payoff.
- It does not take into account any other alternative then the best payoff.
- An optimistic approach.
- Go for it strategy.

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Laplace

- Determines the Average payoff for each alternative
- And chooses the alternative with the best average.
- This is a cautious approach
- Laplace approach treats the states of nature as equally likely.

Example to Calculate Maximin, Maximax and Laplace

Alternatives	Possible Future Demands		
	Low	Moderate	High
Small Facility	Rs. 10 M	Rs. 10 M	Rs. 10 M
Medium	Rs. 5 M	Rs. 8 M	Rs. 12 M
Large	Rs. 1 M	Rs. 2 M	Rs. 15 M

Example to calculate Maximin, Maximax and Laplace

- Maximin , the worst payoff for alternatives
- Pick the Minimum (Least) of the maximum
- Small Facility Rs 10 M since the payoff table shows that

– Small Facility Rs. 10 M
– Medium Rs. 12 M
– Large Rs. 15 M

Example to calculate Maximin, Maximax and Laplace

- Laplace , the best payoff of the average for each alternatives
- Small Facility Rs 10 M since the payoff table shows that

– Small Facility Rs. 30/3= Rs. 10 M
– Medium Rs. 25/3= Rs. 8.33 M
– Large Rs. 18/3= Rs. 6 M

Decision Making under Uncertainty

- Minimax Regret
- Determines the worst regret for each alternative
- Chooses the alternative with the best worst.
- This approach seeks to minimize the difference between payoff that is realized and best payoff for each state of nature.

Example to calculate Minimax Regret

- Minimax Regret ,
- Step I ; Construct the Table of Opportunity Losses or Regrets.

–Subtract the column entries by subtracting the entry from that of the highest column value

–Repeat the process for all columns

- Step II. Select the maximum regret value of each row (alternative meaning small, medium and large scale)

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Example to calculate Minimax Regret

Alternatives	**Possible Future Demands**		
	Low	Moderate	High
Small Facility	Rs. 10-10=0	Rs. 10-10=0	10-15=-5
Medium	Rs. 5-10= -5 M	Rs. 8-10= -2 M	Rs. 12-15= -3 M
Large	Rs.1-10= -9 M	Rs. 2-10= -8 M	Rs. 15-15= 0 M

EXPECTED MONETARY VALUE CRITERION

- Decision Making under Risk
- The area between the certainty and uncertainty is known as Risk.
- Expected Monetary Value Criterion (EMV)which refers to the best expected value among the alternatives
- We use the payoff table with probabilities low =0.3, moderate =0.5 and highest=0.2.These probabilities must add to 1,mutually exclusive and collectively exhaustive)

- EXPECTED MONETARY VALUE CRITERION
- EV small = 0.3(10)+0.5(10)+0.2(10)
  = Rs. 10 M
- EV medium= 0.3(5)+0.5(8)+0.2(12)
  = Rs. 7.9 M
- EV large = 0.3(1)+0.5(2)+0.2(15)
  = Rs. 4.3 M

We select the smallest facility as it has the highest value

- Expected Value of Perfect Information
- In certain situations, it is possible to ascertain which state of nature (level of demand) will occur with certainty. E.g. If you want to construct a restaurant or trauma centre on a motorway highway chances are you would get a great ROI.
- Expected value of perfect information = Expected payoff under certainty -Expected payoff under risk

Visual tool for analyzing Decision Problems

Two visual tools used for analyzing decision problems include
- Decision Trees
- Graphical Sensitivity Analysis

Decision Trees

A schematic representation of the alternatives and their possible consequences is presented graphically. You can refer.

- The diagram resembles a tree.
- Extremely suitable for analyzing and evaluating situations which involve sequential decisions.
- Decision Trees

- *Suppose the Pakistani government decides to operate a gas field. Initially the government had information that it can exploit 1 million cubic feet of gas but later studies indicate potential*

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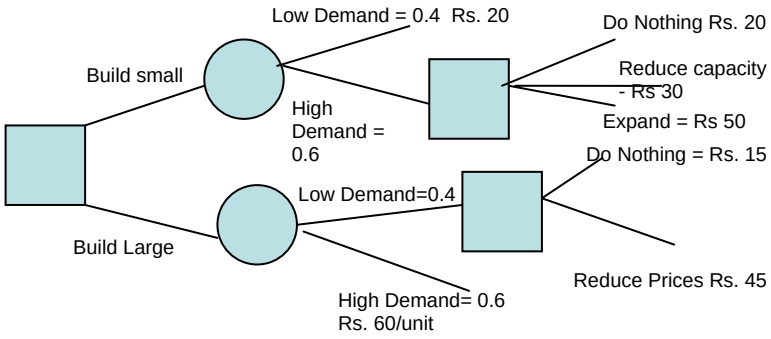
reserves of additional 10 million cubic feet. As an operations manager you may be ask to prepare a feasibility report to either expand or make a new facility using the new reserves.

Decision Trees



Decision Trees

- The tree is read from left to right
- Square nodes represent decisions
- Circular nodes represent chance events.
- Branches leaving square nodes represent alternatives.
- Branches leaving the circular nodes represent the chance events (states of nature)

Decision Trees Analysis

•Step I. Analyze the decisions from Right to left
•Step II. Determine which alternative would be selected for each possible second decision.
–For a small facility with high demand there are three alternatives, select the highest payoff and multiply it with the probable outcome. Put a double slash on the alternatives which have lower value.
–Follow the same procedure for small facility with high demand
•Step III. Repeat the steps for both low and demand pattern for the larger facility.
•Step IV. Determine the product of chance probabilities
•Step V. Determine the expected value of each initial alternative.
•Step VI. Select the choice which has a larger expected value than the small facility.

Decision Tree Example Solution

Option I: Build Small Facility

- Low Demand = 0.4 X Rs. 20= Rs. 8
- High Demand=0.6 X Rs. 50= Rs. 30

Option II: Build Large Facility

- Low Demand = 0.4 X Rs. 45= Rs. 18
- High Demand=0.6 X Rs. 60= Rs. 54

Option III: Determine the Expected Value of each initial alternative

- Build Small Facility = Rs. 8+ Rs. 30= Rs. 38
- Build Large Facility=Rs. 18+Rs. 36= Rs. 54

Select the Larger Facility as it has a larger expected value than the small facility

Sensitivity Analysis

- Determining the range of probability for which an alternative has the best expected payoff.

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- A graphical solution
- Makes use of Algebra
- Prime importance

Conclusion

Decision Making is a critical responsibility that stays with a manager throughout his active professional life. It goes without saying that, at the start of the service, the decision making involves low impact financial impact but with the passage of time, the decision making becomes more critical and highly finance focused. This very aspect gives the field of decision making a competitive edge over other important tools available to an operations manager. The related field of game theory is often used in conjunction with decision theory.

Payoff Table Homework

The following table shows profit payoffs. Calculate the results for the five rules and indicate for each rule the best and worst decision alternatives. All Cost and Revenue numbers in Rs. 000. d1,d2, d3 and d4 represent decision options and s1,s2,s3 and s4 show states of nature.

	0.30	0.25	0.10	0.35					
	S1	S2	S3	S4	**MAXIMIN**	**MAXIMAX**	**LAPLACE**	**EXPECTED MONETARY VALUE**	**MINIMAX REGRET**
d1	50	-20	75	60					
d2	80	30	100	-10					
d3	25	35	10	45					
d4	55	65	-15	40					

The following table shows cost payoffs. Calculate the results for the five rules and indicate for each rule the best and worst decision alternatives.

	0.40	0.15	0.10	0.35					
	S1	S2	S3	S4	**MAXIMIN**	**MAXIMAX**	**LAPLACE**	**EXPECTED MONETARY VALUE**	**MINIMAX REGRET**
d1	40	20	75	60					
d2	30	70	90	10					
d3	60	55	5	85					
d4	40	100	15	35					

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FORECASTING

Introduction

•Forecasting demand is like forecasting weather .Sometimes the forecast or prediction fails completely and sometimes its near the predicted value but still not the exact value. Often scientists call forecasting as an educated guess, but even then forecasting helps us to plan our trips and journeys and most importantly we as farmers make use of forecasting to plant, harvest and take precautionary measures.

•Forecasting in business forms the basis for budgeting and planning for capacity, sales, production, inventory, manpower, purchasing and more.

•Forecasting allows the manager to anticipate the future so then can plan accordingly.
Introduction

•There are two major uses for forecasts. One is to help the Operations Manager plan the system and the other one is to help him plan the use of the system. These are important concepts different distinct but at the same time closely lined.

Planning the system refers to planning long term plans about the type of products or services to offer, what facilities and equipment to have, where to locate and so on and so forth. Planning the use of the system relates to short range and intermediate range planning which means planning inventory workforce resources, planning of purchasing and production activities, budgeting and scheduling etc.

Thus it can be said that planning the systems more of a job of a senior manager, birds eye view and has ORGANIZATIONAL STRATEGY in it where as planning the use of the system is an OPERATIONAL STRATEGY

Business Forecasting is more than just predicting demand. Forecasting is also used to predict profits, revenues, costs, productivity changes, prices and availability of energy and raw materials, interest rates, movements of key economic indicators (GNP, inflation and government loans) and prices of stocks and bonds.

Forecasting is not an exact science. Even with the availability of computers, and algorithms, its unable to make an exact prediction it requires Experience, Managerial Judgment and Technical expertise. General Responsibility lies with the Marketing workforce but to this day not a single marketing forecast has been created without the valuable contribution of the Operations side.

FORECAST:

A statement about the future value of a variable of interest such as resource requirements, capacity planning, SCM and product or service demand.

Forecasts affect decisions and activities throughout an organization

1. Accounting, finance
2. Human resources
3. Marketing
4. MIS
5. Operations
6. Product / service design

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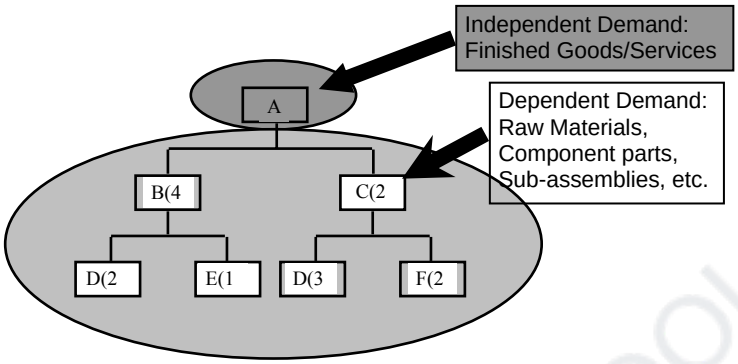
Applications of Forecasts

Accounting	Cost/profit estimates
Finance	Cash flow and funding
Human Resources	Hiring/recruiting/training
Marketing	Pricing, promotion, strategy
MIS	IT/IS systems, services
Operations	Schedules, MRP, workloads
Product/service design	New products and services

Demand Management

Demand Management



Independent Demand: What a firm can do to manage it?

1. Either be Active or Passive meaning?
2. Can take an active role to influence demand
3. Can take a passive role and simply respond to demand

Components of Demand

- Average demand for a period of time
- Trend
- Seasonal element
- Cyclical elements
- Random variation
- Autocorrelation

Finding Components of Demand

Web-Based Forecasting: CPFR Defined

•Collaborative Planning, Forecasting, and Replenishment (CPFR) a Web-based tool used to coordinate demand forecasting, production and purchase planning, and inventory replenishment between supply chain trading partners. You will learn about this in your later part of the semester.

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•Used to integrate the multi-tier or *n*-Tier supply chain, including manufacturers, distributors and retailers.

•CPFR's objective is to exchange selected internal information to provide for a reliable, longer term future views of demand in the supply chain.

•CPFR uses a cyclic and iterative approach to derive consensus forecasts.

Web-Based Forecasting:

Steps in CPFR

1. Creation of a front-end partnership agreement
2. Joint business planning
3. Development of demand forecasts
4. Sharing forecasts
5. Inventory replenishment

•Assumes causal system(That same system that existed in the past will exist in future, where as in reality unplanned events happen like tax rate increase, introduction of a competitors product or service or natural disasters)
•Forecasts rarely perfect because of RANDOMNESS (having no specific pattern). Allowances should be made for inaccuracies.

•Forecasts more accurate for groups vs. individuals naturally because forecasting errors in a group tend to cancel out forecasting errors for individuals.

•Forecast accuracy decreases as time horizon increases indicating it is safe to make short range forecasts instead of long term forecasts. If you can recall we had talked about Flexible and Agile Corporations in the past.

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FORECASTING (Contd.)

Roadmap to the Lecture

- Discuss the requirements of a good forecast.
- Steps in making a forecast.
- Fundamental types of forecast.
- Finer classification of forecast
- Discuss characteristics of Judgmental Forecasts.
- Delphi Method.
- Time Series Analysis.
- Naïve Forecast.

Requirements of a Good Forecast

- **Timely.** The forecast should be timely. Indicating that forecasting horizon should provide enough time to implement possible changes. Capacity cannot be expanded instantly it requires some time to plan, coordinate and increase the required resources.
- **Reliable.** Forecasts should be reliable meaning that it should work consistently. A forecast that is partially correct will succeed at sometime and sometime fail making the end users question the purpose and intent of forecasting.
- **Accuracy.** Forecasts should be accurate. In fact it should carry the degree of accuracy, so the users are aware of the limitations of the forecast. This will also help the end users to plan for possible errors and provide a basis for comparing the forecast with other alternative forecasts.
- **Meaningful Forecast** should be expressed in meaningful units. Financial Planners will use Rupees to show how much capital would be required; Mechanical Project Schedulers would require Forecasts to carry the type of machines and crafts of technicians required.
- **Written/Documented.** The forecasts should be presented in writing. A documented forecast always provides a chance to measure the variance between estimate and actual result at a later stage.
- **Simple to understand and use** meaning that Forecasts should not be dependant upon usage of sophisticated computer techniques or task specific highly qualified technical personnel. A failure or limitation on the part of this can lead to an incorrect decision and less acceptance amongst end users

Steps in the Forecasting Process

- **Determine the purpose of the forecast** meaning what is the purpose and when will it be required. This will provide the level of detail for resources required man, machine, time and capital.
- **Establish a time horizon**. We already know that as time increases the accuracy of the Forecast decreases
- **Select a forecasting technique** whether qualitative or quantitative
- **Gather and analyze the appropriate data**. It goes without saying that before a forecast can be delivered data is required. The closer the real life data more realistic would be the forecast. This may be the time when you would like to identify the important assumptions and suppositions.
- **Prepare the forecast**.
- **Monitor the forecast.** A forecast has to be closely monitored to determine whether it is fulfilling its basic purpose. This helps in re-examining the method, assumptions and validity of the data and preparing a revised forecast.

Fundamental Types of Forecasts

- **Qualitative Techniques** which use subjective inputs and no numerical data. It relies solely on soft information like human factors, personal opinion, hunches. Thus Qualitative Forecasts are often biased and tilted towards what the management wants to predict.

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•**Quantitative Forecast** involves the extension of the historical data. It sometimes makes use of forecasting technique that uses explanatory variables to predict future demands. Quantitative techniques are favored where quality attributes cant be quantified.
•In reality both need to be used together to develop a judicious and realistic forecast.

Finer Classification of Forecasts

•***Judgmental*** **-** uses subjective inputs meaning that a judgmental forecast rely on analysis of subjective inputs obtained from various sources, such as consumer surveys, the sales staff, managers and executives, and panels of experts. These insights are not available publicly.
•***Time series*** **-** uses historical data assuming the future will be like the past and depend on developing relationships between variables that can be expressed to predict future values. Some time series forecast try to smoothen out random variations in historical data. There are some time series forecast which identify specific patterns and then may even extrapolate those patterns into the future.
• ***Associative models*** **-** uses explanatory variables to predict the future for example demand for a small car may be dependant upon increase in price of petrol or CNG. The analysis in this case would employ a mathematical model that would relate the predicted variable with the predictor variable or variables.

Judgmental Forecasts Characteristics

•Judgmental Forecasts rely solely on judgment and opinion to make forecasts.
•In the absence of enough time, it is easy to use qualitative type of forecast.
•In case of changing external environment economic and political conditions, organizations may use judgmental forecasts.
•When introducing new products, services, new features, new packaging, judgmental forecasts are used in preference over quantitative techniques.

Judgmental Forecasts

•**Executive opinions** normally consist of a group of senior level managers from different interfaces, used for long range planning and new product development. Advantage being the collective pool of information from all divisions and departments, disadvantage being that one person will dominate other interfaces, which can lead to erroneous forecasts.
•**Sales force** opinions have the advantage of being in direct contact with customers. The sales force can detect the customers' change of plan, However it suffers from the fact that it can not differentiate between what the customer can do and will do. Current data of sales can often lead to over pessimistic and overly optimistic forecasts, which then results in incorrect sales projections.

•**Consumer surveys** are based on sample taken from potential customers. These type of surveys require skill to develop, administer and interpret the results. Often fall victim of the consumers irrational behavior of buying.

•**Outside opinion** which is a mix of consumer and potential customers. This kind of opinion is now a days readily available through internet, telephonic surveys and newspapers. Its biggest limitation is a fixed format which often fails to quantify the exact demand forecast.

•**Delphi method:** Managers and staff complete a series of questionnaires, each developed from the previous one, to achieve a consensus forecast. Commonly used for Technological forecasting, when to introduce a new technology. It's a long term one time activity and has the same issues like expert opinion type of judgmental forecast.

Time Series Analysis

•Time series forecasting models try to predict the future based on past data
•We as Managers can pick models based on:

1. Time horizon to forecast
2. Data availability
3. Accuracy required
4. Size of forecasting budget

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5. Availability of qualified personnel

Naïve Forecasts

- Simple to use
- Virtually no cost
- Quick and easy to prepare
- Data analysis is nonexistent
- Easily understandable

Drawbacks

- Cannot provide high accuracy
- Can be a standard for accuracy

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FORECASTING (Contd.)

Time Series Forecasts

•*Trend* - long-term upward or downward movement in data often relates to population shifts, changing incomes, and cultural changes.
•*Seasonality* - short-term fairly regular variations in data related to factors like weather, festive holidays and vacations. Mostly experienced by supermarkets, restaurants, theatres, theme parks.
•Cycle – wavelike variations of more than one year's duration these occurs because of political, economic and even agricultural conditions
•*Irregular variations* - caused by unusual circumstances such as severe weathers, earthquakes, worker strikes, or major change in product or service. They do not capture or reflect the true behavior of a variable and can distort the overall picture. These should be identified and removed from the data.
•*Random variations* - caused by chance and are in reality are the residual variations that remain after the other behaviors have been identified and accounted for.
Forecast Variations

Techniques for Averaging

- Moving average
- Weighted moving average
- Exponential smoothing

•*Moving average* – A technique that averages a number of recent actual values, updated as new values become available.
•*Weighted moving average* – More recent values in a series are given more weight in computing the forecast.

Simple Moving Average Formula

•The simple moving average model assumes an average is a good estimator of future behavior
•The formula for the simple moving average is:

$$F_t = \frac{A_{t-1} + A_{t-2} + A_{t-3} + \ldots + A_{t-n}}{n}$$

F_t = Forecast for the coming period
N = Number of periods to be averaged
A_{t-1} = Actual occurrence in the past period for up to "n" periods

Simple Moving Average Problem (1)

Question: What are the 3-week and 6-week moving average forecasts for demand?
Assume you only have 3 weeks and 6 weeks of actual demand data for the respective forecasts.

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Week	Demand
1	650
2	678
3	720
4	785
5	859
6	920
7	850
8	758
9	892
10	920
11	789
12	844

Simple Moving Average Solution (1)

Week	Demand	3-Week	6-Week
1	650		
2	678		
3	720		
4	785	682.67	
5	859	727.67	
6	920	788.00	
7	850	854.67	768.67
8	758	876.33	802.00
9	892	842.67	815.33
10	920	833.33	844.00
11	789	856.67	866.50
12	844	867.00	854.83

$F_4=(650+678+720)/3$
$=682.67$

$F_7=(650+678+720+785+859+920)/6$
$=768.67$

Simple Moving Average Problem (2) Data

Question: What is the 3 week moving average forecast for this data?
Assume you only have 3 weeks and 5 weeks of actual demand data for the respective forecasts.

Week	Demand
1	820
2	775
3	680
4	655
5	620
6	600
7	575

Simple Moving Average Problem (2) Solution

Week	Demand	3-Week	5-Week
1	820		
2	775		
3	680		
4	655	758.33	
5	620	703.33	
6	600	651.67	710.00
7	575	625.00	666.00

$F_4=(820+775+680)/3$
$=758.33$

$F_6=(820+775+680+655+620)/5$
$=710.00$

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FORECASTING (Contd.)

The formula for the moving average is:

$F_t = w_1 A_{t-1} + w_2 A_{t-2} + w_3 A_{t-3} + ... + w_n A_{t-n}$

w_t = weight given to time period "t" occurrence (weights must add to one) $\sum_{i=1}^{n} w_i = 1$

Weighted Moving Average Problem (1) Data

Question: Given the weekly demand and weights, what is the forecast for the 4th period or Week 4?

Week	Demand
1	650
2	678
3	720
4	

Weights:	
t-1	.5
t-2	.3
t-3	.2

Weighted Moving Average Problem (1) Solution

Week	Demand	Forecast
1	650	
2	678	
3	720	
4		693.4

F4 = 0.5(720)+0.3(678)+0.2(650)=693.4

Note: More weight age would be given to recent most values.

Weighted Moving Average Problem (2) Data

Question: Given the weekly demand information and weights, what is the weighted moving average forecast of the 5th period or week?

Week	Demand
1	820
2	775
3	680
4	655

Weights:	
t-1	0.7
t-2	0.2
t-3	0.1

Weighted Moving Average Problem (2) Solution

Week	Demand	Forecast
1	820	
2	775	
3	680	
4	655	
5		672

F5 = (0.1)(755)+(0.2)(680)+(0.7)(655)= 672

Note: More weight age would be given to recent most values.

Exponential Smoothing Model

$F_t = F_{t-1} + a(A_{t-1} - F_{t-1})$

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Where

F_t = Forecast value for the coming time period

F_{t-1} = Forecast value in 1 past time period

A_{t-1} = Actual occurrence in the 1 past time period

α = Alpha smoothing constant

Exponential Smoothing Problem (1) Data

Question: Given the weekly demand data, what are the exponential smoothing forecasts for periods 2-10 using a=0.10 and a=0.60?
Assume $F_1=D_1$

Week	Demand
1	820
2	775
3	680
4	655
5	750
6	802
7	798
8	689
9	775
10	

Exponential Smoothing Solution (1)

Week	Demand	*0.1*	*0.6*
1	820	820.00	820.00
2	775	820.00	820.00
3	680	815.50	793.00
4	655	801.95	725.20
5	750	787.26	683.08
6	802	783.53	723.23
7	798	785.38	770.49
8	689	786.64	786.99
9	775	776.88	728.20
10		776.69	756.28

Exponential Smoothing Problem (2) Data

Question: What are the exponential smoothing forecasts for periods 2-5 using Alpha =0.5?
Assume $F_1=D_1$

Week	Demand
1	820
2	775
3	680
4	655
5	

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Exponential Smoothing Problem (2) Solution

Week	Demand
1	820
2	775
3	680
4	655
5	

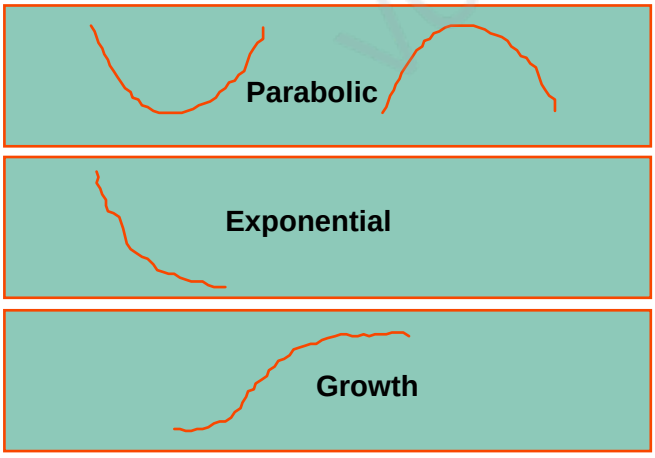
F1=820+(0.5)(820-820)=820

F3=820+(0.5)(775-820)=797.75

Example 3 - Exponential Smoothing

Period	Actual	Alpha = 0.1	Error	Alpha = 0.4	Error
1	42				
2	40	42	-2.00	42	-2
3	43	41.8	1.20	41.2	1.8
4	40	41.92	-1.92	41.92	-1.92
5	41	41.73	-0.73	41.15	-0.15
6	39	41.66	-2.66	41.09	-2.09
7	46	41.39	4.61	40.25	5.75
8	44	41.85	2.15	42.55	1.45
9	45	42.07	2.93	43.13	1.87
10	38	42.36	-4.36	43.88	-5.88
11	40	41.92	-1.92	41.53	-1.53
12		41.73		40.92	

Common Nonlinear Trends



Parabolic Trends

- Concaved Upwards and Concaved Downwards
- The left and right arms are widening as the value increases or the parabola is opening upwards.
- It represents the quadratic function

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Linear Trend Equation

$F_t = a + bt$

Where:

- F_t = Forecast for period t
- t = Specified number of time periods
- a = Value of Ft at t = 0
- b = Slope of the line

Linear Trend Equation Example

$$b = \frac{n\sum(ty) - \sum t\sum y}{n\sum t^2 - \sum t^2}$$

$$a = \frac{\sum y - \sum t}{n}$$

Linear Trend Calculation

$$b = \frac{5\,(2499) - 15(812)}{5(55) - 225} = \frac{12495-12180}{275-225} = 6.3$$

$$a = \frac{812 - 6.3(15)}{5} = 143.$$

$$y = 143.5 + 6.3t$$

Associative Forecasting

1. *Predictor variables* - used to predict values of variable interest
2. *Regression* - technique for fitting a line to a set of points
3. *Least squares line* - minimizes sum of squared deviations around the line

Forecast Accuracy

- Error - difference between actual value and predicted value
- Mean Absolute Deviation (MAD)
  - Average absolute error
- Mean Squared Error (MSE)
  - Average of squared error
- Mean Absolute Percent Error (MAPE)
  - Average absolute percent error

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Simple Linear Regression Formulas for Calculating "a" and "b"

$$a = \bar{y} - b\bar{x}$$

$$b = \frac{\sum xy - n(\bar{y})(\bar{x})}{\sum x^2 - n(\bar{x})^2}$$

Simple Linear Regression Problem Data

Question: Given the data below, what is the simple linear regression model that can be used to predict sales in future weeks?

Week	Sales
1	150
2	157
3	162
4	166
5	177

Answer: First, using the linear regression formulas, we can compute "a" and "b"

Week	Week*Week	Sales	Week*Sales
1	1	150	150
2	4	157	314
3	9	162	486
4	16	166	664
5	25	177	885
3	*55*	*162.4*	*2499*
Average	Sum	Average	Sum

$$b = \frac{\sum xy - n(\bar{y})(\bar{x})}{\sum x^2 - n(\bar{x})^2} = \frac{2499 - 5(162.4)(3)}{55 - 5(9)} = \frac{63}{10} = \mathbf{6.3}$$

$$a = \bar{y} - b\bar{x} = 162.4 - (6.3)(3) = \mathbf{143.5}$$

The resulting regression model is:

$\mathbf{Y_t = 143.5 + 6.3x}$

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Lesson 11

PRODUCT & SERVICE DESIGN

Product and Service Design together form the very basis of design aspect of operations. If SUPARCO today decides to send a person to space, it would not only develop and construct a rocket or spaceship but would also provide services in the training of the astronaut. The fact is that we cannot leave out services from products or exclude products from service. They both complement and supplement each other. We have to respect this concept and pay attention in identifying how products and services are present in tandem everywhere. A cardiologist carrying out angioplasty may be providing services but its unheard of today at least, that the patient would be carrying with him the spare valves for the heart, so those valves also from the same person who is providing those services. If we go to the bank for some financial services, we end up making use of a cheque (product). Similarly if Virtual University is providing students with an education service, it also supplements the services side by providing products like books, compact discs, handouts, and power point slides. The point we are trying to focus upon is that products and services are found in combination and a service organization can also provide products or a manufacturing organization can also provide a service, like the example we discussed in class about an automobile manufacturer providing after sales service.

From this lecture onwards, we will be embarking on the journey to learn about Design of Productive Systems. This journey would require us to complete various milestones like product and service design, capacity planning, Facilities Layout, Design of Work systems and Locations. Please pay special attention to all those examples you have already covered through your lectures. And try to keep two important things in mind:-

1. Design aspect requires strategic planning and may fall under the domain of Organizational strategy and senior management, also
2. Design aspect requires the existing system to be improved or replaced by a better system for this you should always focus on the word Productive. This word reflects the idea of adding value either to the manufacturing or the services System or to be more precise improving the operation system.

Introduction

After completing lectures on product and service design we will be able to understand the importance of product and service design. We will also try to grasp the various important aspects of the design process in detail. We will cover the concept of standardization and advantages and disadvantages. We should be able to appreciate the contribution of R&D to the product service design. And last but not the least; we will focus on the concept of Reliability in order to learn in what possible ways we can aid our organization to improve its product or service's reliability.

Importance of Product/Service Design

Product/Service design plays a strategic role in helping an organization achieve its goals. A good product/service design can ensure customer satisfaction, quality and production costs. On the other hand, If an organization is offering poor product or service, customer's feedback in the form of lack of interest will result in poor sales. Also Quality and production costs are affected by poor design of the product or service. The importance is also often looked, as Pakistani organizations have not yet learnt to pay attention to safe operations of their products or services. A poor product or service can endanger the customers or consumers life. For this it is necessary for us as Operations Manager to question the safe operations of the product or service, our organization offers to its customers and thus safe guard our organization from product or service liability.

Major factors in design strategy

When we discussed organizational and operation strategy concepts we did set a boundary line for our organizations effective, smooth, reliable and safe operations. When we will design a product or service, we need to consider the following facts in our design strategy.

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1. Cost
2. Quality
3. Time-to-market
4. Customer satisfaction
5. Competitive advantage

A good product or service can be produced or delivered at an economical cost with increased quality, with a less time to market provided the organization is willing to aim for customer satisfaction and this most of the time results in competitive advantage as well increase in revenues.

Product or Service Design Activities

When an organization decides to design its new product or service or refine its existing product or service, it is suppose to follow certain activities religiously and diligently. The following activities are necessary:-

1. Translate customer wants and needs into product and service requirements
2. Refine existing products and services
3. Develop new products and services
4. Formulate quality goals
5. Formulate cost targets
6. Construct and test prototypes
7. Document specifications

An organization can initiate a product or service design if it is able to understand what the customer actually wants in the product or service being offered, say for example a customer wants a fuel efficient car and if the automobile manufacturing organization is able to refine its existing product, with the objective of improving quality and reducing costs, it can gain competitive advantage and profits. However this requires the organization to not only construct a prototype automobile but also evaluate its performance for robustness and then the design side should document the specifications in detail, along with test results and performance evaluations, so only that product may be introduced which is able to full fill its intended use throughout the country. A CNG fitted car should function effectively in Karachi as well as Lahore or Islamabad or hilly areas of the northern part of the country.

Reasons for Product or Service Design

An organization takes into account both external and internal reasons in order to design a new product or service or redesign an existing product or service. The reasons listed below have often been the primary reason for the design process.

1. Economic
2. Social and demographic
3. Political, liability, or legal
4. Competitive
5. Technological

What is important is to realize that whether it's a single reason or multiple reasons for a design strategy, the end result should always be an improved, safe and reliable product which should bring revenue and competitive advantage to the organization.

Objectives of Product and Service Design

The primary focus for designing a new product or service is Customer satisfaction along with the secondary focus being an improved function of product/service, increase in revenues/profits, Quality along with reduction in costs.

The current trend for designing a new product is to pay special attention to the product or services visual appearance, the ease of production/assembly along with the ease of maintenance/service.

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However, the design department of the organization should take into account the capabilities of the organization in designing goods and services

Steps in the Design Process

Most of the organizations follow the design process with the following steps not necessarily in the same order to achieve improvement in the performance of the system and adding value.

1. Motivation: refers to the achievement of the goals for the organization, for mature and existing organizations the motivation also includes government regulations (provides new incentives, tax free zones), competitive process, customer needs and appearance of new technologies that have product or service applications.
2. Customers: The design process would never be complete without the valuable inputs of the customers. Any organization that fails to satisfy and meet customer requirements loose ground to their competitors.
3. R&D: refers to the Research and Development departments or divisions which generate new ideas for the existing products or services or simply new ideas for new products or services. Mostly the activities are ITERATIVE and employ the feedback of customer as well as operations side.
4. Competitors: The design process often compels a company to dismantle and inspect a competitor's product. Yes we call it REVERSE ENGINEERING. This helps the organization to improve its own product. Quite often companies get the blame that they improved incrementally their competitors products design or certain features to win the competition.
5. Forecast Demand: refers to the demand for the company's new product or service.
6. Manufacturability means the ease of fabrication or assembly of a product as it directly affects cost, quality and productivity.
7. General considerations: The design process requires design, production/operations and marketing departments to work closely together. This would mean sharing customer feedback, quality issues, and operations bottlenecks. In addition legal or regulatory issues and Product Life Cycle Issues must be addressed as a part of design function.

Legal, Ethical, and Environmental Issues

Organizations whether manufacturing a product or delivering a service are made to operate in a three dimensional frame work of legal, ethical and environmental boundaries.

1. Legal. Operations Managers should be able to understand the legal environment in which their organizations are functioning, not only there are governmental (federal, provincial or district) regulations but also industrial or service sector obligations. These obligations are guidelines which need to be followed and if the designers can adhere to them, they only make life easy for themselves as well as for the organization.
   - FDA, OSHA, CRS. There are legal issues in which even the CEO can be implicated if there are violations with respect to pollution. FDA as the name indicates refers to Federal Drug Agency, OSHA refers to Occupational Safety Hygiene Administration, and CBR denotes Center Board of Revenue, which monitors the organizations taxable income.
   - Product liability refers to a manufacturer being liable in case of an injury or damages caused by a faulty product.
   - Uniform commercial code. Products carry an implication of merchantability and fitness, which is a product, must be usable for the intended purpose. An organization should strictly follow a uniform commercial code; imagine if a manufacturer of electricity cable manufactures a non uniform product that can lead to electric shock to the end user.
2. Ethical. Operations Manager should understand that he is under
   Contractual agreement not to exhibit unethical behavior. Releasing products with defects should be informed to the customers. This is a golden practice amongst Muslims from the

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days of Holy Prophet (PBUH) and its heartening to see the same being employed here in the field of International Business

3. Environmental. Operations Manager should also work with in the same Environmental laws as his organization. EPA is active in all countries including Pakistan and even a CEO can be jailed if there is a failure to comply with the Environment laws. It is the responsibility of the design side to ensure that no design would be finalized that can seriously jeopardize the organizations standing towards environment.

Designers of Product/Service should adhere to Guidelines

The design side needs to adhere to certain guidelines which can ensure that the organization is able to achieve its organizational strategy. These guidelines are often form the vary basis of an organizations design strategy and indicates the importance of standardization in the design of a product or service.

1. Produce designs that are consistent with the goals of the company. An economical upscale model automobile design if replaced with a luxurious model can invite a small number of customers and may loose the existing stronger customer base.
2. Give customers the value they expect .Reliability, safety, endurance, aesthetic and quality dimensions are what the customers are looking for.
3. Make health and safety a primary concern .Green Rickshaws seen functioning on the roads these days are a result of taking care of health and safety of the users as well as those who operate them.
4. Consider potential harm to the environment .A new product should be as a primary guideline should be better than the existing one and should aid in the protection of environment. A number of automobile manufacturers are using hybrid models or cars where as its expected that steam operated cars may be available in 5 years.

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Lesson 12

PRODUCT/SERVICE DESIGN (Contd.)

In our last discussion we focused on the objectivity and importance of Product and Service Design. We also went through the primary and secondary reasons due to which organizations opt for designing a new product or offering of a new service. We also talked about the strategy for designing of new products and services. We investigated the legal, ethical and environmental regulations. We also formulated a design strategy and also discussed guidelines, which the organizations must fulfill in order to achieve competitive advantage through designing of effective productive systems.

Critical Issues in Product and Service Design

An organization needs to decide about the following critical issues in developing its product and service design.

- How much standardization
- Product/service reliability
- Range of operating conditions
- Product/service life cycles

Standardization

Standardization is the extent to which there is an absence of variety in a product, service or process. Standardized products are immediately available to customers. You go to a market and request for a charger for your cellular phone, the shopkeeper would ask for the model, make and deliver you as special product which is made by your cell phone company or by an independent manufacturer, who provides a standardized compatible model.

Advantages of Standardization

1. Fewer parts to deal with in inventory & manufacturing .The trend is to use the same components for different models of products or even in services side, the data of a customer once taken as input can be utilized for other services.
2. Design costs are generally lower (the standardized product has a proven track record, so there is no need to check its safety and reliability features from square 1, its true, its tested and verified on prototype models before being marketed)
3. Reduced training costs and time. An important advantage and can improve PRODUCTIVITY.
4. More routine purchasing, handling, and inspection procedures (These indicate a decrease in cost and can improve reliability as well as over all design and manufacturing processes)
5. Orders fillable from inventory, no need to carry extra safety stock levels as compatible components/parts can be used. Any product registering lower sales can be phased out but its components may be reused in an other more popular product even Softwares in cellular phones, hands free arrangement etc)
6. Opportunities for long production runs and automation .Uninterrupted stock of components available, so production can be controlled and if possible a demand forecast may be used.
7. Need for fewer parts justify increased expenditures on perfecting designs and improving quality control procedures. The company can free up its inventory carrying costs and use it on increasing its long term tangible and intangible quality standards

Disadvantages of Standardization

1. Designs may be frozen (Standardized) with too many imperfections remaining (An existing shortcoming may never be removed because of this leading to product or component failure, catalytic converter failure led to a number of good cars in 1980s).
2. High cost of design changes increases resistance to improvements (associated with its lack of confidence on the design side as well as outsourcers, who provide design services).

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3. Reduction in Variety which leads to decreased variety results in less consumer appeal. This also at times lead to the competitor producing a better product or greater variety which itself is a feature of lean production.

Mass Customization

Mass customization is a strategy of producing standardized goods or services, but incorporating some degree of customization through delayed differentiation and modular design.

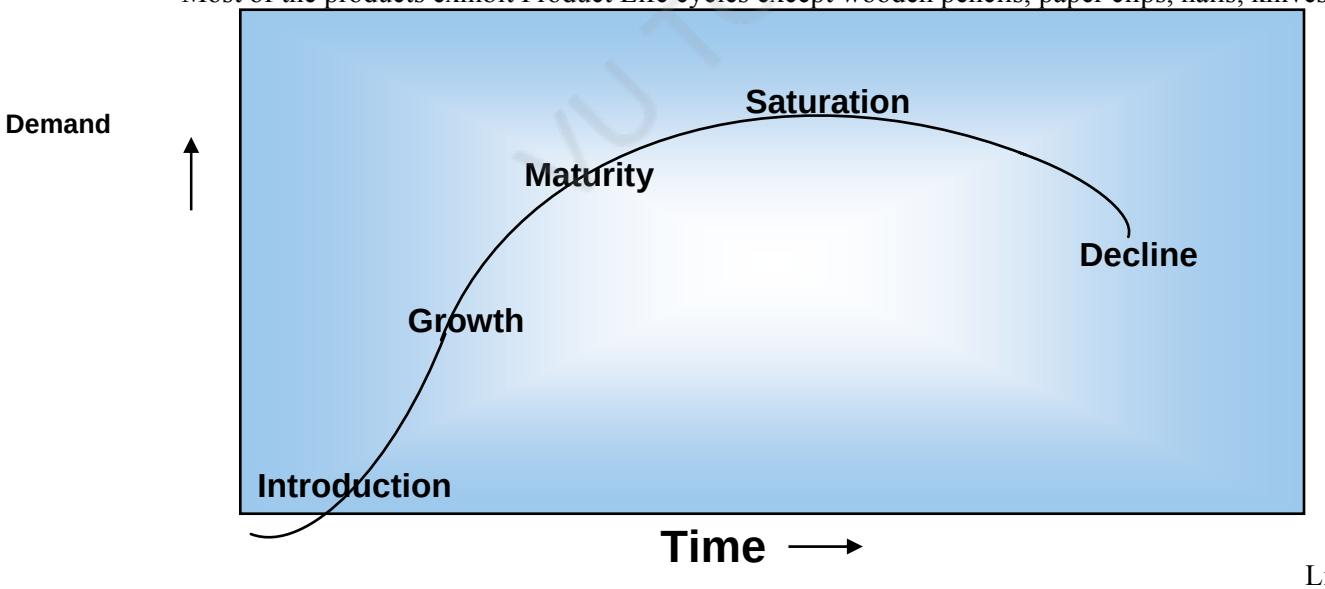
Delayed Differentiation is the postponement tactic. Producing but not quite completing a product or service until customer preferences or specifications are known, a pc manufacturer employed this technology and improved its time of delivery. This led to new concepts of marketing and manufacturing to register higher profits and revenues.

Product/Service Reliability

Reliability: The ability of a product, part, or system to perform its intended function under a prescribed set of conditions
Failure: Situation in which a product, part, or system does not perform as intended
Normal operating conditions: The set of conditions under which an item's reliability is specified e.g. an automobile designed for operation Europe may not fulfill its intended service in Pakistan. SO IT WOULD FAIL AND BE LESS RELIABLE

Life Cycles of Products or Services

We often hear the term short and long product lives which reflect upon the idea how product lives are governed by Technological rate of change. In other words the need and utility of the Product gets severely reduced. E.g. VCR no longer enjoys the source of entertainment it enjoyed in 1970s to 1990s. Most of the products exhibit Product Life cycles except wooden pencils, paper clips, nails, knives etc.



Life Cycles of Products or Services normally entail the following phases.

1. INTRODUCTION PHASE: When items are first introduced, it is received with curiosity. Demand is low in the beginning then when buyers begin familiar with the product and see it as a reliable and good buy, they start buying it.
2. GROWTH PHASE: With the passage of time, production and design improvements lead to decrease in cost and price becomes an attractive feature with increase in reliability.

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3. MATURITY PHASE: When the product reaches maturity stage its demand can only increase if design is refined or changed and some differentiation feature is added this may increase the demand but when it goes down
4. SATURATION PHASE: In this phase product demand declines and the market is saturated with either a compatible product or substitutes.
5. DECLINE: In this phase, most of the organizations adopt a defensive design R&D Strategy in an attempt to prolong the life of the product by employing new packaging, redesigning it, improving its reliability

As students of Operations Management, you may be asked to suggest the Product Life Cycle for Telecom Industry constituents or in other words where would you place cell phones, wireless phones, landline phones or satellite/cable based telephones in view of the life cycle you just studied. You can make an attempt to answer this for Pakistan as well as other developed countries. Can you appreciate the similarities and points of differences?

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PRODUCT & SERVICE DESIGN STRATEGIES

We have covered certain important concepts like standardization and mass customization, through which organizations as well as governments are able to address the requirements of a broad customer population. It is important now to understand how design strategies are applied and how to differentiate between product and service design. There are certain common features to both. An effective operations manager should know both about goods and services. It is also important to understand that a good design should address the issues relating to cost, performance and quality.

Design Strategies

Design strategies have one common characteristic, which is to achieve customer satisfaction, along with reasonable profit in a way which does not go beyond the organizations manufacturing abilities. An exaggerated example being that if an automobile car manufacturing organization's design department decides to design a truck. This would probably mean testing the organizations manufacturing capability, as the organization would not be have the infrastructure to manufacture a truck.
Some of the common design strategies are

1. Design for Manufacturing (DFM)**:** The designers' consideration of the organization's manufacturing capabilities when designing a product. The more general term design for operations encompasses services as well as manufacturing. Manufacturability is the ease of fabrication and/or assembly which is important for:
    i. Cost
    ii. Productivity
    iii. Quality
2. Design for Assembly (DFA): Design focuses on reducing the number of parts in a product and on assembly methods and sequence.
3. Design for Disassembly (DFD): Design focuses on facilitating the disassembly in a logical and an exact reverse sequential manner to the assembly methods and sequence.
4. Design for Recycling (DFR) : Design allows and facilitates the recovery of material of materials and components from used products for reuse. The designers' consideration of the organization's manufacturing capabilities when designing a product. The more general term design for operations encompasses services as well as manufacturing.
5. Design for Remanufacturing: Using some of the components of the old products in the manufacture of new products. Remanufactured products are sold at 30 to 50% of the price of new product .e.g. Printers, copiers, cameras, PCs and Cell/Telephones. This can be done by original equipment manufacturer or a competitor or end user (in the latter case its called cannibalization)

It is important now to learn as an Operations Manager the concept of Recycling. Recycling is in simple words recovering materials for future use. The common recycling reasons are

- Cost savings
- Environment concerns
- Environment regulations

Design for recycling is a design strategy that facilitates the recovery of materials and components of old products in the manufacture/assembly of new products. The focus here is to design components that would allow for disassembly and reuse or even CANABALIZATION.

Robust Design

Robust Design: Design that results in products or services that can function over a broad range of conditions. The idea is to have consistent, safe and reliable operations with no excuse for environmental characteristics. E.g. Automobiles/Products produced for European conditions may not perform well in Pakistan because of different environmental conditions. Similarly if you happen to visit an industrial

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area, please make sure that you have a proper OSHA standard safety boot available to you. In Pakistan certain automobile manufacturers do not comply with the safety boot requirements for all its workers working at the assembly plants. A non OSHA compliant safety boot can probably cause more harm resulting in foot amputation etc.

Taguchi Approach To Robust Design

Genichi Taguchi, a Japanese Manufacturing Engineer pioneered and championed the concept of reduction in the variability factor in manufacturing process. His approach helped manufacturing organizations to isolate and eliminate waste. This approach resulted in quality improvement and cost reduction.
With the aid of the Taguchi Approach we can determine the factors that are controllable and those not controllable along with their optimal levels relative to major product advances.
The defining characteristics for the Taguchi approach include:

- Design a robust product
- Insensitive to environmental factors either in manufacturing or in use.
- Central feature is Parameter Design.

An added concept to Taguchi Approach is the Degree of Newness. Degree of newness is an incremental enhancement of certain quality based performance features for the product. The various ways in which degrees of newness can be achieve include

1. Modification of an existing product/service
2. Expansion of an existing product/service
3. Clone of a competitor's product/service
4. New product/service
5. Degree of Design Change

Phases in Product Development Process

A manufacturing organization when carrying out design of a product goes through the following phases.

1. Idea generation
2. Feasibility analysis
3. Product specifications
4. Process specifications
5. Prototype development
6. Design review
7. Market test
8. Product introduction
9. Follow-up evaluation

Idea Generation often captures what we have already discussed as reverse engineering. Reverse engineering is the dismantling and inspecting of a competitor's product (or any other manufacturers old or existing product) to discover product improvements.

Research & Development (R&D) is the organized efforts to increase scientific knowledge or product innovation & may involve:

- Basic Research advances knowledge about a subject without near-term expectations of commercial applications.
- Applied Research achieves commercial applications.
- Development converts results of applied research into commercial applications.

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Concurrent Engineering

Concurrent engineering is the bringing together of engineering design and manufacturing personnel early in the design phase.

Concurrent Engineering Advantages

- Manufacturing Personnel are able to identify production capabilities and capacities .They have thus the opportunity to inform the design group about the suitability of certain materials on the flipsides the designer would know the suitability of certain designs in aiding in cost reduction and quality improvement in production/assembly process.
- Early opportunities for design or procurement of critical tooling, some of which might have long lead times. This can result in a major shortening of the product development process, which should be a key competitive advantage.

- Early consideration of the Technical Feasibility of a particular design or a portion of a design. Again this can avoid serious problems during production. The emphasis can be on problem resolution instead of conflict resolution.

Concurrent Engineering Disadvantages

- Long standing existing boundaries between design and manufacturing can be difficult to overcome. Simply bringing a group of people together and thinking that they will be able to work together effectively is probably naïve.
- There must be extra communication and flexibility if the process is to work, and these can be difficult to achieve.

Computer-Aided Design

Computer-Aided Design (CAD) is product design using computer graphics.

- Increases productivity of designers, 3 to 10 times
- Creates a database for manufacturing information on product specifications
- Provides possibility of engineering and cost analysis on proposed designs

Modular Design

Modular design is a form of standardization in which component parts are subdivided into modules that are easily replaced or interchanged. It allows:

- Easier diagnosis and remedy of failures
- Easier repair and replacement
- Simplification of manufacturing and assembly
- A concept idolized in the IT industry for software development

Service Design

Service is an act and service delivery system focuses on facilities, processes and skills.
Many services are bundled with products, like oil change would require you to pay for the oil canister as well. A good service design involves

- The physical resources needed which are somewhat Explicit Services
- The goods that are purchased or consumed by the customer which are the services that we call the implicit services

Operations Manager should be aware of the fact that service is something that is done to or for a customer and service delivery system are the required facilities, processes, and skills needed to provide

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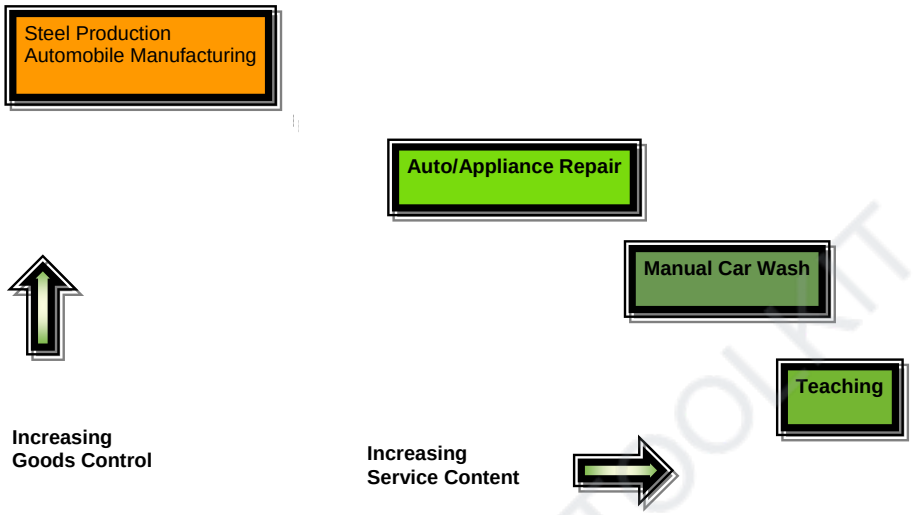
a service, also the words used are product bundle and service package. We should know that the product bundle is the combination of goods and services provided to a customer and service package is the physical resources needed to perform the service

Good Service Spectrum

Operations Managers often end up answering whether a certain activity falls under product manufacturing or service development. The figure below tries to capture the concept of the whole spectrum/band of Goods and Services. The spectrum or band has on Y axis the control on goods and on X axis the control on services.

This is to help understand how a purely manufacturing organization would handle a services assignment as well as how the operations manager would effectively handle both products as well as services.



Difference between Product and Service Design

1. Products are Tangible and generally services are intangible. Services give peace of mind which is again an intangible thing.
2. Services are created and delivered at the same time, haircut, car wash. Services like these if not properly designed are instantly discovered by the customers.
3. Services highly visible to customers and should be designed with that in mind. This adds an extra dimension to process design, one that is absent in product design.
4. Services cannot be inventoried. This poses on restriction on flexibility and leads to an increased importance in capacity design.

5. Location important to service design. In fact design of services and choice of location are often closely linked.
6. Services have low barrier to entry. Some services (Non Information Technology BASED) have lower barriers to entry and exit. This places an additional pressure on service design to be innovative and cost effective.

Phases in Service Design

Service Design process requires the thorough understanding of what the service should be and how it should be delivered and that too with in certain standardized specifications or requirements.

1. Conceptualize
2. Identify service package components

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3. Determine performance specifications
4. Translate performance specifications into design specifications
5. Translate design specifications into delivery specifications

A good operations manager should be able to see the compatibility between design requirements for a product or a service.

Service Blueprinting

Service blueprinting is a method used in service design to describe and analyze a proposed service. It is a useful tool for conceptualizing a service delivery system

Major Steps in Service Blueprinting

1. Establish boundaries and decide on the level of detail that is needed.
2. Identify steps involved and describe them. If there is an existing process, get an input from those who do it.
3. Prepare a flowchart of major process steps.
4. Identify potential failure points. Incorporate features that minimize the chances of failures.
5. Establish a time frame for service execution and estimate of variability in processing time requirements. Time is a fundamental determinant of cost, so establishing a time standard for service is important.
6. Analyze profitability. Customer waiting time is important, leading to negative profitability

Characteristics of Well Designed Service Systems

A well designed service system should be consistent with the organization's vision as well as mission. It should be user friendly, robust, easy to sustain, cost effective and should bring value to customers.

A good and well design should create an effective linkage between back operations and front operations. It should aim for a single unifying theme. It should ensure reliability and high quality.

An operations manager often faces challenge of a poor service design. The reasons of a poor service design include variable requirements, difficult to describe requirements, high volume of customer contact. These challenges can be overcome easily with the aid of defining a standardized requirement that would be addressed by the service, make simpler requirements and handle only limited number of customers at each service station or outlet.

The House of Quality

It makes a lot more sense to introduce the concept of quality in product and service design here. We already know a superior product enjoys a broader customer base because of its superior quality.

Similarly a service is a customer encounter. A popular managerial view is that the Quality Function should be deployed at the source or at the design stage. We also should know what Quality Function Deployment is. Two common answers being that it is the voice of the customer (which always sets a standard for the service organization to follow) and the second one being that it should be in the form of a house of quality

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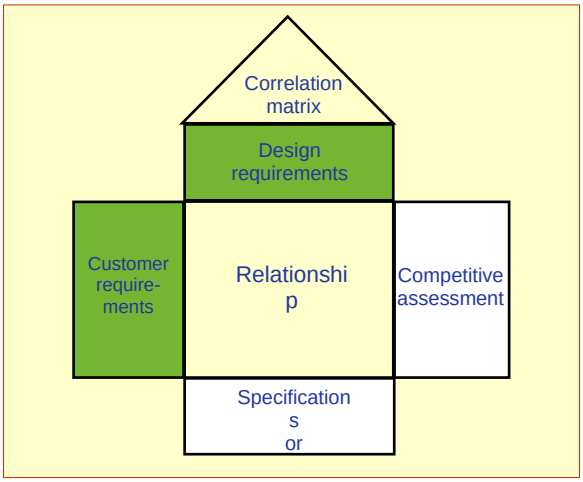

Conclusion

How organization can improve their product or service design is based purely on how much they are willing to invest in Research & Development(R &D). Organizations should shift some emphasis away from short term performance to long term Performance. They should work towards continual and gradual improvements instead of the big bang approach. This is clearly an example of Japanese incremental modification approach to the contrasting American philosophy of introducing a different model. Whatever may be the approach, a good design should aim to provide a reduced product life cycle.

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RELIABILITY

We often come across statements similar to these, this bulb (product) is not as reliable as the previous bulb or my newspaper's analysis and report writing (service) is not as reliable as my friend's newspaper analysis. These two sentences summarize what human mind is looking for? That is reliability. Reliability is sought by customers from all organizations. Interestingly enough, the personnel working inside the organization whether engineers or managers also seek reliability of operations, management, IT, Accounting and other host of functions that help an organization perform its day to day routine activities effectively. Reliability is no longer that art which was considered to be possessed by a family of skilled craftsman rather has now evolved in to a vast and ever increasing field of Engineering. Reliability in general and reliability engineering in fact play a very critical part in an organizations product or service gaining competitive advantage over the organizations competitors.

Reliability

We often overlook the concept of Reliability and confuse it with the concept of safety. Safety is one small aspect of reliability. Reliability needs to be looked into with the important perspective of failure of a product /service and normal operating conditions for that particular product or service. Lets us briefly look at the definitions of reliability, along with what is termed as failure and what are the normal operating conditions for a product.

- ***Reliability***: The ability of a product, part, or system to perform its intended function under a prescribed set of conditions
- ***Failure***: Situation in which a product, part, or system does not perform as intended
- ***Normal operating conditions***: The set of conditions under which an item's reliability is specified e.g. an automobile designed for operation in Europe may not fulfill its intended useful service in Pakistan. SO IT HAS THE POTENTIAL TO FAIL AND BE LESS RELIABLE. Kindly pay more attention to the word potential here, potential refers to something hidden or attached either to the performance or operations of a product. A bank servicing its client if fails to provide reliable normal operating service can lead to disastrous financial consequences for its customers similarly if a pharmacy starts dispensing expired medicines it can cause serious health hazards to its customers. All products and services carry with them the potential of doing something harmful if they are unable to function according to normal operating conditions. The thing or characteristic or quality that avoids something aberrant happening is known as RELIABILITY.

Measuring Reliability

Reliability can be measured, quite effectively by making use of the concept of chance or probability, in other words we can quantify the concept of reliability in terms of statistical probability. Often products are made more reliable (dependable and safe) by increasing the safe operations of certain critical parts by increasing the presence of such important elements. E.g. a computer being used as a server may be having two or more uninterrupted power supply units ensuring its safe operations. Similarly, building code requirements in the past followed a more stringent and increased factor of safety, often leading to redundancy (subassembly or components or elements which were never brought into action or play or operations or never used in the normal routine operations of an assembly). In our earlier lectures we covered the important concept of Tacguchi method which made us realize that a product or service should be able to provide what it promises under a well defined range of operating conditions. A car manufactured in Lahore should be able to provide the same service in northern areas of Pakistan or coastal belt with same reliability and robustness.

We now quantify Reliability in terms of Probability. E.g. If a component or item has a reliability of 0.9, it means that it has a 90% probability of functioning as intended, the probability it will fail is 1-0.9 = 0.1 which is 10%

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We can use Probability in two functions

1. The probability that the product or system will function when activated.
2. The probability that the product or system will function for a given length of time

Reliability and Probability Basics

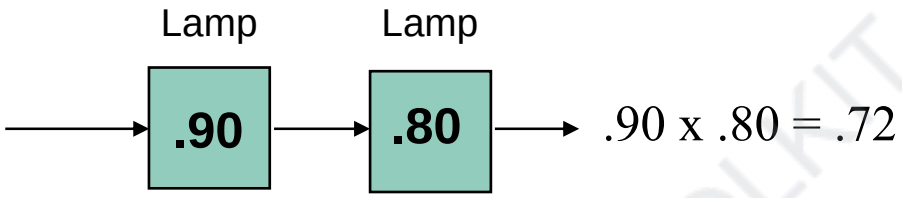
Probability is used to explain reliability by taking into account the fact that the product or system will Function when activated or Function for a given length of time. This also means we need to know about the independent events as well as redundancy.

Now Independent events are those events whose occurrence or nonoccurrence do not influence each other, also Redundancy is the use of backup components to increase reliability.

Let's first take into account the fact that Probability that a system will function when activated.

RULE 1

If two or more events are independent and success is defined as probability that all of the events, occur then the probability of success is equal to the product of probabilities

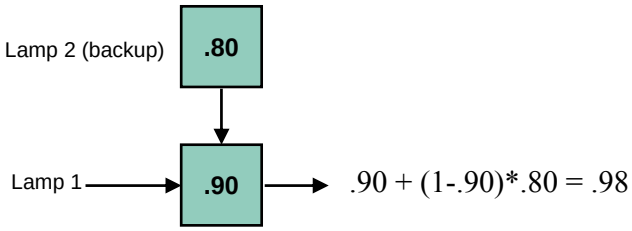


Both the lamps should be lighted up in order to ensure visibility. Reliability of the System equals (Reliability of component 1)(Reliability of Component 2)

RULE 2

If two events are independent and "success" is defined as probability that at least one of the events will occur, then the probability of either one plus 1.00 minus that probability multiplied by the other probability

Lamp 2 is an example of redundancy here, as it being backup Lamp increases the reliability of the system from 0.9 to 0.98



RULE 3

•If three events are involved and success is defined as the probability that at least one of them occurs, the probability of success is equal to the probability of the first one (any of the events), plus the product 1.00 minus that probability and the probability of the second event (any of the remaining events), plus the product of 1.00 minus each of the two probabilities and the probability of third event and so on. This rule can be extended to cover more than three events.

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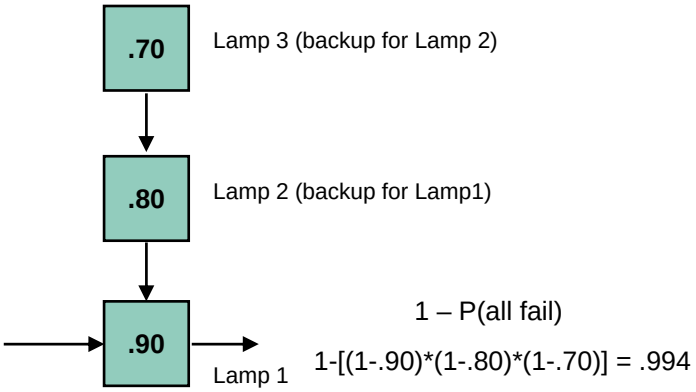
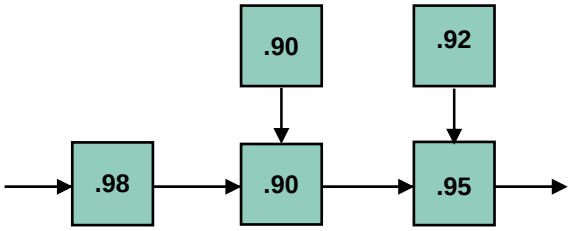


Rule 3

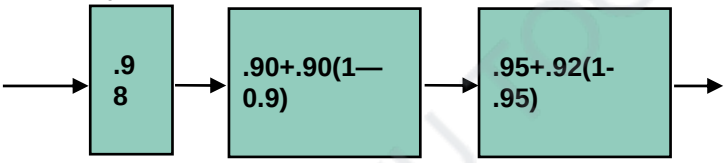
Example S-1 Reliability

Determine the reliability of the system shown



Example S-1 Solution

The system can be reduced to a series of three components



.98 x .99 x .996 = .966

2. Time based Reliability "Failure Rate"

The second measurement of reliability is carried out in terms of the time. We all know that component, products or even services have limited lives. They function or fulfill their expected work in some normal operating conditions. A product or service's working life when exhausted or ending prematurely is often referred to as Failure rate.

Let us go back to the first statement of the lecture, when we made a comment that this bulb is less reliable, if we are investigate further, we can take up the example in a more detail manner. Say if 1000 bulbs are being manufactured at a facility in Karachi, these bulbs once manufactured are not sent to the customers without quality checks. They are made to go through stringent testing, after conducting statistical analysis. The manufacturers can identify the time based reliability or failure of the bulb. This is quite simple as well as a standard procedure in determining the expected life of any product. In fact this has been a part of manufacturing industry for years now. Some of the bulbs would fail in testing and would not be shipped. As a part of process control, we can plot the testing of bulbs.

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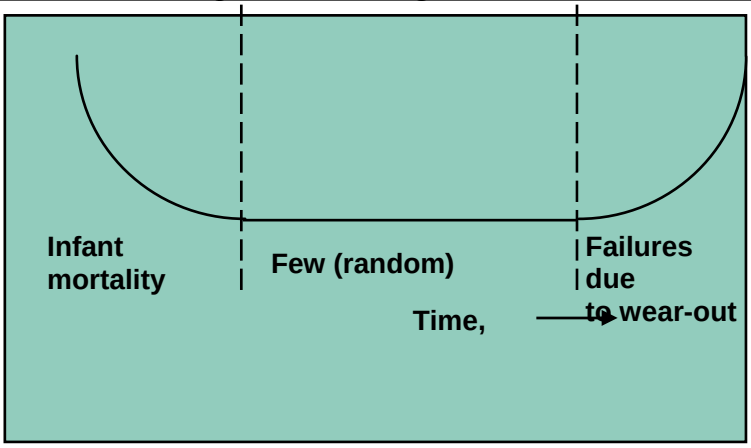

The figure above shows a bathtub shape and thus rightly is referred to as the Bathtub curve. On the Y axis we represent the Failure rate and on the X axis we represent the Time. A careful look at the graph would help us to identify the three phases

- Phase I near the origin is called Infant Mortality.
- Phase II in the middle refers to few random failures.
- Phase III at the far end from the origin represent failures due to wear out.

What can we observe in the Bath Tub Curve?

In Phase I : One can easily see that quite a few of the products fail shortly put into service, not because they wear out but they are defective to begin with.

In Phase II: The rate of failure decreases rapidly once the truly defective items are WEEDED OUT (Eliminating inferior products/Services). During phase II, there are fewer failures because the inferior/defective has already been eliminated. This phase is free of worn out items and as seen is the LONGEST PERIOD here.

In Phase III: In the third phase, failure occurs because the products have completed the normal life of their service life and thus worn out. As we can see the graphs steeps up in this phase indicating an increase in the failure rate.

- The question now is how can we collect information on the distribution, length of each phase? We know that all this requires collection and analysis of data. we are interested in calculating mean time between failure for each phase.

If we analyze phases I and III separately and observe them in exploded or enlarged views we may be able to trace the presence of exponential curve in both the phases. Its clear that in Phase I we observe a clear exponential decrease in the time expected of a products life.

Exponential Distribution FOR INFANT MORTALITY STAGE

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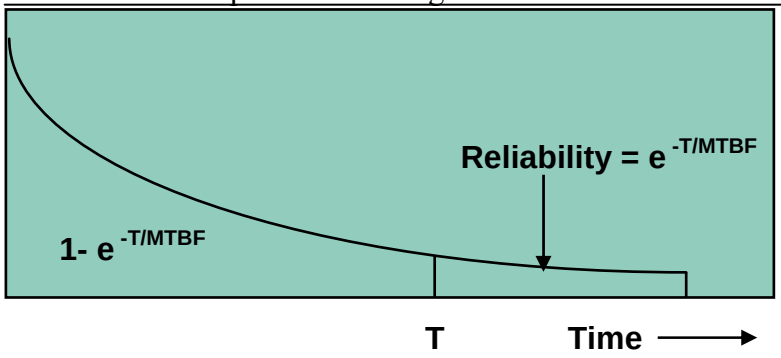
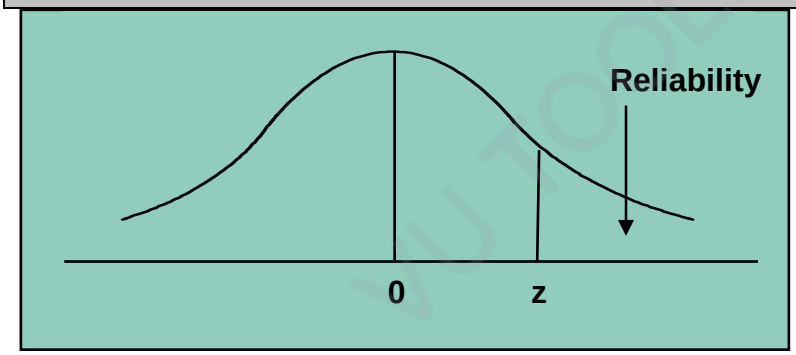


EXPONENTIAL DISTRIBUTION

Equipment failures as well as product failures may occur in this pattern. In such a case the exponential distribution, such as depicted on the graph. We can identify two phases Phase I and Phase II. Phase I indicates the probability that equipment or product put into service at time 0 will fail before specified T is ability that a product will last until Time T and is represented by area under the curve between O and T.

Phase II indicates that the curve to the right of Point T increases in Time but reduces in reliability. We can calculate the reliability or probability values using a table of exponential values. An exponential distribution is completely described using the distribution mean, which reliability engineers call it the MEAN TIME BETWEEN FAILURES. Using T to represent the length of service, we can calculate P before failure as P (No failure before T)= $e^{-T/MBTF}$.

NORMAL DISTRIBUTION



Product failure due to wear out can be determined by using normal distribution. From our knowledge of statistics we already know that the statistic table for a standardized variable Z represents the area under the normal curve from essentially from the left end of the curve to a specified point z, where z is a standardized value computing use

$$z = \frac{\text{T-Mean wear out time}}{\text{Std Deviation of Wear out Time}}$$

Thus we must know the mean and the standard deviation of the distribution. Again for the sake of easy reference we can use the statistical table available to us would always show the area that lies to the left of Z.

To obtain a probability that service life will not exceed, some value T, compute Z and refer to the table. To find the reliability for some T, subtract this probability from 100 percent.

To obtain the value of T that will provide a given probability, locate the nearest probability under the curve to the left in the statistical table.

Then the corresponding z in the preceding formula and determine T.

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$$z = \frac{\text{T-Mean wear out time}}{\text{Std Deviation of Wear out Time}}$$

Example

The mean life of a certain steam turbine can be modeled using a normal distribution with a mean life of six years, and a standard deviation of one year. Determine each of the following:

- The probability that a stem turbine will wear out before seven years of service.
- To probability that a steam turbine will wear out after seven years of service (i.e. find its reliability)
- The service life will provide a wear-out probability of 10 percent.

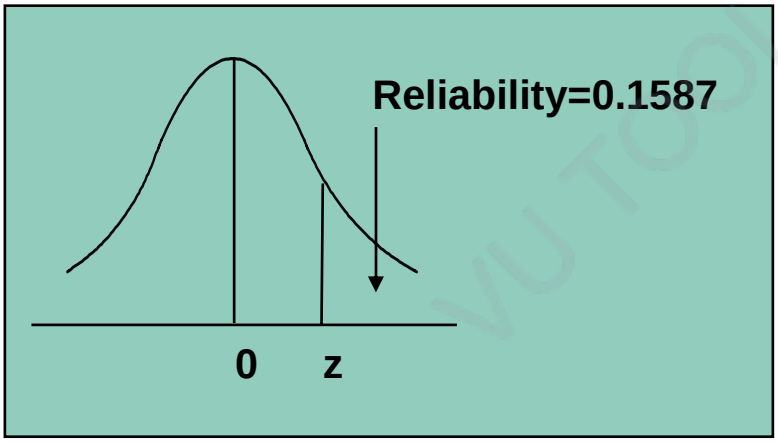
•Wear out life mean= 6 years.
•Wear out life standard deviation = 1 year
•Wear out life is normally distributed.

For Normal Distribution, we can compute Z and use it to obtain the probability directly from a statistical table

$$z = \frac{\text{T-Mean wear out time}}{\text{Std Deviation of Wear out Time}}$$

= 7-6/1= +1.00
Since P (T<7) =0.8413

Also, subtract the probability (reliability) determined in part a from 100 percent
1.00 -0.8413
= 0.1587



We can see that on the Z scale, both a and b gives 1.00

•Use the normal table and find the value of z that corresponds to an area under the cure of 10%

We are focusing on 10 % of the area under the curve and check only the left hand side
Z=-1.28= (T-6)/1
Thus T =6-1.28=4.72
We calculate and find value of T is 4.72

AVAILABILITY

The fraction of time a piece of equipment is expected to be available for operation.
Mathematically, If we represent mean time between failures by MTBF and mean time to repair by MTR then

Availability = (MTBF)/(MTBF + MTR)

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Improving Reliability

We should develop the ability to understand the importance of reliability and at the same time identify the ways in which Reliability can be improved in the following generic ways.

1. Component design : Parts of a car
2. Production/assembly techniques: No reworks also fool proof assembly.
3. Testing :for trouble free final product
4. Redundancy/backups: not possible all the time but common remedy.
5. Preventive maintenance procedures
6. User education(operating manuals)
7. System design (we will discuss in later chapters, a senior management issue, but indicative that reliability is always considered VIP)
8. Research & Development (R&D) : Organized efforts to increase scientific knowledge or product innovation & may involve:

Basic Research advances knowledge about a subject without near-term expectations of commercial applications.

- Applied Research achieves commercial applications.
- Development converts results of applied research into commercial applications.

CONCLUSION

It is important to understand the concept of reliability in terms of normal operating conditions as well as safe operations. Services in general and Products in particular are designed to provide this opportunity to the fullest. It is recommended to invest more in R &D, with regards to increase in Reliability. Quality checks should be incorporated at suitable places to enhance product and services reliability.

It is also suggested that emphasis should be shifted away from short term performance to both short as well as long term Performance improvement while formulating a reliability based operations strategy. Operations Manager should work towards continual and gradual improvements instead of big bang approach. They should work to shorten the product life cycle (not the products life) as it increases products safety as well as reliability. Operations side should be encouraged to pot for component commonality continual improvement and shorten time to market.

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CAPACITY PLANNING

After completing discussion on product or service design, organizations end up answering the questions relating to capacity and demand. Since we have already discussed demand forecasting, we should now focus on what capacity planning decisions are. We should also try to understand the importance of capacity.

Capacity decisions are important to all departments of the organization; an accountant would be interested in collecting cost accounting information in order to ensure that correct capacity expansion decision is reached. Similarly a financial manager would be interested in performing the financial analysis of whether the investment decision is justified for a plant or capacity increase. An Information Technology Manager would end up preparing data bases that would aid the organization again to decide about the capacity and last but not the least an operations manager would select strategies that would help the organization achieve the optimum capacity levels to meet the capacity demand.

Learning Objectives

Capacity planning lectures deal with different types of Capacity like Design, Effective; Utilization etc Quite often the operations manager has to identify various determinants of Effective Capacity. The manager has to formulate Strategy with respect to Capacity Planning and plans by looking in to developing Capacity Alternatives and studying Economies of Scale and focusing on Cost Volume Relationship

Hopefully by completing the lecture on Capacity Planning an Operations Management the students would be able to:-

- Understand, appreciate and explain the importance of capacity planning.
- Discuss ways of defining and measuring capacity.
- Describe the factors that determine effective capacity alternatives.
- Discuss the major considerations related to developing capacity alternatives.

Capacity Planning

Capacity is the upper limit or ceiling on the load (demand for a product or service) that an operating unit can handle.

An Operations Manager is supposed to identify tactics and formulate a strategy in order to answer the basic questions with respect to capacity handling. These questions are:

1. What kind of capacity is needed?
2. How much is needed?
3. When is it needed?

This word "Capacity Planning" reached us a day after the tragic and life changing incident of earthquake of 8th October 2005. We were exposed to the idea of capacity limitation with respect to food, shelter, medicines and rescue operations. As a consequence we also faced the challenge of planning how to overcome this shortcoming.

- If you could recall in our earlier lectures we talked about *Irregular variations* caused by unusual circumstances such as severe weathers, earthquakes, worker strikes, or major change in product or service. These irregular variations do not capture or reflect the true behavior of a variable and can distort the overall picture. These should be identified and removed from the data.
- There are two uses for forecasts. One is to help the Operations Manager plan the system and the other one is to help him plan the use of the system.
- Planning the system refers to planning long term plans about the type of products or services to offer, what facilities and equipment to have, where to locate and so on and so forth. Planning the use of the system relates to short range and intermediate range planning which means planning inventory workforce resources, planning of purchasing and production activities, budgeting and scheduling etc.

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Importance of Capacity Decisions

Capacity decisions impacts ability to meet future demands, affects operating costs. These decisions often act as a major determinant of initial costs, as they involve long-term commitment. These decisions affect competitiveness and gives ease of management. Capacity Decisions focus on globalization as it is more complex and impacts long range planning.

- Impacts ability to meet future demands. Capacity essentially limits the rate of possible output. Having capacity to satisfy demand can allow a company of taking advantage of tremendous opportunities. An international automobile manufacturer of good repute increased its production by working on its capacity decision after its quality product received a lot more demand than it was originally anticipated.
- Affects operating costs. We already know that estimated or forecasted demand differs from actual demand, so the ideal concept of capacity matching demand is untrue. Organizations should be willing to take a critical decision to balance the cost of over and under capacity. Overcapacity reflects overkill of resources and under capacity shows a weak management philosophy to make best use of an available market.
- Acts as a major determinant of initial costs. It is typical to see that greater the capacity of a productive unit, greater would be the cost. This does not mean I am advocating a one to one relationship for higher capacity for production to costs; in fact larger units tend to cost proportionately less than smaller units. E.g. Pakistan Steel Mill at Karachi is one good example, where higher costs are misunderstood as the mills capacity is not being fully utilized
- Involves long-term commitment. Once long term commitments of resources have been taken, the difficulty of reversing would cost more. Indicating a capacity increase or decrease for an organization set up would mean additional costs.
- Affects competitiveness. This is very critical, if a firm has an excessive capacity or can quickly add capacity, which fact may serve as a barrier against entry by other firms.
- Affects ease of management. Capacity increase or decrease decisions involves management to answer the question of operating the organization as well as an increase or decrease in the plant capacity
- Globalization adds complexity. Capacity decision often involves making a decision in a foreign country which requires the management to know about the political, economic and cultural issues.
- Impacts long range planning. Capacity decisions extend beyond 18 months and thus get classified as long term in nature.

Organizations often end up making use of rupees amount in order to show their capacity ceiling this unfortunately needs a constant updating due to changes in price of raw materials as well as utilities. A simple way out is to reflect the load or capacity in terms of unit produced but this has the limitation that its only good for a single unit and fails in case of multiple types , designs of units being produced. A preferred type of capacity measurement is to identify capacity in terms of availability of input units.e.g. like hospitals are identified to have a capacity of 200 beds, a workshop by its man-hours and so on and so forth.

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CAPACITY PLANNING (Contd.)

It is important to realize that managers make capacity decisions at the organizational level and not at the operational level. Often, debottlenecking a process can increase departmental efficiency without increasing or improving the organizational performance. This does not mean that capacity decisions are not taken at the operational level rather managers end up making capacity decisions at the individual process level in accounting, finance, human resources, information technologies, marketing and operations departments.

Operations Mangers must understand capacity measures, economies and diseconomies of scale, capacity cushions and trade off between customer service and capacity utilization.

Efficiency and Utilization

Operations Manager should know what is Capacity? They should be able to identify the terms Design Capacity and Effective capacity before they can understand another important concept of Utilization.

- Design capacity is the maximum output rate or service capacity an operation, process, or facility.
- Organizations facility or operation is designed for Effective capacity which refers to Design capacity minus allowances such as personal time, maintenance, and scrap
- Actual output is the rate of output actually achieved--cannot exceed effective capacity.

Efficiency/Utilization Example
Use the following data to determine the Efficiency and Utilization

Design capacity = 50 trucks/day
Effective capacity = 40 trucks/day
Actual output = 36 units/day

$$\text{Efficiency} = \frac{\text{Actual Output} = 36 \text{ units / day}}{\text{Efficiency Capacity} = 40 \text{ units / day}} = 90\%$$

$$\text{Utilization} = \frac{\text{Actual Output} = 36 \text{ units / day}}{\text{Design Capacity} = 50 \text{ units / day}} = 72\%$$

Determinants of Effective Capacity

Operations Manager often focus on determinants of effective capacity by taking into account both macro and micro levels. At the macro levels the managers look for Supply chain and External factors, while at the micro level they look for operational factors including facilities and man and machine resources. There are 7 determinants of effective capacity namely:-

1. Facilities. The design of facilities includes the size as well as the provision of expansion. Other important factors that are necessary include transportation costs, distance to market, labor supply, energy supply sources and the ease and smoothness with which work can be performed. We should also include environmental factors such as heating, lighting and ventilation which not only increase the performance of the workforce but also act as source of motivation and worker loyalty. A failure to comply with this would indicate poor design which in reality translates to lack of managerial acumen.

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2. Product and service factors can have a tremendous influence on capacity. E.g. when items are similar, the ability of the system to produce those items is generally much greater than when successive items are different and unique. The idea is more uniformity in the final product service output the greater capacity. I am making a reference to a PC manufacturer in USA which decided that it would standardize its products and split its assembly lines only at the point where the a small differential product feature was required.
3. Process factors refer to the quantity and quality requirements of a process. Quantity always refers to capacity. Another added feature is quality of output. If quality of output does not match the standard requirements it would generate inspection and possible reworks.
4. Human factors include skill, craftsmanship, training and qualification to handle any job it also includes the motivational factors.
5. Operational factors with respect to effective capacity always refer to scheduling, late deliveries, acceptability of purchased materials, parts, quality inspection, control procedures and inventory problems. Scheduling issues arise when an organization has a difference in equipment capabilities for development of alternative capacities. Inventory problems have a negative impact on capacity
6. Supply chain factors relate to any short coming to suppliers, warehouse processing, operational hick up or distribution issues.
7. External factors include product standards, safety regulations, unions and pollution control standards. At times organizations have experienced shutting down of their facility if they could not provide support to government regulations of pollution control.

Strategy Formulation With respect to Capacity Planning

1. Capacity strategy for long-term demand which focus on demand patterns and takes into account growth rate and variability
2. Facilities that focus on cost of building and operating
3. Technological changes relate to rate and direction of technology changes
4. Behavior of competitors
5. Availability of capital and other inputs

Key Decisions of Capacity Planning

It is important to identify the key decisions in order to carryout a correct capacity planning decision. Some of the common key decisions are

1. Amount of capacity needed
2. Timing of changes
3. Need to maintain balance
4. Extent of flexibility of facilities

Steps for Capacity Planning Strategy

It is important to understand how to formulate a capacity planning strategy

1. Estimate future capacity requirements
2. Evaluate existing capacity
3. Identify alternatives
4. Conduct financial analysis
5. Assess key qualitative issues
6. Select one alternative
7. Implement alternative chosen
8. Monitor results

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Developing Capacity Alternatives

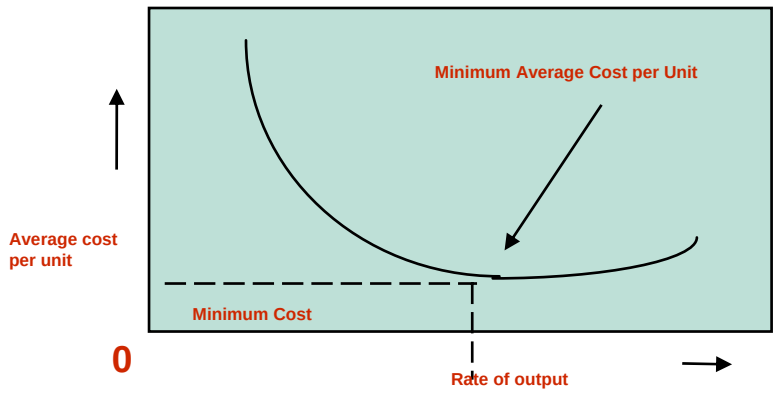
1. Design flexibility into systems refers to long term nature of expansion, if at the time of original design, flexibility alternative is provided, and it would save cost in remodeling and modifications when expansion is carried out later.
2. Take stage of life cycle into account. It is important that operations manager observe and check whether the capacity increase alternative is for a new product/service or mature product or service. The predictability for a new service is riskier as compared to an established mature product or service.
3. Take a "big picture" approach to capacity changes while developing the capacity of the system, it is necessary to understand the interrelationship of the components of the system. The big picture approach relates to setting up of parking space, house keeping and landscaping if an expansion is to be accommodated in a multi purpose shopping plus apartment complex.
4. By developing capacity alternatives, organizations prepare to deal with capacity "chunks" Capacity increases are normally obtained in big chunks instead of incremental increase. A steel mills furnace may not be able to provide exact required increase in capacity and thus would provide excessive capacity which may lead to increase in inventory. E.g. the demand for steel say is 2000 tone per annum in the city of sukkhur, from a local steel mill the capacity is 1800 tones per annum. The steel mill can increase its production from 1800 tones to 2200 tones per annum and not to exactly 2000 tones per annum.

Organizations attempt to smooth out capacity requirements. This topic is discussed in more detail when we will cover the topic of aggregate planning for the time being we can see that simply adding capacity by increasing the size of workforce, machines, facility does not help. Operations manager should be able to identify the optimal operating level. All Production units have an ideal or optimal level of operation in terms of unit cost of output. At the ideal level, cost per unit is the lowest for that production unit.

Economies of Scale and Diseconomies of scale

An operations manager should know what economies and diseconomies of scale are
Economies of scale reflects a concept that states the average unit cost of a good or service can be reduced by increasing its output rate while diseconomies of scale reflects the case when the average cost per unit increases as the facility's size increases.
If the output rate is less than the optimal level, increasing output rate results in decreasing average unit costs then it reflects Economies of Scale. On the other hand if the output rate is more than the optimal level, increasing the output rate results in increasing average unit costs

Evaluating Alternatives



Explanation of the Cost Curve
The explanation for the shape of the cost curve is that low levels of output (Production), the costs of facilities and equipment must be absorbed (paid for) by few units. Hence the cost per unit is very high.

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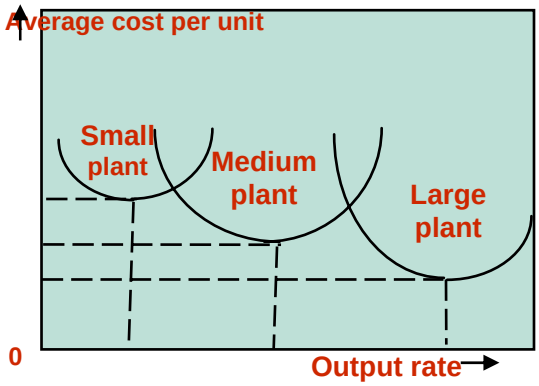
As the output is increased, there are more units to absorb the fixed cost of utilities, facilities and equipment, so unit cost is decreased.

Minimum Cost would be recorded at the optimal rate, beyond that the unit cost will start to increase. Other factors now become more important which include worker fatigue, equipment breakdown, the loss of flexibility, which leaves less margin for error and increases difficulty in coordinating activities.

Evaluating Alternatives

Minimum cost & optimal operating rate are functions of size of production unit.



Evaluating Alternatives

- As the general capacity of the plant increases, the optimal output rate increases and the minimum cost for the optimal rate decreases.
- This is the prime reason why larger plants tend to have higher optimal output rates and lower minimum costs than smaller plants.
- The senior management normally takes in to account the same considerations in addition to availability of financial, capital resources and forecasted demand.
- The important step is to determine enough points for each size facility to be able to make a comparison among different sizes.
- In some industries or types of services, facility sizes are given, where as in other facility size are continuous variable.
- Occasionally the management decides for a size which does not have the desired rate of output. E.g. Pharmaceutical Company, oil field, gas fields.
- An organization needs to examine the alternatives for future capacity from a number of different perspectives.
- Economic Conditions set the external conditions which influence the following
  1. Will Alternative be feasible?
  2. How much will it cost?
  3. How soon can we have it?
  4. What will be the operating and maintenance costs?
- Possible Negative Opinion due to the following decisions.
  1. Decision to build a new power plant, nuclear, coal, geothermal
  2. Displacement of people if a new hydro plant is to be built.
  3. Environmental issues related to company's new project.

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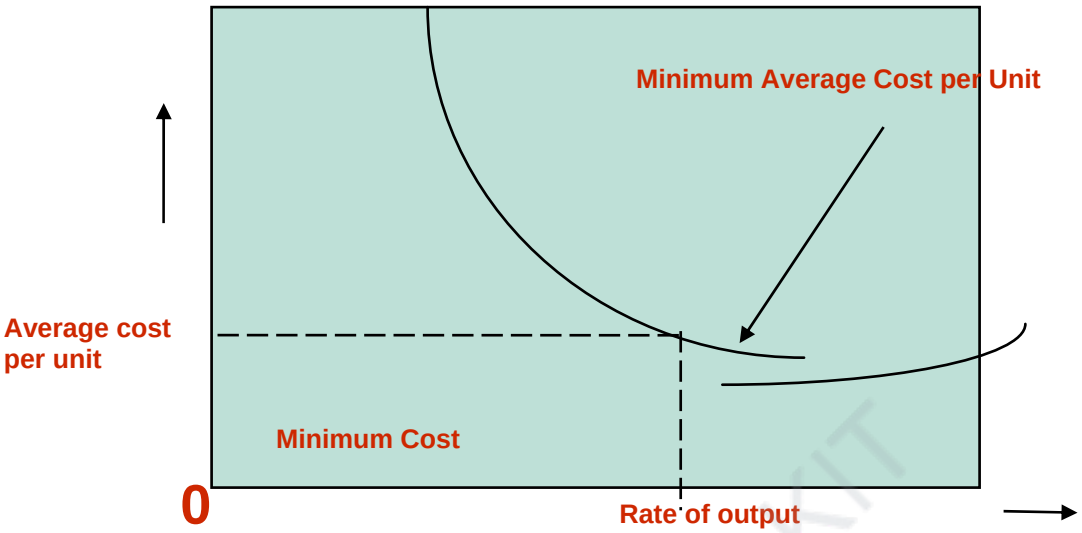
CAPACITY PLANNING (Contd.)

In our earlier lectures we talked about importance of capacity planning along with the idea that capacity planning decisions are carried out with certain objectivity in mind both at the individual level as well as at the organizational level. We also learnt the various measures of capacity. We now focus our attention on various alternatives available to us along with cost volume relationship.

Evaluating Alternatives



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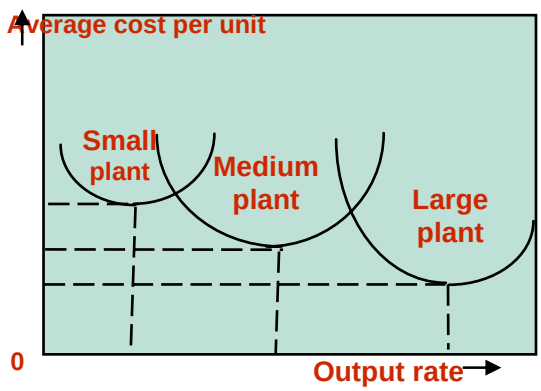

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Evaluating Alternatives

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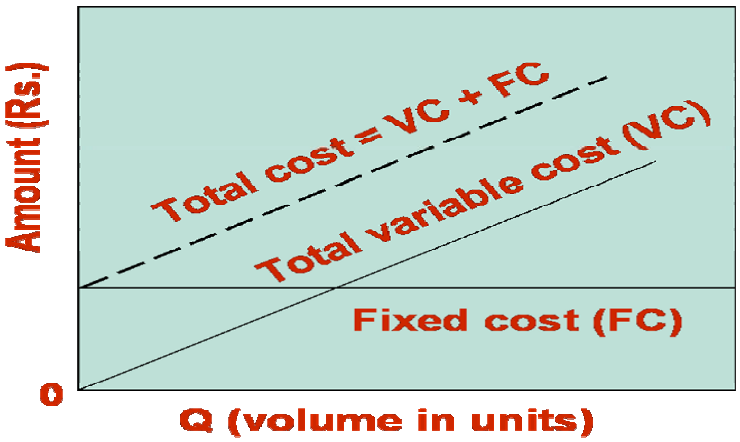
- Possible Negative Opinion due to the following decisions.
  4. Decision to build a new power plant, nuclear, coal, geothermal
  5. Displacement of people if a new hydro plant is to be built.
  6. Environmental issues related to company's new project.

Planning Service Capacity

Services are different that manufacturing cant be inventoried while services cannot be inventoried, this reason alone makes it necessary and pertinent to plan for service capacity.

- Need to be near customers as Capacity and location are closely tied.
- Inability to store services as Capacity must be matched with timing of demand
- Degree of volatility of demand it can vary between peak and low periods.

Cost-Volume Relationships



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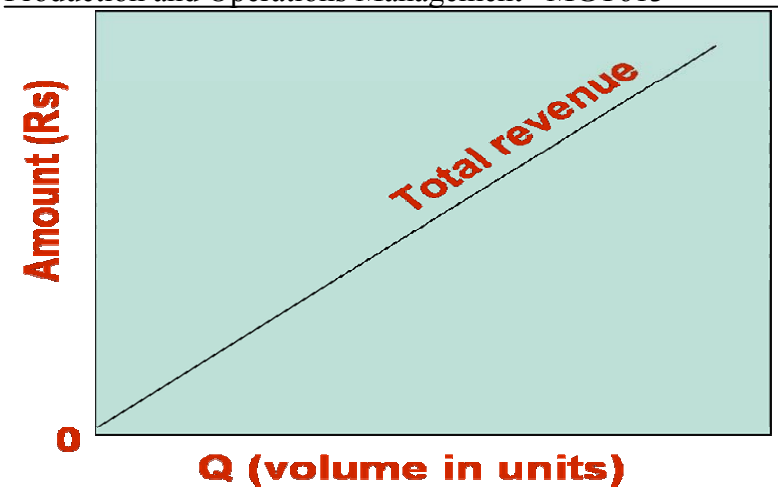

Assumptions of Cost-Volume Analysis

1. One product is involved
2. Everything produced can be sold
3. Variable cost per unit is the same regardless of volume
4. Fixed costs do not change with volume
5. Revenue per unit constant with volume
6. Revenue per unit exceeds variable cost per unit

Cost Volume Relationship focuses on relationships between costs, revenue and volume of output. The primary purpose of cost volume analysis is to estimate the income of an organization under different operating conditions. It is particularly useful as a tool for comparing capacity alternatives.

- The application of Cost Volume Relationships requires identification of all costs related to the production of a given product. These costs are assigned to fixed costs or variable costs.
- Fixed costs tend to remain constant regardless of volume of output. Examples include Rental costs, property taxes, equipment costs, heating and cooling expenses, and certain administration costs.
- Variable costs vary directly with volume of output. The major portions of variable cost are materials and labor cost. For our analysis part we can assume that the variable cost per unit remains the same regardless of volume of output.

Let us construct the model for Cost Volume Relationship. If we select FC , VC, TC, TR R , Q, Q_{BEP} , P and R to represent Fixed Cost, Variable Cost, Total Cost, Total Revenue, Revenue per unit, Quantity or Volume of Output, Quantity or Volume of Output at BREAK EVEN and Profit respectively then

Step I

The total cost TC associated with a given volume of output is equal to the sum of the fixed cost FC and the Variable Cost per Unit

TC= FC+ VC X Q

Step II

Revenue per unit, like variable cost per unit, is assumed to be the same regardless of the quantity of output. Total Revenue will have a linear relationship with the output.

TR= R X Q

Cost-Volume Relationships

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Step III

Profit is P difference between Revenue TR and Costs TC. Construct the model for Cost Volume Relationship

P= TR-TC

P= R X Q –(FC + VC X Q)

Rearranging and factorizing

P=Q (R-VC) –FC

Or P + FC= Q (R-VC)

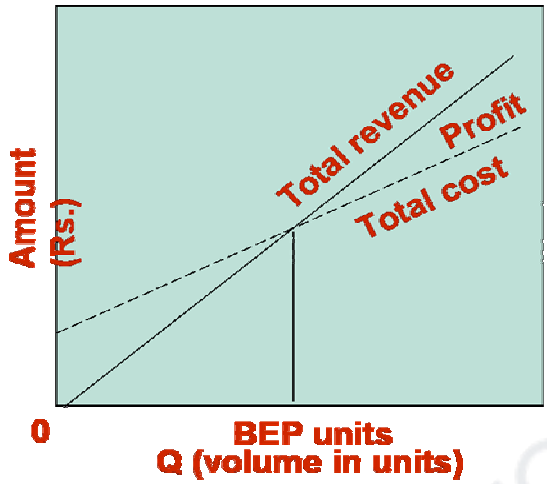
Also Q = (P +FC)/ (R-VC)

Q= Quantity or Volume of Output

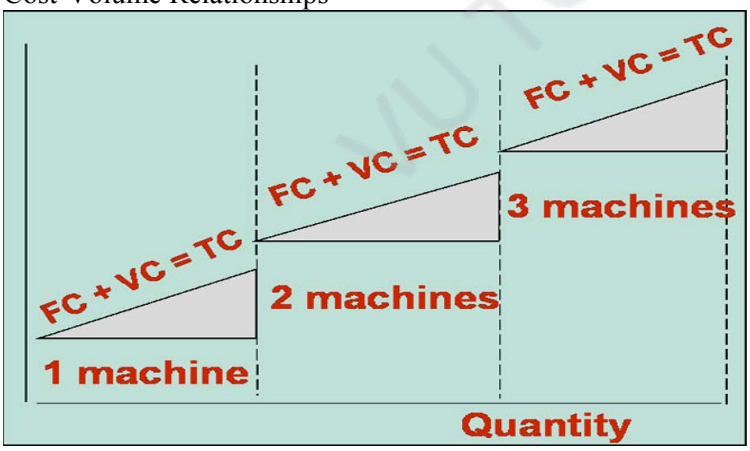
QBEP= Quantity or Volume of Output at BREAK EVEN, would be where

P=Profit is 0

So QBEP = FC/ R-VC



Cost-Volume Relationships



Step fixed costs and variable costs.

Capacity alternatives involve step costs.

- These step costs increase in stepwise as potential volume increases.
- For example an organization may have the option of purchasing one, two or three machines, with each additional machine increasing fixed cost in a non linear way.
- In such a scenario, the fixed costs and potential volume would depend on number of machines purchased or installed.

Break-Even Problem with Step Fixed Costs

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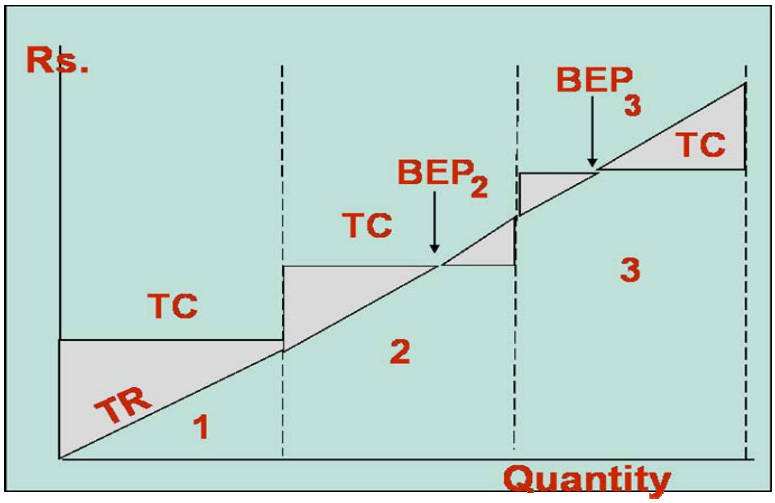
- The implication is that multiple break even quantities may occur, possibly one for each range.
- Note the total revenue line might not intersect the fixed cost line in a particular range, meaning that would be no break even point in the first range.
- In order to decide how many machines to purchase a manager must consider projected annual demand (volume) relative to Multiple Break Even Points and the most appropriate number of machines.



Multiple break-even points

Example

The Business Owner of a sports good factory in Sialkot is contemplating adding a new line of cricket bats, which will require leasing new equipment for a monthly payment of Rs. 60,000. Variable Costs would be Rs. 200 per bat and Bats would be sold for Rs. 2000 only.

1. How many bats would be sold in order to break even?
2. What would be the profit or loss if the 100 bats are made and sold in 1 month?
3. How many bats must be sold to realize a profit of Rs. 40,000?

Solution

1. Q_{BEP}= FC/ (R-VC)
   =Rs. 60,000/ 2000-200= 60,000/1800
   = 33.33 bats = 33 Bats

2. For Q =100 bats, the Profit or Loss would be
   P= Q(R-VC)-FC=100(2000-200)-60,000=100X 1800-60,000=180,000-60,000=120,000

3. For P =40,000
   Q = (FC+P)/ (R-VC)=(60,000+40,000)/(2000-200)
   =100,000/1800=55.56 = 56 Bats

Financial Analysis

Mathematical Techniques that can be used to evaluate alternatives are
- Cost Volume Relationships
- Financial Analysis
- Decision Theory
- Waiting Line Analysis

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Capacity alternatives are often evaluated with the aid of certain financial analyses. Operations manager along with managerial accountant often work to calculate what cash flow or present value in terms of rupees is available for the organization to proceed with a capacity alternative decision. It is important to understand what cash flow and present values are

1. Cash Flow - the difference between cash received from sales and other sources, and cash outflow for labor, material, overhead, and taxes.
2. Present Value - the sum, in current value, of all future cash flows of an investment proposal.

Waiting Line Analysis and decision theory are also two important ways in which capacity alternatives are evaluated.

Conclusion

Capacity planning is important that it helps an organization to formulate its long term (organizational) strategy and short term (operational) strategy. Long term capacity decisions relate to overall level of capacity while short term capacity decisions refer to seasonal, random or irregular variations in demand. Ideally capacity should match demand but it rarely happens. Capacity alternative decisions should be taken in view of what we have already covered the concept of systems approach or the over all big picture approach as quite often removing a bottle neck at the department level may not improve the organizations effectiveness. An effective operations manager would make use of qualitative as well as quantitative analysis to evaluate capacity alternatives.

Capacity decisions are often based on facilities layout and together they define the very existence of an organizational unit.

VU TOOLKIT

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PROCESS SELECTION

Process Selection plays an important part in over all design of production and operations management systems. Process Selection allows an organization to offer a safe and reliable product and service through pragmatic design and effective capacity planning. With the help of process selection we can understand the different types of processing including manual, rigid, and flexible as well as various automated approaches to processing. Process selection allows an operations manager to better understand the need for management of technology. Together with capacity planning it helps an organization to develop different approaches to meet the irregular demand pattern of the customers.

Introduction and Meaning

Process Selection refers to the way an organization chooses to produce its good or services. It takes into account selection of technology, capacity planning, layout of facilities, and design of work systems. Process selection is a natural extension after selection of new products and services.

An organizations process strategy would include

1. Make or Buy Decisions. The extent to which an organization will produce goods or provide in house as opposed to relying on an outside organization to produce or provide them.
2. Capital Intensity. The mix of equipment and labor will be used by the government.
3. Process Flexibility: The degree to which the system can be adjusted to changes in processing requirements due to such factors as changes in product or service design, changes in volume processed, and changes in technology.

Reasons to (Produce in-House or Outsource) Make or Buy

There are 6 reasons which are available to us in order to decide whether to develop a competence in house or hire an outside competent organization to supply that product, service or particular expertise. The latter requires that the outsourcer to be honest, ethical, competent. It also requires that outsourcing contract should be flexible yet pragmatic and carry proper levels of services.

- Available capacity if an organization has the equipment, necessary skills and time, it often makes sense to produce an item or perform a service in house. The additional costs would be relatively small compared with those required to buy items or subcontract them.
- Expertise. If a firm lacks the expertise to do a job satisfactorily, buying might be a reasonable alternative.
- Quality considerations. Firms that specialize can usually offer higher quality than an organization can attain itself. Conversely, special quality requirements or the ability to closely monitor quality may cause an organization to perform a job itself.
- Nature of demand. When demand for an item is high and steady, the organization is often better off doing the work itself. However, wide fluctuations in demand or small orders are usually better handled by specialists, who are able to combine orders from multiple sources, which results in higher volume and tend to offset individual buyer fluctuation.
- Cost. Any cost savings achieved from buying or making must be weighed against the preceding factors. Cost savings might come from the item itself or from transportation cost savings. If there are fixed costs associated with making an item that cannot be reallocated if the item is purchased, that has to be recognized in cost analysis.
- Risk. Outsourcing or buying the services carries risk; often companies retain flexibility by carrying out certain critical activities in house and repetitive menial activities through outsourcing.

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Types of Operation

The degree of standardization and the volume of output of a product or service influence the way production is organized. Output can range from high volume, highly standardized, to low volume, highly customized.

1. Continuous Processing.
    1. Repetitive Processing.
2. Intermittent Processing.
    1. Batch Processing
    2. Job Shop.
3. Automation
    1. Computer Aided Manufacturing
    2. Numerically Controlled Machines
    3. Robot
    4. Manufacturing Cell.
    5. Flexible Manufacturing System.

Continuous and Semi Continuous Operations

1. A system that produces highly uniform products or continuous services, often performed by machines.
    1. Processing of chemicals, photographic film, newsprint and oil products
2. Repetitive Processing. A production system that renders one or a few highly standardized products or services.
    1. Automobiles, televisions, computers ,calculators, cameras and video equipments

Intermittent Processing

1. A system that produces lower volumes of items or services with a greater variety of processing requirements.
    1. Processing of chemicals, photographic film, newsprint and oil products
2. Batch Processing. A system used to produce moderate volumes of similar items.
    1. Paint, ice cream, canned vegetables
    2. Magazines, newspapers, textbooks and user manuals.
3. **Job Shop**. A system that renders unit or small lot production or service with varying specifications according to customer needs

Automation.

Machinery that has sensing and controlling devices that enables it to operate automatically.

1. Computer Aided manufacturing the use of computers in process control.
2. Numerically Controlled Machines that perform operations by following mathematical processing instructions
3. Robot a machine that consists of a mechanical arm, a power supply and a controller.

Flexible Automation

1. Manufacturing Cell. One or a few N/C machines that produce a variety of parts.
2. Flexible Manufacturing System. A group of machines designed to handle intermittent processing requirements and produce a variety of similar products.
    1. Designed to handle Intermittent processes
    2. Offers reduce labor costs and consistent quality.
    3. Higher Flexibility as compared to hard automation
    2. **Disadvantage**.
        1. Requires longer time for planning and development

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2. Can handle only narrow range of parts variety.

Computer Integrated Manufacturing

1. Manufacturing Cell. One or a few N/C machines that produce a variety of parts.
2. Flexible Manufacturing System. A group of machines designed to handle intermittent processing requirements and produce a variety of similar products.
    1. Designed to handle Intermittent processes
    2. Offers reduce labor costs and consistent quality.
    3. Higher Flexibility as compared to hard automation
2. **Disadvantage**.
    1. Requires longer time for planning and development
    2. Can handle only narrow range of parts variety.

Operations Strategy with respect to Process Selection

Operations strategy has the quality of being fine tuned whenever we discuss a new idea, process selection is no different, and we can formulate a process selection based operations strategy as follows.

1. Hire and Promote Managers who have both Technical and Managerial Skills. As engineers fail in managerial decisions and managers end up relying on engineers who create WHITE ELEPHANTS.
2. Flexibility as a competitive strategy to be incorporated at all levels.
3. Judicious use of Automation as unnecessary Automation causes increase in cost and a subsequent increase in product and inventory.

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Lesson 19

FACILITIES LAYOUTS

Facilities layout corresponds to configuration of departments, sections, work centers, equipment with focus being on movement of goods or services or works. A traveler making use of the railway platform, or bus station or airport would be a good example of work being moved through a facility. Often poor design of productive system can result in poor design of the facilities layout. After 9, 11, most of the airports in the western world have shown that they are poorly designed to handle air traffic and passengers end up paying a heavy price in the form of long waiting hours and even people visit airports to see of their family or friend travelers end up reaching the lobby area. The reason being no attention was paid at the time of design or construction to separate boarding lounge form the ticketing counter or lounge. Such short comings plague organizations and it's the task of the operations manager to ensure that product as well as service layouts match organizations short as well as long term plans.

Basic Layout Types

The common Basic Layout Types are

1. Product/Service layout. A layout that uses standardized processing operations to achieve smooth, rapid, high-volume flow
2. Process layout. A Layout that can handle varied processing requirements
3. Fixed Position layout. A Layout in which the product or project remains stationary, and workers, materials, and equipment are moved as needed
4. Hybrid/Combination. A Layout that makes use of the combination of Product, Process or Fixed Position Layout.

Product Layout Characteristics

1. Product layouts are used to achieve a smooth and rapid flow of large volumes of goods and customers through a system.
2. The work is divided into a series of standardized tasks, permitting specialization of both labor and equipment.
3. The large volumes handled by these systems make it pertinent and necessary to invest in equipment and job design.
4. Layouts should be arranged to make the best use of technological processing abilities to fulfill the requirements of both product and services.
5. In manufacturing environments the lines are referred to as production lines or assembly lines, depending on the type of activity involved.
6. In services side, the word line may or may not be used like Healthcare/Hospital Services line, Carwash (absence of word line here) or Cafeteria Line.
7. Without standardization, many of the benefits of the repetitive processing are lost.
8. Product Layouts achieve a high degree of labor and equipment utilization, which tends to offset their high equipment costs.
9. Operations are so closely tied up that a mechanical failure or high absenteeism (rains) would increase vulnerability of the Systems.
10. We can prevent breakdowns if we religiously follow preventive maintenance schedules, inspection and replacement of worn parts.

Advantages of Product Layout

1. High rate of output.
2. Low unit cost.
3. Labor specialization.
4. Low material handling cost.
5. High utilization of labor and equipment.
6. Established routing and scheduling.

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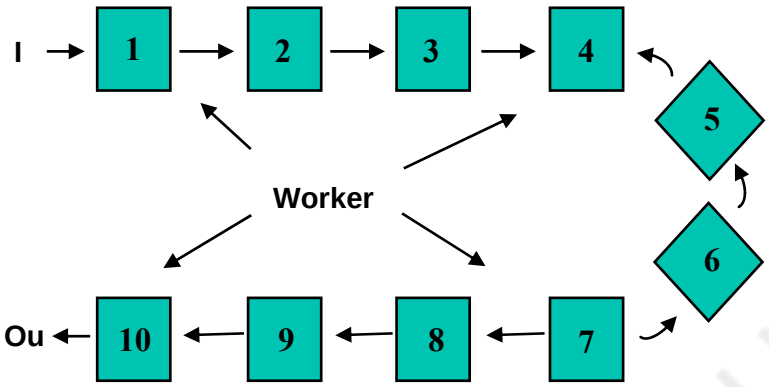
7. Routing accounting and purchasing.

Disadvantages of Product Layout

1. Creates dull, repetitive jobs.
2. Poorly skilled workers may not maintain equipment or quality of output of service.
3. Fairly inflexible to changes in volume.
4. Highly susceptible to shutdowns.
5. Needs preventive maintenance.
6. Individual incentive plans are impractical.

A U-Shaped Production Line

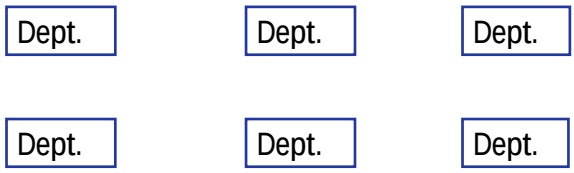


A U-Shaped Production Line

Straight Line designs are often not practical because of space constraints. U shape Production Line is more compact, and requires often half the length of a Straight Production Line.

U shaped Layouts are a must for teamwork where communication is necessary. U shaped Layouts allow flexibility in work assignments as workers can handle adjacent stations as well as stations on opposite ends. Sometimes U shaped production line interferes with the cross travel/movement of workers, mobile equipment. Highly automated processes do not require teamwork or communication, noise or contamination factors then U shaped Production Lines are not required.

Process Layout
(Functional)



Used for intermittent processing
Job Shop or Batch

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Product Layout

Product Layout
(Sequential)

Used for Repetitive Processing
Repetitive or Continuous

Advantages of Process Layouts

1. Can handle a variety of processing requirements.
2. Not particularly vulnerable to equipment failures.
3. Equipment used is less costly.
4. Possible to use individual incentive plans.

Disadvantages of Process Layouts

1. In-process inventory costs can be high.
2. Challenging routing and scheduling.
3. Equipment utilization rates are low.
4. Material handling slow and inefficient.
5. Complexities often reduce span of supervision.

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FACILITIES LAYOUTS (Contd.)

In our last lecture, we identified Facilities layout as the configuration of departments, sections, work centers, equipment with focus being on movement of goods or services or works. So whether it's a traveler making use of the railway platform, or bus station or airport, or an automobile or a product during its production stage or a patient needing medical attention, they all would qualify as good examples of work being moved through a facility. Often poor design of productive system can result in poor design of the facilities layout. We discussed product, process and hybrid layouts, we now focus our attention on cellular production. In cellular manufacturing, production work stations and equipment are arranged in a sequence that supports a smooth flow of materials and components through the production process with minimal transport or delay. Implementation of this lean method often represents the first major shift in production activity, and it is the key enabler of increased production velocity and flexibility, as well as the reduction of capital requirements. The concept of lean production and Just in Time Production Systems would be studied in detail when we will discuss improvement of Productive Systems.

Cellular Layouts

Cellular production techniques reflect a relatively new concept in manufacturing and have yet found immediate acceptance in Pakistani manufacturing industry as well. Organizations which opt for cellular manufacturing follow the lean production strategy. There are two important concepts to understand at the moment, what cellular production is and what group technology is? We will discuss lean production systems in detail towards the end of our semester later, for the time being we can consider lean production systems as systems which focus on high quality process with elimination of waste and effective use of available resources.

Cellular Production

- Layout in which machines are grouped into a cell that can process items that have similar processing requirements.

Group Technology

- The grouping into part families of items with similar design or manufacturing characteristics.

Cellular production always would represent the layout of machines while group technology would reflect the collection of items or products which need the same manufacturing requirements. Both these terms greatly influence the improvements of process and operations for any organization.

It is pertinent to understand the advantage of cellular layouts over the functional layouts. We already know that functional layouts are not only conventional in nature but also require more space as well as somewhat rigid layout plans, with increased special workforce and continuous supervision. The table below represents the same concept.

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Primary Differences between Functional and Cellular Layouts

Dimension	Functional	Cellular
Number of moves between departments	many	few
Travel distances	longer	shorter
Travel paths	variable	fixed
Job waiting times	greater	shorter
Throughput time	higher	lower
Amount of work in process	higher	lower
Supervision difficulty	higher	lower
Scheduling complexity	higher	lower
Equipment utilization	lower	Higher

Facilities Layouts

We have so far discussed what product and process based layouts are, in between we also focused our attention on hybrid configuration as well as cellular production layouts. We can thus safely define facilities layout as *the configuration of departments, work centers and equipment, with particular emphasis on movement of work (customers or materials) through the system.*

We come across different layouts in our daily lives especially with respect to the services side. Some important Service Layouts, which we should know include

- Warehouse and storage layouts
- Retail layouts
- Office layouts

People often confuse retail stores with warehouse stores, an effective way to understand the importance of these important business channels is to identify the layouts associated with it. Retail configurations are human friendly and allow the movement of goods through small trolleys for the customers and if placement of goods in the aisle is to be carried out then simple forklifts or small vehicles are used, sometimes over head cranes or hoists are also used.

Another important point of difference being the way the goods are displayed and shelved. The layouts are properly illuminated and ventilated and mostly maintained at a human comfort temperature through effective heating and air-conditioning. The floors too are mostly vinyled and designed to make the customer movement less stressful. The movement of goods involves light loads and easy transportation, as against this the warehouse and storage layouts, which require heavy loads and transportation. These goods require heavy vehicles and loaders for movement. The stores have different illumination arrangement then retail outlets. The security measures are different for both types of layouts, ranging from close circuit television cameras to electric barbed wires.

Importance of Layout Decisions

Operations Managers are often questioned about the importance of a new or existing facilities layout. In addition to the fact that operations manager work for improvement towards design and effect use of operation systems, they should also know the importance of layout decision in terms of money. Some of these are:-

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1. Layout decisions require substantial investments of money and effort.
2. Layout decisions involve long-term commitments.
3. Layout decisions have significant impact on cost and efficiency of short-term operations.

The Need for Layout Decisions

An operations manager should be aware of the fact that the need for a proper and effective layout facility is always there, it is often said that if there is no facilities layout problem being faced by an organization then it is probably unaware of its true potential. The need for layout planning arises both in the process of designing new facilities and in redesigning existing facilities. Some of the common reasons faced by the organization include:-

1. In-efficient Operations (High Cost/Bottlenecks that hamper true potential).
2. Accidents or Safety Hazards.
3. Changes in design of products or services.
4. Introduction of new products or services.
5. Changes in volume of output or mix of outputs.
6. Changes in Methods or equipment.
7. Changes in Environmental and Legal requirements.
8. Morale Problems (e.g. lack of face to face contact between supervisor and worker or even senior management and junior management).

Design Product Layouts: Line Balancing

Line Balancing is the process of assigning tasks to workstations in such a way that the workstations have approximately equal time requirements.
The objective of line balancing is to obtain equal time requirements at majority of the workstations. This shortens the time of manufacturing as well as reduces the idle time. Often industry uses the term cycle time to represent the time in which the organizations resources are engaged to complete a process and idle time to represent the time in which the resources are left unused.

Cycle Time

Cycle time is the maximum time allowed at each workstation to complete its set of tasks on a unit. If CT represents cycle time and D represents the desired output then we can calculate cycle time as

$$CT = \text{cycle time} = \frac{OT}{D}$$

Maximum Output

If we know what is the cycle time required for the manufacturing of a product or offering of a service we can calculate the maximum output. If OC is the Output capacity, OT is the operating Time and CT is the Cycle time then

$$OC = \text{Output capacity} = \frac{OT}{CT}$$

If an automobile manufacturer works for 8 hours and requires 4 hours to complete its cycle then the out put capacity would be 8/4= 2 automobiles.

Minimum Number of Workstations Required

Organizations working especially service organizations side often design their work facilities in a way that they can increase their capacity output by increasing the number of work stations. If D is the desired

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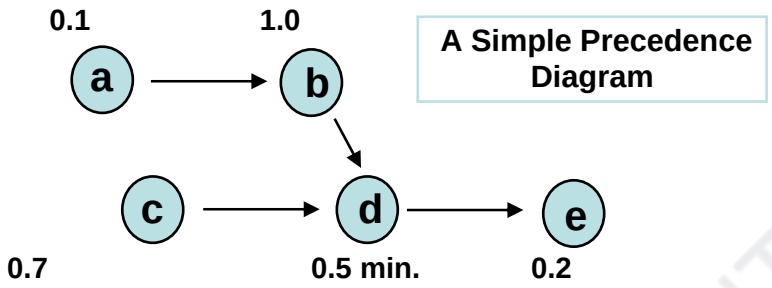
output, t is the time required for a specific time and OT is the Operating Time then the number of workstations N can be calculated as.

$$N = \frac{(D)(\sum t)}{OT}$$

$$\sum t = \text{sum of task times}$$

Precedence Diagram

Precedence diagram: Tool used in line balancing to display elemental tasks and sequence requirements



Line Balancing Rules

- Assign tasks in order of most following tasks.
  - Count the number of tasks that follow.
- Assign tasks in order of greatest positional weight.
  - Positional weight is the sum of each task's time and the times of all following tasks.

Designing Process Layouts require certain information, which includes the following:

1. List of departments
2. Projection of work flows
3. Distance between locations
4. Amount of money to be invested
5. List of special considerations
6. Location of key utilities

Summary

Facilities layout plays an important part in an organization achieving its maximum potential. This also indicates that facilities layout allow an organization to enjoy a competitive advantage over its competitors. Facilities layout requires more than just cost benefit analysis infect the decision requires how much space is required by the facility and how to configure or optimize the use of this space for the product or process. Of the different types of product, process, fixed and hybrid types of configurations, the current trend is towards cellular manufacturing and group technology.

Capital investments, materials handling costs and flexibility are important criteria in judging most facilities layout. Low volumes of production do allow the use of Group Technology or cellular manufacturing. Designing a process layout requires collecting information about acceptable block plan, and translating the block plan into a detailed layout. In product layout, workstations are arranged in a naturally occurring, heuristic (commonsense) for high volume of production. In line balancing the tasks are assigned to workstations so as to satisfy all precedence and cycle time constraints while minimizing the number of work stations.

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DESIGN OF WORK SYSTEMS

Objective

Design of Work Systems is an important component in Production and Operations Management. Design of Work Systems forms the basis and explains the importance of work design. Design of Work Systems is used to describe the two basic approaches to job design, the first approach focuses on Efficiency through job specialization and the other focuses behavioral approaches to job design. Design of Work System also entails method analysis which in turn centers on how jobs are performed. Motivation and Trust also form an important dimension in Design of Work systems as this alone provides an opportunity to the Organization to develop effective teams who can achieve organizations short and long term objectives. Motivation and Trust observations also emphasizes working conditions that in turn lead to work measurements which leads to reward and compensation of the individual working for the organization. In short this topic of Design of Work Systems provides the perfect bridge between Production and Operations Management with Human Resource Management.

Design of Work Systems Introduction

➢ Work System Design consists of job design, work measurement and establishment of time standards and worker compensation.

➢ The interesting fact is that even in decisions in other areas of design can affect the work design system or even a change in the work design system can change the decisions in other areas. Like Product or Service design will affect Design of Work Systems. Layout Decisions will also affect Design of Systems.

➢ It is thus logical to ensure that SYSTEMS approach is followed in a decision for DESIGN, so a decision in one part of the system is equally replicated and acceptable to all the system. E.g. Product or Service Design would require proper people with standardized job description

Job Design

➢ Job design involves specifying the content and methods of job. In general the goal of the job design is to create a work system that is not only productive but also efficient.

➢ Job designers are concerned with:-

- What will be done
- Who will do the job
- How the job will be done
- Where the job will be done
- Ergonomics

A successful Job Design must have the following qualities

1. Carried out by experienced personnel who have the necessary training and background.
2. Consistent with the goals of the organization.
3. In documented form.
4. Understood and agreed by both management and employees.
5. Shared with the new employees.
6. Factors that affect Job Design

FACTORS that affect Job design include

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1. Lack of knowledge of the employees.
2. Lack of Management support.
3. Lack of documented job design which often leads to poor audit review and referral.
4. Job Design can be carried out in 2 ways the Efficient School and the Behavior School.
5. Efficiency School was popular in 1950s based on Frederick W Taylor's Scientific Management principles.
6. Behavior school is relatively new concept and focused on ways to eliminate workers dissatisfaction and incorporate the feeling of control in work.

Design of Work Systems

1. Specialization
2. Behavioral Approaches to Job Design
3. Teams
4. Methods Analysis
5. Motions Study
6. Working conditions

Specialization

- The term specialization refers to work that concentrates on some aspect of a product or service.
- Jobs that have a narrow scope.
- Assembly lines, medical specialties, MBA courses.
- Specialization jobs tend to yield high productivity, low unit costs and lead to high standard of living in most of the industrial nations.
- Specialization in Business: Advantages
- Disadvantages

Behavioral Approaches to Job Design

In order to make jobs more interesting and meaningful job designers often consider Job Enlargement, Job Rotation and Job Enrichment.

- Job Enlargement relates to giving a worker a larger portion of the total task by horizontal loading
- Job Rotation pertains to Workers periodically exchange jobs
- Job Enrichment is increasing responsibility for planning and coordination tasks, by vertical loading

Motivation

The importance of these approaches to job design is that they have the potential to increase the motivational power of jobs by increasing worker satisfaction through improvement in quality of work life.

Motivation always influences quality and productivity. It contributes to work environment where as Trust influences productivity and employee-management relations

Teams

Organization adopt teams in order to exploit the benefits of teams

- Higher quality
- Higher productivity
- Greater worker satisfaction

Self-directed teams are groups of empowered to make certain changes in their work process

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Methods Analysis

- Methods analysis deals with analyzing how a job gets done, begins with overall analysis and then moves to specific details like changes in tools and equipment, Changes in product design or new products, Changes in materials or procedures and Other factors (e.g. accidents, quality problems)

Methods Analysis Procedure is simple and effective and does the following

- Identifies the operation to be studied
- Gets employee input
- Studies and documents the current method
- Analyzes the job
- Proposes new methods
- Installs new methods
- Follow-ups to ensure improvements have been achieved

Selecting Operations to study

- Sometimes a supervisor or a foreman may request an operations or part of the operations to be studied. This would be with the intent to increase productivity and reduce costs. The guidelines for studying a job would include
- A high labor content.
- Repeated frequently.
- Unsafe, tiring, unpleasant, noisy and environmentally poor.
- Quality problems, scheduling bottlenecks etc.

Analyzing the Job and proposing new methods

- Job Design Analyst should question the integrity and effectiveness of present and proposed methods. He or she should use charts, graphs and verbal descriptions to capture how the job is being performed. This can be the first basis and can lead to improvement in job design.

Flow process chart

- Chart used to examine the overall sequence of an operation by focusing on movements of the operator or flow of materials
- Worker-machine chart
- Chart used to determine portions of a work cycle during which an operator and equipment are busy or idle

Experienced Job design analysts often develop a checklist and try to answer these questions

- Why is there a delay or storage at this point?
- How can travel distances be shortened
- Can material handlings be reduced?
- Would a rearrangement of the workplace result in greater efficiency.
- Can similar activities be grouped?
- Would the use of additional or improved equipment be helpful?
- Does the worker have any suggestion or recommendation for improvement?

Installing the Improved Method

Successful implementation of the proposed method changes requires convincing management of the desirability of the new method and obtaining the cooperation of the worker.

- If the worker has been consulted than the task of installing the new method is easier otherwise it can become the toughest part.

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- If there is a paradigm change (major change or new method) from the old method, the implementation makes take a longer time.
- Follow up is required to ensure that the changes have been incorporated..

Motion Study and Motion Study Techniques

Motion Study is the systematic study of the human motions used to perform an operation. The purpose is to eliminate /weed-out unnecessary motions and identify the best sequence of operations for maximum efficiency. Motion study forms an important part in productivity improvements. It is based on Frank Gilbreths brick laying trade in the early 20th century, through the use of time motion study techniques.

Motion Study Techniques often incorporate the following four types

1. Motion study principles - guidelines for designing motion-efficient work procedures
2. Analysis of therbligs - basic elemental motions into which a job can be broken down
3. Micro motion study - use of motion pictures and slow motion to study motions that otherwise would be too rapid to analyze
4. Charts

Motion study principles – Gilbreths work laid the foundation for motion study principles, which are guidelines for designing motion efficient work procedures. The guidelines are divided into three categories.

1. Principles of the use of body.
2. Principles for the arrangement of the work place.
3. Principles for the designs of tools and equipments.

Developing Work Methods
An operations manager along with an analyst aims for motion efficiency by achieving the following

Elimination of unnecessary motions
1. Combination of various activities
2. Reduction in fatigue
3. Improvement in the arrangement of the workplace
4. Improvement in the design of tools and equipment

Therblig Techniques

Analysis of therbligs - basic elemental motions into which a job can be broken down

- Search implies hunting for an item with eyes or hands.
- Select means to choose from a group of objects.
- Grasp means to take hold of the object.
- Hold refers to retention of an object that has been grasped.
- Therblig Techniques
- Transport load means movement of an object after hold.
- Release load means to deposit the object.
- Some other common Therbligs are Inspect, Position, Plan, Rest and Delay.
- Also Frank and Lillian Gilbreth are responsible for micro motion study as well.
- Working Conditions
- Working Conditions (cont'd)

Work Measurement determines how long it should take to do a job. This may be focusing on an individual's performance or completion of a mega scale project. When we discuss the design part of work systems we often discuss the importance of standard time in work measurement. Standard time is

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the amount of time it should take a qualified worker to complete a specified task, working at sustainable rate, using given methods, tools and equipments, raw materials and work place arrangements. It also employs the following common types of work measurement techniques

1. Stopwatch time study
2. Historical times
3. Predetermined data
4. Work Sampling

Stopwatch time study

- Stopwatch time study is used to develop a time standard based on observations of one worker taken over number of cycles. That is then applied to work of others of the same organization who perform the same work. The basic steps in stop watch time study include
  1. Define the task to be studied and inform the workers who be studied.
  2. Determine the number of cycles to observe.
  3. Time the job and rate the workers performance
  4. Compute the standard time

Also, the number of cycles that must be timed is a function of three things

1. The variability of observed times
2. The desired accuracy
3. The desired level of confidence interval for the estimated job time

Desired accuracy is expressed as percentage of the mean of the Observed Time.

$$N= (zs/a\ x\ ^{-})^2$$

Where

Z is the number of normal standard deviations needed for desired confidence
S is sample standard deviation
a is desired accuracy percentage
x^{-} (x bar) is the sample mean

EXAMPLE

A Mechanical Engineer working for an automobile manufacture in Lahore presents the following information to the Operations Manager. The assembly workers take a mean time of 120 minutes to assemble a single car with a standard deviation of 5 minutes. The confidence limit if 95%. The Operations Manager will need how many observations if the desired maximum error is $\pm$ 5%

Solution

Given Data

S= 5 minutes,

Z is 1.96 (since 95 CI)

x^{-} = 120 minutes,

a= 5 %

The formula is

$$N= (zs/a\ x\ ^{-})^2$$

Substituting the values

$$N= ((1.96)(5)/(0.05)(120))^2$$

$$=(96.04)/(36)=2.67 \text{ studies} = 3 \text{ studies}$$

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Development of a Time Standard

Development of a Time standard involves Observed Time (OT), Normal Time(NT) and Standard Time (ST).
Mathematically Observed Time OT is represented by $OT = \Sigma X / n$

- Observed Time OT is just the average of the recorded times. Also Normal Time NT is the observed time adjusted for worker performance.

Similarly Normal time NT=OT X PR

- Computed by multiplying observed time with Performance rating.
- Normal time is the length of time a worker should take to perform a job.

Another important concept is Standard time

- Standard Time=ST=NT X AF is the normal time plus allowance for delays like (getting a glass of water or going to the washroom human needs)

Predetermined Time Standards

1. Predetermined Time Standards are published data that is based on extensive research to determine standard elemental times.
2. A common system is the Methods Time Measurement (MTM)
3. Analysts are trained and certified before they can be allowed to use MTM.

MTM Advantages

1. They are based on large number of workers under controlled conditions.
2. The analyst is not required to rate performance in developing the standard.
3. There is no disruption of the operation.
4. Standards can be established even before a job is done.

Compensation

An Operations Manger comes across two types of compensation, working for any service or manufacturing based organization:-

1. Time-based system, which is the compensation based on time an employee has worked during a pay period.
2. Output-based (incentive) system, which is compensation based on the amount of output an employee produces during a pay period

Characteristics and Form of Incentive Plan

Operations Manager making use of an Incentive Plan must be able to understand and identify the following characteristics and form of Incentive Plan.

1. Accurate
2. Easy to apply
3. Consistent
4. Easy to understand
5. Fair
6. Compensation

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Types of Individual Incentive Plans

Pakistani organizations have employed various types of individual incentive plans which find judicious applications in other countries of the world.

1. Group Incentive Plans
2. Knowledge-Based Pay System
3. Management Compensation

Of the three mentioned above, the operations manager should be able to identify the advantages and disadvantages of each type of incentive plan.

Summary

The importance of work design has been often overlooked because the work of Operations Manager in the past was not linked with the Human Resource Department of the same organization. Times have changed and now Operations side work in tandem with Human Resource Department. Operations Managers are trained to understand the two basic approaches to job design. This lecture provided us with an opportunity that we discussed the advantages and disadvantages of specialization and Behavioral approaches to Job Design.
Supplementary discussions focused on Method Analysis and Motion Study Techniques, which focused on efficiency aspect of the job. This may ignore the behavior aspect but still form an important and integral part of job design.

And last but not the least work measurements dealt specifically with the length of time needed to complete a job and was linked with Personnel Planning, Cost Estimation, Budgeting, Scheduling and Worker Compensation.

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Lesson 22

LOCATION PLANNING AND ANALYSIS

Lecture Objectives

By studying location planning and analysis, an operations management student should be able to understand the

- Importance of Location Planning and Analysis
- Criteria for Manufacturing and Service Location selection considerations
- Transportation Model

Importance of Location

Location decisions are not limited to one time strategic planning decisions for building a new manufacturing or service facility rather most of the organizations face the challenge of increasing their capacity through selection of new locations or extension of existing locations.

As an operations management student, we can focus on the importance of location for any organization through various departments of the organization.

- Accounting which prepares cost estimates for changing locations as well as operating at new locations.
- Distribution which seeks warehouse layouts that make material handling easier and customer response shorter.
- Importance of Location
- Engineering which considers the impact of product /service location choices.
- Finance which performs the financial analysis for investments in new locations.
- Human Resources, which hires and trains employees to support new locations or relocations of operations.
- Management Information Systems which provide information technologies that link operations at different locations.
- Importance of Location
- Marketing which assesses new locations and revised locations that are popular with the customers.
- Operations Management which seeks and finalizes locations that create, sustains, protect and project the best performance criteria for the whole organization.

Location plays an important role for every business whether new or existing. We can refer to the same airport example we discussed in our earlier lectures before. The airport is not only crowded but fails to separate the different services it provides to different categories of individuals present at the airport. The airport may need to explain its existing facility. In Pakistan too, we have seen new airports set up at Karachi, Lahore and Islamabad which cater to greater traffic of the aero planes and more passengers. Location decisions play an integral part of the strategic planning process of every organization. It is important to learn about the need and nature of location decisions. As a part of his routine responsibilities a senior Operations Manager often carries out the evaluation of different available locations.

Globalization and Geographic Dispersion of Operations

Globalization has affected Pakistan tremendously. A number of Multi National Corporations are operating and functioning in Pakistan. It is important to spend some time in understanding how globalization makes it necessary and pertinent for a MNC to disperse and spread its scope and function of Operation. It would be more correct if try to understand the philosophy of MNC's not operating in certain regions or certain particular countries. The western worlds call these the disadvantages of Globalization, if an organization decides to pack up its business and leave a host company.

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Disadvantages to Globalization

The common disadvantages which lead to a MNC forgoing globalization includes.

- Handing over proprietary Technology to host countries.
- Political risks.
- Poor Employee (Managers and worker) skills.
- Slow customer response time.
- Effective communication between interfaces difficult

Managing Global Operations

When organizations become global they often end up paying a heavy price in terms of managing complex managerial issues and challenges.

- Host country languages
- Host Country Norms and Customs.
- Workforce management
- Unfamiliar laws and regulations.
- Unexpected Cost mix.

Need for Location Decisions

Quite often MNC's move to a host country with a lot of hype and propaganda of bringing jobs to the local labour but the reality is its own need to increase its revenue and profits. Most of the time the need for location decision focuses on

- Marketing Strategy
- Cost of Doing Business
- Growth
- Depletion of Resources

Nature of Location Decisions

Location Decisions are primarily strategic in nature and have certain objectives and options attached

- Strategic Importance
  1. Long term commitment/costs
  2. Impact on investments, revenues, and operations
  3. Supply chains
- Objectives
  1. Profit potential
  2. No single location may be better than others
  3. Identify several locations from which to choose
- Options
  1. Expand existing facilities
  2. Add new facilities
  3. Move

Making Location Decisions

1. Decide on the criteria
2. Identify the important factors
3. Develop location alternatives
4. Evaluate the alternatives

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5. Make selection

Location Decision Factors

Regional Factors

- Location of raw materials
- Location of markets
- Labor factors
- Climate and taxes

Community Considerations

- Quality of life
- Services
- Attitudes
- Taxes
- Environmental regulations
- Utilities
- Developer support

Site Related Factors

- Land
- Transportation
- Environmental
- Legal

Multiple Plant Strategies

1. Product plant strategy
2. Market area plant strategy
3. Process plant strategy

Mostly mix of all three

Factors Affecting Location Decisions

The process of determining a geographic site for firms operations takes into account both manufacturing and marketing aspects. We just focus on the manufacturing aspects as its more closely related to Operations Management

Manufacturing

- Favorable Labor Climate
- Proximity to markets.
- Quality of Life
- Proximity of Suppliers and Resources.
- Proximity to the Parent Company's facilities.
- Utilities, Taxes and Real estate costs.
- Other factors (expansion, construction costs, and location near the highway or main railways)

Dominant Factors in Services

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Look for concept check information provided by our expert. We also present the following dominant factors in selection of locations for services.

- Proximity to Customers.
- Transportation costs and proximity to markets.
- Location of competitors.
- Site specific factors.

Trends in Locations

Foreign producers locating in different host countries even Pakistan

- Currency fluctuations
- Just-in-time manufacturing techniques
- Micro-factories
- Information Technology

Evaluating Locations

Cost-Profit-Volume Analysis

- Determine fixed and variable costs
- Plot total costs
- Determine lowest total costs

Location Cost-Volume Analysis

Assumptions

- Fixed costs are constant
- Variable costs are linear
- Output can be closely estimated
- Only one product involved

Example 1: Cost-Volume Analysis

The quantity is 10,000 and the Fixed and variable costs for four potential locations

Location	Fixed Cost	Variable Cost
A	Rs 250,000	Rs 11
B	100,000	30
C	150,000	20
D	200,000	35

Example 1: Solution

	Fixed Costs	Variable Costs	Total Costs
A	Rs250,000	Rs11(10,000)	Rs360,000
B	100,000	30(10,000)	400,000
C	150,000	20(10,000)	350,000
D	200,000	35(10,000)	550,000

Example 1: Solution

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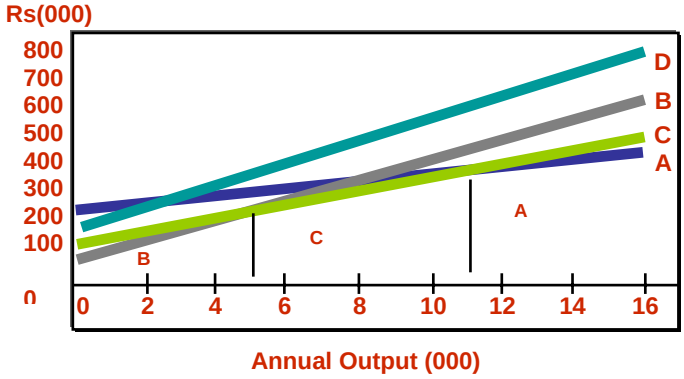
- We calculate the variable costs by multiplying the unit cost with the given quantity and calculate total costs for all four locations
- We also graph them to decide effectively, the total costs are graphed and we see that for 10,000 units clearly location c has an advantage, beyond 10,000 units, diseconomies of scales set in and makes Location C look less lucrative.
- We select the Location for which the total cost is the lowest.
- Our Location C, shows the lowest total cost for an equal quantity of 10,000 units.



Evaluating Locations

Operations Manager can evaluate business site locations by making use of the following three techniques

1. Transportation Model
   Decision based on movement costs of raw materials or finished goods
2. Factor Rating
   Decision based on quantitative and qualitative inputs
3. Center of Gravity Method
   Decision based on minimum distribution costs

Transportation Method

Transportation Method is a quantitative approach that can help solve multiple facility location problems. It is used to determine the allocation pattern that can be used to minimize the cost of shipping products from two or more plants or sources of supply to two or more warehouses or destinations.

- Based on Linear Programming.
- It does not solve all the problems of the multiple facility location.
- It only finds the best shipping pattern between plants and warehouses for a particular set of plant locations with a given capacity.
- The Operations manager or logistics analyst must try a variety of location-capacity combinations and use this to find the optimal distribution for each alternative.
- Distribution costs(variable shipping and possible variable production costs) are important inputs in evaluating a particular location allocation combination.
- Investments costs and other fixed costs are also considered.
- Qualitative factors (like land and construction cost against annual profits) are also included in the analysis for each location capacity combination.

Transportation Method

- Step I

- Set up the initial matrix/tableau. The basic steps include
- Create a row for each plant (existing or new) being considered and a column for each warehouse.
- Add a column for plant capacities and a row for warehouse demands and then insert specific numerical values.

Transportation Method

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•Step II

- Each cell not in the requirement row or capacity column represents a shipping route from a plant to warehouse. Insert the unit costs in the upper right hand corner of each of these cells.

Example

Pakistan Cellular Mobile Company plans to build a 5000 unit production plant at Islamabad because demand for mobile phones in Pakistan has gone up. The tableau on the next slide shows the unit cost of shipping one truck/loader of mobiles from the existing plant at Lahore and the possible location at Islamabad.

Transportation Method

Plant	WAREHOUSE			Capacity
	1	2	3	
Lahore	500.0	600.0	5500	5000
Islamabad	700.0	4500	6000	5000
REQUIREMENTS	2500	4500	3000	10000 / 10000

Matrix/Tableau

- In transportation method, the sum of the shipments in a row must equal the corresponding plants capacity.
- Similarly the sum of the shipments to a column must add to corresponding warehouses demand requirements. Thus shipments to Warehouse 1 from Lahore and Islamabad must equal 2500 mobiles.
- Dummy Plants or Warehouses
- The prime requirement of transportation model is that the sum of capacities must equal the sum of demands, which happens to be 10,000 units of mobile phones.
- IN reality the total capacity may exceed total requirements or vice versa.

Dummy Plants or Warehouses

- If capacity exceeds requirements by say M units, we add extra column (a dummy warehouse) with a demand of M units and make the shipping costs in the new created cell equal to Rs. 0.
- Since no shipments are made to the dummy warehouse so it represents an unused plant capacity.
- Dummy Plants or Warehouses
- If requirements exceed capacity by say M units, we add extra row (a dummy plant) with a supply of M units and make the shipping costs (stock out costs) in the new created cell equal to Rs. 0.
- Since no shipments are made to the dummy warehouse or plants so this step is automatically taken care of in software used for such issues.
- Optimal Solution
- We try to find the least allocation cost process.
- And we keep on repeating with various options till a new solution with least costs are obtained and we call it the optimal solution.

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Transportation Method

Plant	WAREHOUSE				Capacity
	1	2	3	Dummy	
Lahore	1.0 **2500**	6.0	1.0 **2500**	0	5000
Islamabad	7.0	2.00 **4500**	6.00 **500**	0	5000
Dummy	0	0	0	0	
REQUIREMENTS	2500	4500	3000	0	10000 / 10000

- The total transportation cost would be Sum of all Units time X the Unit Cost

= 2500(1.0)+4500(2.0)+2500(1.0)+500(6.0)
=2500+9000+2500+3000=Rs 17,000.
The operations manager needs to be judicious in his approach and may decide to expand the plant at Lahore and build a small plant in Islamabad.

Summary

The lecture focused primarily on the importance of location. Various aspects relating to Location Planning and Analysis were focused. MNC's reasons for not selecting various countries under the garb of disadvantages in Global Operations were also examined. Site locations for both manufacturing and services were considered. Last but not the least a detailed study of the Transportation Model was also carried out. Students should also know how to make use of cost volume analysis and transportation model to carry out practical investigation of real life time Operations Management problems.

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MANAGEMENT OF QUALITY

After completing the lecture on Management of Quality, the POMA students should be able to understand the term quality and the importance of Quality. The student should be able to learn the Determinants of Quality, when they discuss Total Quality management also they should be able to identify the various costs associated with Quality. The students should also be able to appreciate the famous ISO 9000 and ISO 14000 quality systems, which are also actively seen in Pakistan. And last but not the least out of curiosity than academic interest the students should be aware of philosophies of Quality Gurus.

Introduction

Quality Management can be understood only if we are able to understand the term *quality, which* is defined as

Quality is the ability of a product or service to consistently meet or exceed customer expectations.

Quality as determinant of Revenue has been often neglected, people tend to associate quality with high price of the product or item they want to purchase, historically speaking this is an incorrect statement. The debate between American and Japanese philosophy proves that quality is offered free of cost and is the prime source of revenue or profit.

- When the American industry in 70s and 80s talked about cost cutting and productivity improvement they did not paid heed to Quality Management, which was the "Holy Grail" for the Japanese Industry.

- When Japanese manufacturers entered and occupied the American Markets the only thing that made their products and services better than the Americans was the concept of Quality, which led to increase in the revenues and productivity of Japanese manufacturers.

Evolution of Quality Management

1. Prior to Industrial Revolution, the skilled craftsman performed all stages of production. Pride in workmanship and reputation often formed the basis of producing a quality well. One or small group of workers was responsible for the entire product. After industrial revolution and specialization and division of labour each worker was then responsible for small portion of work. This led to loss in pride of workmanship and failure to produce quality products.

2. Frederick Winslow Taylor the father of scientific management brought back the concept of quality by incorporating product inspection as well as focusing on the importance of manufacturing management.
3. G.S. Radford introduced the concept of quality in the product design stage and linked high quality with increased productivity and lower costs.
4. 1924 – W. Shewhart of Bell Technologies introduced the Statistical process control charts.
5. 1930 – H.F.Dodge and H.G.Romig also of Bell Technologies introduced Tables for acceptance sampling.
6. 1940's - Universities, Bell Technologies and US Army were using Statistical sampling techniques for training engineers. American Society for Quality Control aka ASQC (now ASQ) was formed during the same era
7. 1950's - Quality assurance/TQC (The era of Deming, Juran and Feigenbaum) which changed the concepts of quality for ever.

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8. 1960's - Zero defects championed by Quality Guru Phillip Crosby. It produced the perfect missile for US army
9. 1970's - Quality assurance in services like health care, banking and travel industry.
10. Late 1970s the quality assurance concept changed to Strategic quality approach, Harvard Professor David Garvin advocated preventing mistakes from occurring all together.

Quality Assurance vs. Strategic Approach

- Strategic Approach is the SUPERLATIVE form of Quality Assurance
- Quality Assurance places emphasis on finding and correcting defects before reaching market
- Strategic Approach is Proactive, focusing on preventing mistakes from occurring and places greater emphasis on customer satisfaction

Quality Guru

The Quality Gurus are given more respect and recognized as Key Contributors to Quality Management. Presented below is their contributions in a nut shell, students should learn to recognize these

1. Walter Shewhart is also known as "Father of statistical quality control"
2. W. Edwards Deming presented 14 points for quality management which focused primarily on common cause of variation.
3. Joseph M. Juran is famous for his concept of "Quality is the fitness for use".
4. Armand Feigenbaum said, "Quality is a total field or total function".
5. Philip B. Crosby is famous for his philosophy that "Quality is free".
6. Kaoru Ishikawa- presented the "fish bone diagram" or "cause effect diagram".
7. Genichi Taguchi –robust design for designing products insensitive to change in environment. Taguchi's contribution was, "Taguchi loss function".

Dimensions of Quality

The concepts of dimensions of quality represent the fact that customers value a product keeping in mind different dimensions. Quality and Operations Managers come across customer perceptions relating to demand for durable, reliable, performance to a standard and that too in away that is aesthetically correct.

1. *Performance* - main characteristics of the product/service
2. *Aesthetics* - appearance, feel, smell, taste
3. *Special Features* - extra characteristics
4. *Conformance* - how well product/service conforms to customer's expectations
5. *Reliability* - consistency of performance
6. *Durability* - useful life of the product/service
7. *Perceived Quality* - indirect evaluation of quality (e.g. reputation)
8. *Service ability - service after sale*

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Examples of Quality Dimensions

Dimension	(Product) Automobile	(Service) Auto Repair
1. Performance	Everything works, fit & finish Ride, handling, grade of materials used	All work done, at agreed price Friendliness, courtesy, Competency, quickness
2. Aesthetics	Interior design, soft touch	Clean work/waiting area
3. Special features	Gauge/control placement Cellular phone, CD player	Location, call when ready Computer diagnostics

Examples of Quality Dimensions (Cont'd)

Dimension	(Product) Automobile	(Service) Auto Repair
5. Reliability	Infrequency of breakdowns	Work done correctly, ready when promised
6. Durability	Useful life in miles, resistance to rust & corrosion	Work holds up over time
7. Perceived quality	Top-rated car	Award-winning service department
8. Serviceability	Handling of complaints and/or requests for information	Handling of complaints

Service Quality

- Tangibles
- Convenience
- Reliability
- Responsiveness
- Time
- Assurance
- Courtesy

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Examples of Service Quality

Dimension	Examples
1. Tangibles	Were the facilities clean, personnel neat?
2. Convenience	Was the service center conveniently located?
3. Reliability	Was the problem fixed?
4. Responsiveness	Was customer service personnel willing and able to answer questions?
5. Time	How long did the customer wait?
6. Assurance	Did the customer service personnel seem knowledgeable about the repair?
7. Courtesy	Were customer service personnel and the cashier friendly and courteous?

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SERVICE QUALITY

Learning Objectives

After completing this lecture the students should be able to describe the five dimensions of service quality in detail. This would enable them to use the service quality gap model to diagnose quality problems also understand the quality service by design concepts. This lecture would provide the students with an opportunity to learn and illustrate how Taguchi methods and poka-yoke methods are applied to quality design. The students should be able to at least gain awareness how organizations perform service quality function deployment in order to improve their operations side. The students should also be able to construct a statistical process control chart.

Moments of Truth

- Each customer contact (between the service provider and customer) is called a moment of truth.
- An organization has the ability to either satisfy or dissatisfy them when you contact them.
- A *service recovery* is satisfying a previously dissatisfied customer and making them a loyal customer.

Dimensions of Service Quality

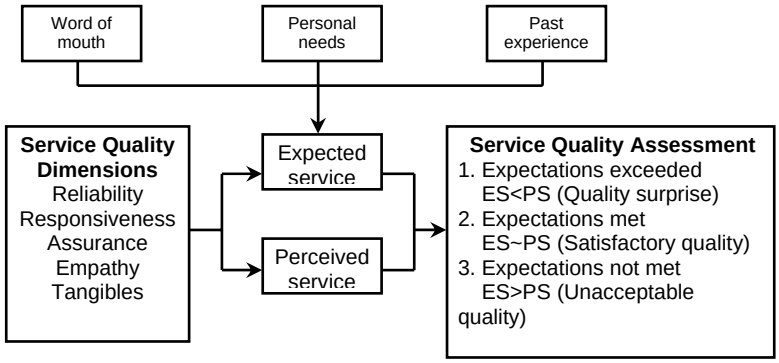
Dimensions for Service Quality are more or less the same which we associate with the concept of Quality in General. Also, we as service demanders (customers) are well aware of the fact that we always seek reliability, agility (prompt responsiveness), assurance, tangibility and empathy while being provided with a service. More or less these dimensions help the customer to rate and distinguish one service provider from another. A good service from a bad service. Often organizations use a performance measure matrix using the same service dimensions and they often call it RATE based on the 5 dimensions described below.

1. *Reliability*: Perform promised service dependably and accurately.
2. *Responsiveness*: Willingness to help customers promptly.
3. *Assurance*: Ability to convey trust and confidence.
4. *Tangibles*: Physical facilities and facilitating goods.
5. *Empathy*: Ability to be approachable.

Normally in such situations, R represents Reliability and Responsiveness, A represent Assurance, T represents Tangibles and E represents Empathy respectively.

Perceived Service Quality

It is often seen that a customers required service is not provided by the service provider primarily because of a gap between Service Quality Dimensions and Service Quality Assessment by the customer.



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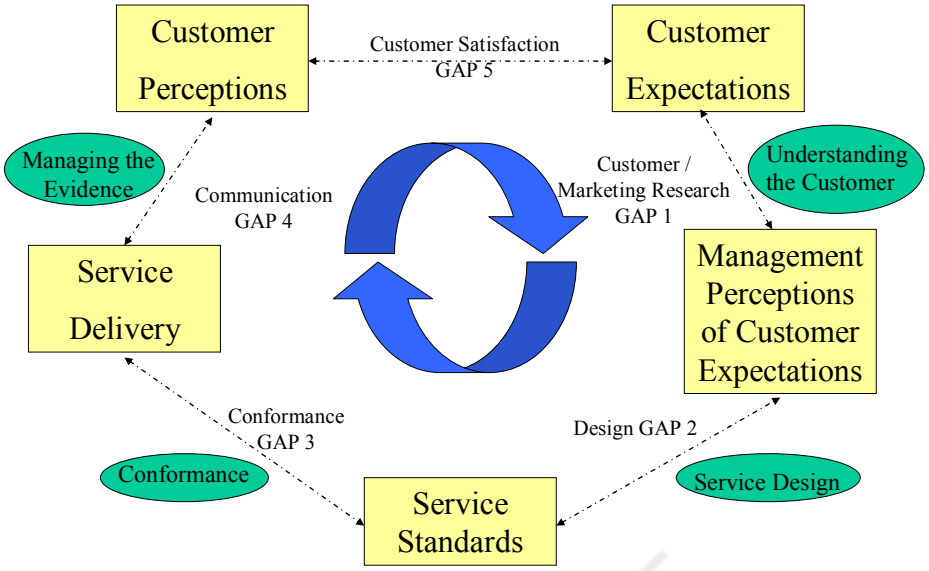
Service Quality Gap Model

We can pictorially capture the gaps that exist between service provided and the service demanded



Service Gap Analysis

- A good example where gap analysis is used for improvements in business is in the services field
- The most popular assessment tool used in service quality is called SERVQUAL, which involves a set of the 5 most important dimensions of quality according to rankings of customers
- Also involves a set of 5 gaps which represent the difference between customers' expectations and perceptions or in other words the difference between expected level of service vs. Actual level of service provided
- SERVQUAL (Stands for SERVICEQUALITY).

Servqual Model Gaps

Let's try to capture all 5 gaps; one by one this would help us to understand in detail the 5 dimensions of service quality.

Gap 1

The difference between actual customer expectations and management's idea or perception of customer expectations.

- Managers and employees have a very internal process-oriented view of their business, it is tough to break this view and to see things the way the customer does
- This gap of the SERVQUAL Model can help management with customer service

Gap 2

Mismatch between manager's expectations of service quality and service quality specifications

- To implement a system to improve this gap, management must first understand exactly what the customer wants

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- If this understanding is not present, it will be impossible for management to know whether their expectations are aligned with customer specifications.

Gap 3

Poor delivery of service quality

- Once the specifications from gap 2 are aligned the next step is to deliver these services in a perfect manner
- Quality of delivery must be perfected during the interaction with the customer
- The employees that are responsible for these actions are referred to as contact personnel
- Some reasons for a lack of quality include poor training, communication, and preparation.

Gap 4

Differences between service delivery and external communication with customer

- Customers are influenced by what they hear and see about a company's service
- Word-of-mouth publicity and advertising are main outlets which customers open their opinions to
- The difference between what a customer hears about a company's service and what is actually delivered is represented by gap 4
- This gap can lead to dangerously negative customer perceptions

Gap 5 : Differences between Expected and Perceived Quality

- This gap is directly related to everyone's perception of service quality
- Customers expect certain things from certain companies
- When someone goes into a McDonalds to order their favorite meal – a Big Mac, they are expecting exactly what they are accustomed to getting (a quick, no hassle, tasty big burger with all the works). If it takes 15 minutes to get a Big Mac that doesn't even have the famous special sauce on it the customer's perceived service of McDonalds is going to plummet.
- If gaps 1 through 4 are closed to a minimum then gap 5 should follow, if there are any gaps left in steps 1 through 4 the perceived customer service quality will be negatively affected
- The way to make sure these gaps are closed is through thorough systems design, precise communication with customers, and a well-trained workforce.

Quality Service by Design

We had discussed earlier, that design of a product or service half ensures a good productive system and we did mention about Quality indirectly. We now take a direct approach and identify the ways in which we can incorporate and identify Quality in the Design of Services.

1. Quality in the Service Package :Quality based service should be offered at same price, club class passengers in an airline though being provided additional luxury are not able to bring enough revenue. An airline that does not add quality would loose out to its competitors.
2. Taguchi Methods (Robustness): Relate to the quality based methods being able to deliver under all possible environments. If a company is unable to offer an after sales service to a customer at any particular place in the same country, it would simply lose out to its competitors.
3. Poka-Yoke: Poka Yoke (pronounced POH-kah YOH-kay) is the Japanese word for mistake proof. In services, a simple mistake can have dire consequences, think of a hair dresser or stylist giving you a wrong haircut. His mistake cannot be rectified because service again is an entity which is based on transaction between the service provider and service receiver. These devices/strategies/mechanisms/methods are used either to prevent the special causes that result in

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defects, or to inexpensively inspect each item that is produced to determine whether it is acceptable or defective.

4. Quality Function Deployment: is also known as QFD or House of Quality. It is an important tool of Quality Management and allows a company not only to benchmark itself with industry leader but also to review its internal operations critically.

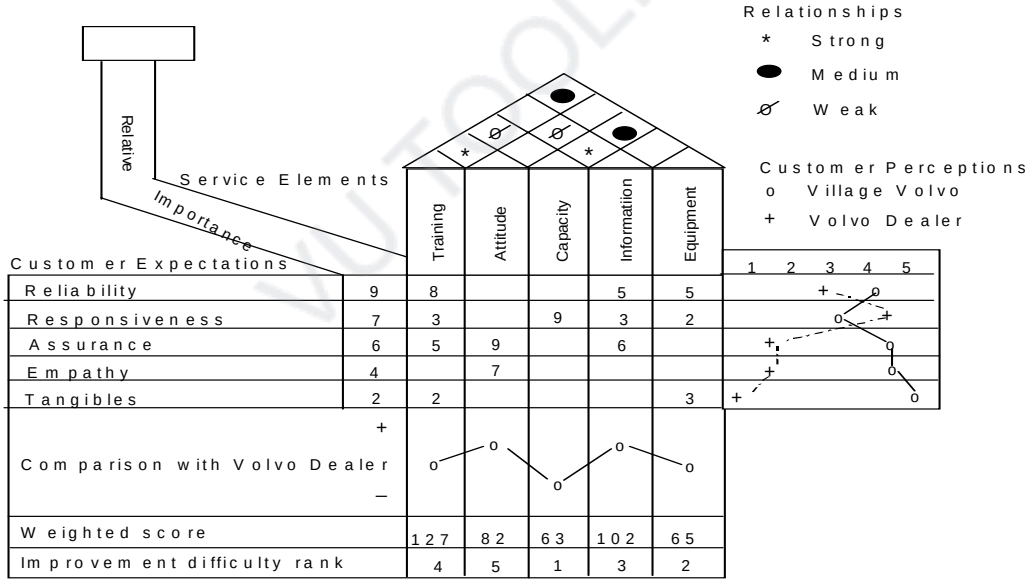
The thing to remember here is that Quality in design ensures the safe as well as reliable operations of the service. Consider for example the simple case of an oil change or a hair cut. If the service provider is unable to include Quality in service, or fails to provide a consistent service under all conditions or fails to do justice to idea of mistake proof service or is unable to deploy Quality Function in his service, he or she would lose customers and competitive advantage along with loss in revenues and increase in costs.

Classification of Service Failures with Poka-Yoke Opportunities

Server Errors	Customer Errors
Task: Doing work incorrectly	Preparation: Failure to bring necessary materials
Treatment: Failure to listen to customer	Encounter: Failure to follow system flow
Tangible: Failure to wear clean uniform	Resolution: Failure to signal service failure

House of Quality

QFD can strongly help an organization focus on the critical characteristics of a new or existing product or service from the separate viewpoints of the customer market segments, company, or technology-development needs.



Achieving Service Quality: Service Quality can be achieved by making use of the following strategies

- Cost of Quality
- Service Process Control
- Statistical Process Control
- Unconditional Service Guarantee

We will discuss all four in detail during our discussions in lectures that follow this lecture for the time being we can reiterate the fact that quality is offered free of cost. Also, as prevention is better than cure, it makes a lot more sense to incur cost in prevention of defects instead of allowing the defects to occur and then rectifying them. Statistical Process Control is one important tool to ensure that Service Quality is achieved before a defect is introduced in the service being offered or product being manufactured.

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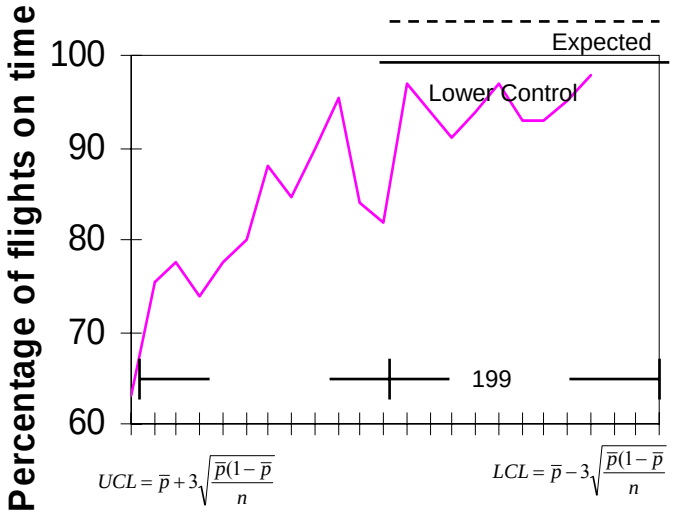
Costs of Service Quality (Bank Example)

This example shows how a weak design service can incur loss in customer service, which leads to loss in revenues. With this example we also try to focus our attention on the concept of cost in quality dimension. We try to capture the importance of prevention costs and how they are more beneficial to the organization as compared to detection and failure costs. As a rule of thumb it is said that prevention costs are half the detection costs and about 12 to 16% of failure costs, but these percentages often fail to represent, the cost expenditures in all types of services.

Failure costs	Detection costs	Prevention costs
***External failure*:**		
Loss of future business	Process control	Quality planning
Negative word-of-mouth	Peer review	Training program
Liability insurance	Supervision	Quality audits
Legal judgments	Customer comment card	Data acquisition and analysis
Interest penalties	Inspection	Recruitment and selection
		Supplier evaluation
Internal failure:		
Scrapped forms		
Rework		
Recovery:		
Expedite disruption		
Labor and materials		

Control Chart of Departure Delays

We talked about the concept of Service quality and one of its dimensions was Tangibility. We can apply this dimension to the service provided by airlines operating in Pakistan. If we happen to visit any airport in the northern part of Pakistan during winters especially during the months of December and January, we face a situation where often there is a delay in the flight arrival and departure. We can make good use of statistics to improve our service quality. In the graph below we have been able to identify a Lower Control Limit and an Upper Control Limit.



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TOTAL QUALITY MANAGEMENT

Total Quality Management is a philosophy that involves each and every individual in an organization in a continual effort to improve quality and achieve customer satisfaction.

The TQM Approach

TQM is not called philosophy for nothing. It is that common viewpoint as well as attitude shared by the whole organization that helps the organization achieves its prime objective of increase in revenue as well as a continuous relationship with the customer, by providing a quality based service which fulfills the customer's needs and requirements.

If we apply the TQM approach we can identify the role played by various departments and interfaces of the organization. These roles at the functional and departmental levels if not in line with the organizational strategy would not allow the organization to pursue TQM.

Sr. #	TQM Approach	Department
1	Find out what the customer wants	Marketing
2	Design a product or service that meets or exceeds customer wants	Design Dept
3	Design processes that facilitates doing the job right the first time	Operations Dept
4	Monitor and Audit (Keeping track of) results	Senior/GM Managers
5	Extend these concepts to suppliers	SCM / Logistics/Warehouse /Materials

TQM CRITICISMS

TQM Philosophy is often criticized for reasons which show weak implementation or poor management perspective. The common criticism against TQM is:

1. TQM program not linked to overall Organizational Strategy: This is the weakness of top management not a weakness in the TQM philosophy.
2. Quality based decisions not attached to revenue or marketing strategies: Quality concept should be included in the functional side and not treated as separate and distinct from the functional departments.
3. Incomplete planning with no clear cut road map for TQM implementation: A weak implantation strategy that does not identify the milestones, goals and step by step objectives.
4. Rigid and impractical TQM goals: An absence of managerial skill, TQM goals should be achievable and tangible.
5. Non training of employees about TQM philosophy. Employees if not trained wont be able to make best use of TQM philosophy.

Elements of TQM

TQM is a philosophy so its elements consist of the various strategies, tactics which includes the following:

- Continual improvement
- Competitive benchmarking
- Employee empowerment
- Team approach
- Decisions based on facts
- Knowledge of tools
- Supplier quality
- Champion
- Quality at the source
- Suppliers

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Of the elements described above, we should also focus our attention on the idea of continuous improvement as well as Quality at the Source.

Continuous Improvement: Philosophy that seeks to make never-ending improvements to the process of converting inputs into outputs. The Japanese manufacturer as well as service providers have longed used this concept. Kaizen is the Japanese word for continuous improvement.

Quality at the Source: The philosophy of making each worker responsible for the quality of his or her work.

Determinants of Quality

The various Determinants associated with the quality concept in general and TQM philosophy in particular is:

1. Quality of design: Intension of designers to include or exclude features in a product or service
2. Quality of conformance: The degree to which goods or services conform to the intent of the designers
3. Quality of Ease of Use: Ease of use and instructions to use increase the chances but do not guarantee that a product will be used for intended purpose and function properly and safely.
4. Quality of Service after Delivery: The degree to which goods or services can be recalled and repaired, adjustment, replacement or buyback or reevaluation of service all come under this category.

The Consequences of Poor Quality

The common consequences of Poor Quality are:

1. Loss of business: Loss in sales, revenues and customer base.
2. Liability: A poor quality product or service comes with the danger of the organization being taken to court by an unhappy or affected customer.
3. Productivity: Loss in productivity as more time is spend in rectifying the errors or short coming then producing more.
4. Costs: Increase in costs as a poor quality product is repaired or replaced or made new.

Responsibility for Quality

Quality Control Department cannot be held responsible for Quality alone. Quality is the responsibility of each and every individual working for the organization. If we look into any organization be it a manufacturing or service provider we can see the following departments working diligently for achievement of Quality.

1. Top management
2. Design Department
3. Procurement Department
4. Production/operations Department
5. Quality assurance Department
6. Packaging and shipping Department
7. Marketing and sales Department
8. Customer service Department

Costs of Total Quality Management

There is a difference in opinion amongst experts when they analyze costs with respect to TQM. Few experts feel that failure costs should be taken up as internal and external separately and others feel they should be taken as one single entity of failure cost.

1. Failure Costs - costs incurred by defective parts/products or faulty services. Experts are of the opinion that on average an organization loses 20 to 30% of its revenue because of poor quality or costs associated with the failure of the product or service. Failure costs are of two types internal and external:

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a. Internal Failure Costs are the Costs incurred to fix problems that are detected before the product/service is delivered to the customer.
b. External Failure Costs are all costs incurred to fix problems that are detected after the product/service is delivered to the customer.

Of the two, Internal Failure Costs are less painful and can help an organization to register increase in revenue and not compromising its product or service in the eye of its customers as well as its competitors.

2. Appraisal Costs are the Costs of activities designed to ensure quality or uncover defects
3. Prevention Costs include all TQM training, TQM planning, customer assessment, process control, and quality improvement costs to prevent defects from occurring.

Quality and Ethics

Quality is closely associated with Ethics. A good service would always be able to fulfill customer needs if it is able to follow Ethics in its true spirit. A service or product that has been poorly designed carries liability. On the other hand if the organization has followed ethics to manufacture a product or service, it would be able to provide a quality product or service to its customer.

TQM is an important concept and is followed by various departments of the organization. Accounting department measures the costs associated with a poor quality based service or product, Finance department measures the cash flows associated with various departments, Human Resources employees workforce which is able to turn out quality based work, Management Information Systems design TQM based systems to ensure increased productivity, similarly marketing department uses TQM techniques to increase its market share and customer base. And last but not the least Operations department which designs and implements TQM strategies.

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TOTAL QUALITY MANAGEMENT (Contd.)

In this lecture we will look into detail TQM. We will initially focus on Six Sigma concept. We will try to understand six sigma concepts in terms of managerial and technical perspective. We will also try to understand the Deming Wheel of Quality and seven common tools of quality. And last but not the least we will also try to understand the concepts of statistical process control and benchmarking with respect to quality.

ISO Certifications

Quality Certification ensures that the organization has been able to achieve TQM philosophy. The two popular certifications which are pursued by the organizations include ISO 14000 and ISO 9000.

1. ISO 14000: Is a set of international standards for assessing a company's environmental performance.
2. ISO 9000: Is a set of international standards on quality management and quality assurance, critical to international business.

Six SIGMA

Statistically speaking a process is said to be in Six Sigma stage if it does not have more than 3 or 4 defects per million. Most of the organizations, measure their quality program in terms of Six Sigma. Conceptually the Six Sigma Program is designed to reduce defects and requires the use of certain tools and techniques.

Six Sigma Programs are always directed towards quality improvement, cost cutting and time saving. Six Sigma Programs are employed in:

- Design
- Production
- Service
- Operation management
- Inventory management
- Delivery

Six Sigma Management concepts find greater appreciation and application in recent times. The Six Sigma Management characteristics include:

1. Providing strong leadership.
2. Defining performance merits.
3. Selecting projects likely to succeed.
4. Selecting and training appropriate people.

Six Sigma Technical aspects form a part and parcel of managerial strategy and aids in cost cutting and defect minimization. The Technical aspects of Six Sigma include

1. Improving process performance
2. Reducing variation
3. Utilizing statistical models
4. Designing a structured improvement strategy

Six Sigma Team

Six Sigma Teams are formed for implement of Six Sigma in true spirit keeping in mind both managerial as well as technical aspects.

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1. Top management
2. Program champions
3. Master "black belts"
4. "Black belts"
5. "Green belts"

Six Sigma Process

Six Sigma Process has various stages often organizations combine one or two stages for better monitoring and control purposes. Quality Experts normally identify the following 5 stages.

1. Define
2. Measure
3. Analyze
4. Improve
5. Control

Obstacles to Implementing Six Sigma (TQM) includes the lack of:

1. Company-wide definition of quality.
2. Strategic plan for change.
3. Customer focus.
4. Real employee empowerment.
5. Strong motivation.
6. Time to devote to quality initiatives.
7. Leadership.
8. Poor inter-organizational communication.
9. View of quality as a "quick fix".
10. Emphasis on short-term financial results.
11. Internal political and "turf" wars.

Criticisms of TQM

- Blind pursuit of TQM programs.
- Programs may not be linked to strategies.
- Quality-related decisions may not be tied to market performance.
- Failure to carefully plan a program.

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Basic Steps in Problem Solving

The problem solving method is more or less the same what we covered in the initial part of our semester, we always try to follow the same procedure or method which is to analyze the problem and then generate pragmatic solutions and implement the best solution.

1. Define the problem and establish an improvement goal.
2. Collect data
3. Analyze the problem
4. Generate potential solutions
5. Choose a solution
6. Implement the solution
7. Monitor the solution to see if it accomplishes the goal.

Process Improvement

A systematic approach to improving a process would always result in process improvement. Following are the common approaches for improving the process.

1. Process mapping
2. Analyze the process

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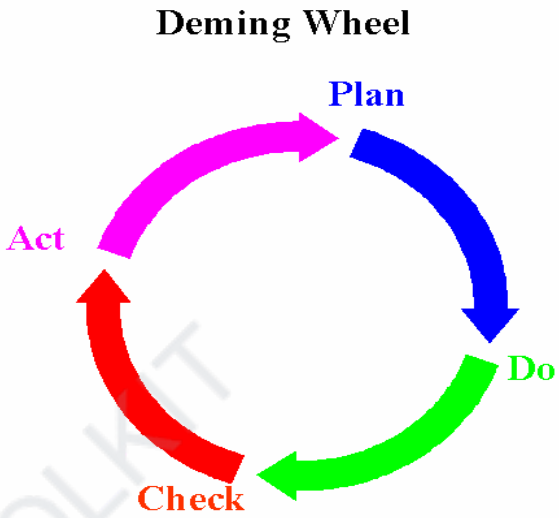
3. Redesign the process

- Process mapping consists mainly of collecting information about the process, identifying the process for each step and determining the inputs and outputs.
- Analyze the process: Ask questions about the process including process flow being logical, any activities or steps being missing or identification of duplication activities.
- Questions about each step which includes is a particular step necessary, does the step adds value, does it generates waste, could the time to perform the step be reduced, could two or more steps be combined.
- Redesign the process: takes a fresh approach to solve an issue on hand.

The PDSA Cycle (shewhart Cycle/Deming Wheel)



The concept of the PDCA Cycle was first introduced by Walter Shewhart, the leading statistician, who also developed statistical process control in the Bell Laboratories in the US during the 1930's. It is often referred to as `the Shewhart Cycle'. It was taken up and promoted very effectively from the 1950s on by the famous Quality Management authority, W. Edwards Deming, and is consequently known by many as `the Deming Wheel'. It is a continuous process and enables the operations manager to check the work at various stages.

The PDCA Cycle is a checklist of the four stages which you must go through to get from `problem-faced' to `problem solved'.

The four stages of PDCA/Shewhart Cycle or Deming Wheel are:

1. **PLAN**
   - Study & Document the existing process.
   - Collect data to identify problems.
   - Survey data and develop a plan for improvement.
   - Specify measures for evaluating the plan.
2. **DO**
   - Implement the plan on a small scale.
   - Document any changes made during this phase.
   - Collect data systematically for evaluation.
3. **CHECK**
   - Evaluate the data collection during this phase.
   - Check how closely the results match the original goals of the plan phase.
4. **ACT**
   - If the results are successful, standardize the new method and communicate the new method to all people associate with the process.
   - Implement training for the new method.
   - If results are unsuccessful, revise the plan and repeat the process or cease this project.

Seven Basic Tools

1. Check Sheet
2. Flow Chart
3. Histogram
4. Pareto Chart
5. Scatter Diagram
6. Cause & Effect Diagram
7. Statistical Process Control

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Quality Circles

- Team approach
  - List reduction
  - Balance sheet
  - Paired comparisons

Benchmarking Process

- Identify a critical process that needs improving.
- Identify an organization that excels in this process.
- Contact that organization.
- Analyze the data.
- Improve the critical process.

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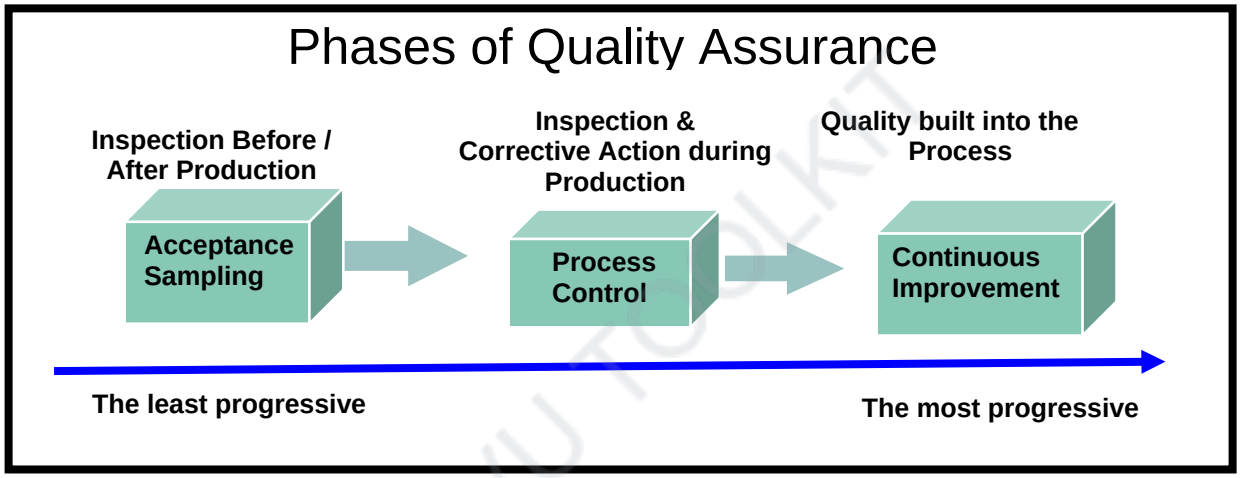
QUALITY CONTROL & QUALITY ASSURANCE

Quality Control or QC as it is popularly referred as "is concerned with quality of conformance of a process". The prime purpose of QC is to assure that the processes are performing in an acceptable manner. Organizations accomplish QC by monitoring process outputs using statistical techniques. The practical and pragmatic QC based Operations Strategy for a service or manufacturing organization would focus on the principle of quality in design.

Learning Objectives

1. Introduction to Quality Control and Assurance
2. Phases of Quality Control
3. Elements of Control Process
4. How control charts are used to monitor a process and the concepts that underlie their use.
5. Use and interpret control charts.
6. Use of run tests to check for non randomness in process output.

Phases of Quality Assurance

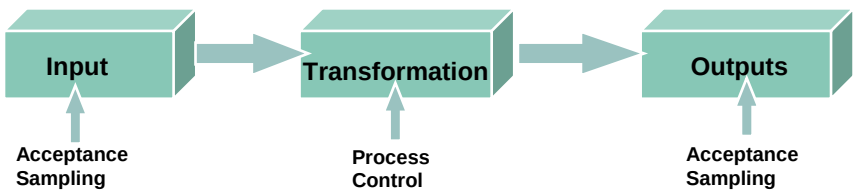


Inspection

Inspection is an important strategy, in its simplest form, is any method or device or tactics used to minimize defects in products or services being offered to the customers. As Operations Manager we should be able to identify the following four questions while considering Inspection process.

1. How Much/How Often
2. Where/When
3. Centralized vs. On-site
4. Whether to inspect Variables or Attributes.

An important thing to remember is that No inspection is necessary for low value, high volume products like common items like common pins, erasers or pencils while automated inspection is necessary for high value items. Automated inspection may be necessary for even high value, low volume items as well. The word volume here refers to quantity.



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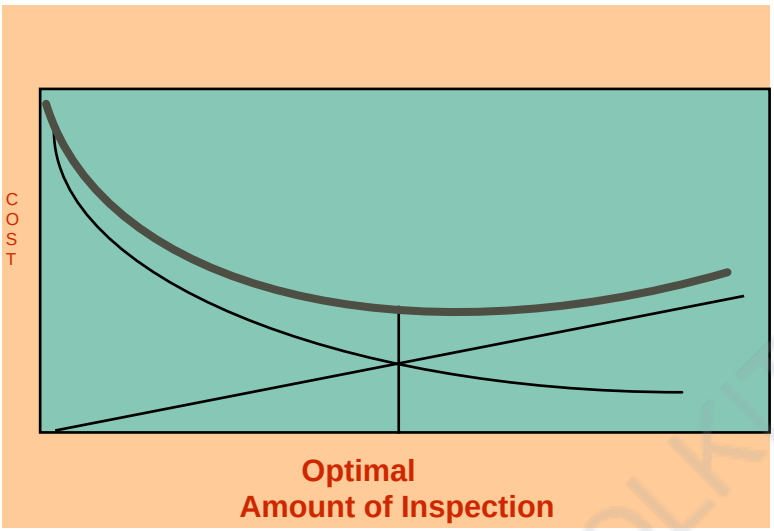
Inspection Costs for How Much/How Often

The graph below shows the relationship between amount of inspection required and costs incurred in carrying out such inspection.

1. With increase in Inspection activities the cost of undetected defectives decreases.
2. With increase in inspection activities the cost of inspection increases.

We need to observe for Total cost function curve which shows high costs at no inspection and gradually comes down and reaches a minimum value at the optimal amount of inspection and then start increases.



Inspection Costs for How Much/How Often

1. Where to Inspect in the Process
2. Raw materials and purchased parts (DO not purchase poor quality products)
3. Finished products (Poor products returned by customers can also lead to additional shipping costs)
4. Before a costly operation (Do not waste Resources of Man, Material and Machine)
5. Before an irreversible process (Pottery, Ceramics, Tiles, PC chips, glass filaments)
6. Before a covering process (Before painting, plating and assembly)

Examples of Inspection Points in Service Industry

We cannot have same inspection points for the service industry, infact we need to pay attention to the type of industry or business in which a service organization competes. Please refer to the table on the next page and note the difference in characteristics and location of inspection points.

Type of business	Inspection points	Characteristics
Fast Food	Cashier Counter area Eating area Building Kitchen	Accuracy Appearance, productivity Cleanliness Appearance Health regulations
Hotel/motel	Parking lot Accounting Building Main desk	Safe, well lighted Accuracy, timeliness Appearance, safety Waiting times
Supermarket	Cashiers Deliveries	Accuracy, courtesy Quality, quantity

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Centralized vs Onsite Inspection

1. Inspection of Ships, Nuclear Plants, Petroleum Refinery, Chemical Plant equipments for cracks, brittle fracture etc both external and internal inspection.
2. Lab tests include blood tests, material testing

Quality Control in Terms of Statistical Process Control:

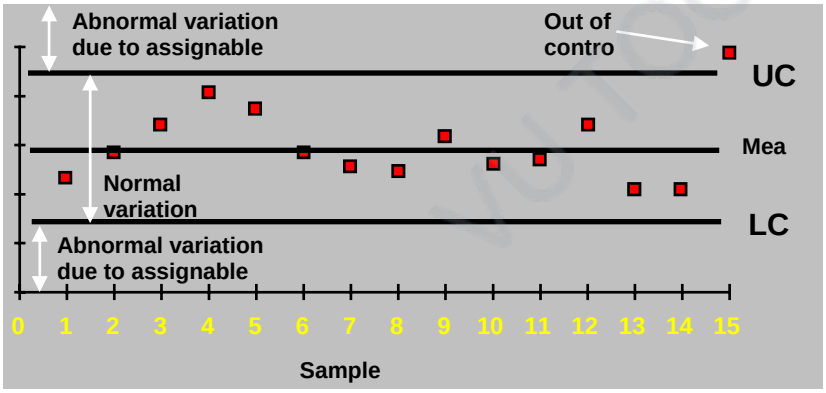
We now focus on the idea of Quality Control in terms of Statistical Process Control, for this we need to define

- *Statistical Process Control*: Statistical evaluation of the output of a process during production
- *Quality of Conformance:* A product or service conforms to specifications
- Which Characteristics can be controlled: Only those characteristics which can be counted or measured.
- Main Task of QC: is to distinguish random from non random variability, because non random variability indicates that the process is out of control

Control Chart

- Control Chart: A time ordered plot representative sample statistics obtained from an on going process (e.g. sample means)
- Purpose: to monitor process output to see if it is random
- Upper and lower control limits define the range of acceptable variation

Control Chart & Statistical Process Control



Statistical Process Control

- The essence of statistical process control is to assure that the output of a process is random so that *future output* will be random.
- Statistical Process Control
- The Control Process consists of the following important stages.
    1. Define
    2. Measure
    3. Compare
    4. Evaluate
    5. Correct
    6. Monitor results

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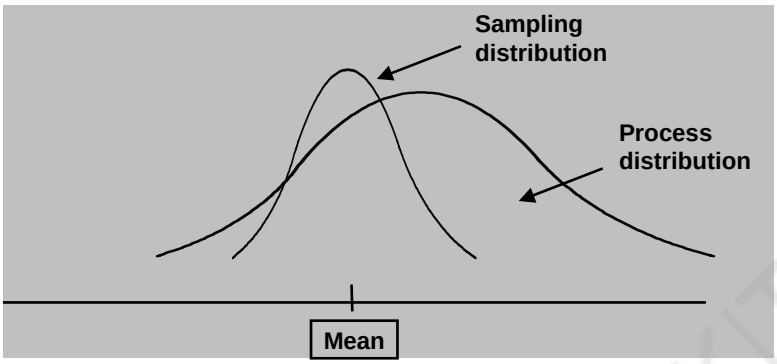
Variations and Control

•*Random variation*: Natural variations in the output of a process, created by countless minor factors Also called COMMON/ CHANCE. INHERENT and part of the process. E.g. Difference between old and new machines.
•*Assignable variation*: A variation whose source can be identified

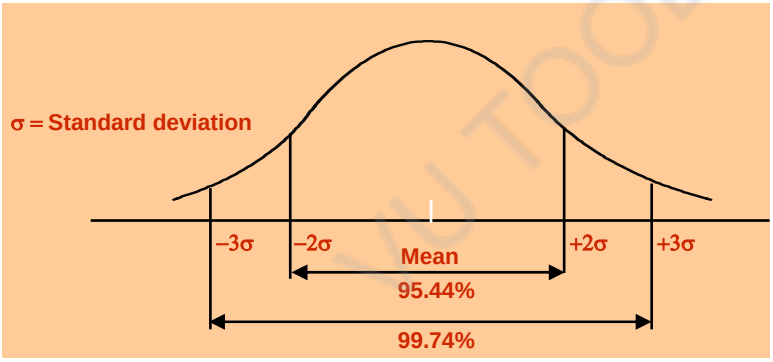
Sampling Distribution

The variability of a sample statistic can be described by its SAMPLING DISTRIBUTION. The goal of sampling is to determine whether non random /assignable/ correctable sources of variation are present in the output of the process. E.g. Soft drinks bottle are never 250 ML. slight differences among the mean.

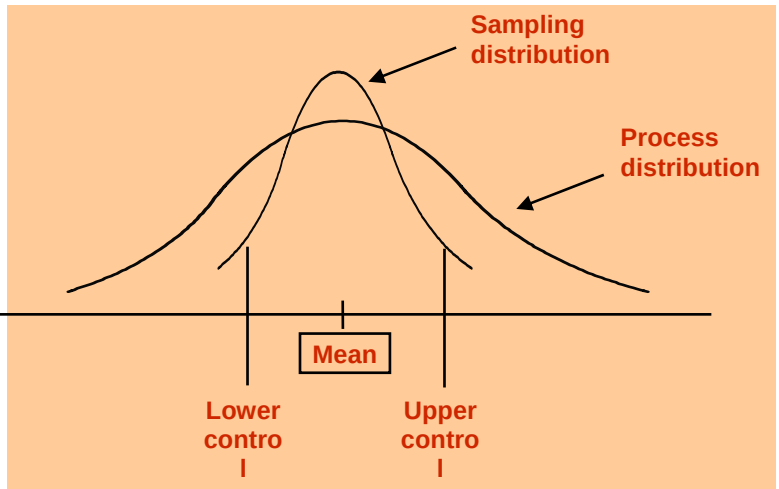
Sampling Distribution



Normal Distribution



Control Limits



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Control Charts

- A control chart is a time ordered plot of sample statistics.
- It is used to distinguish between random variability and non random variability.
- The basis of control chart is sample distribution which essentially describes random variability.
- Theoretically any value is possible as the distribution extends to infinity.
- 99.7% of all values will be within $\pm$ **3** standard deviations
- Control Charts
- We draw a line at $\pm$ 3 and call it control chart limits and observe any value beyond this to be out of limits.
- Control Chart limits are the dividing lines between random deviations and mean of the distribution and non random deviations and mean of the distribution.
- The limits that separate random variations from non random variations is known as UCL and LCL.

A sample statistic that falls between UCL and LCL suggests (does not proves) randomness and a value outside suggests (does not proves) no randomness.

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QUALITY CONTROL AND QUALITY ASSURANCE (Contd.)

Learning Objectives

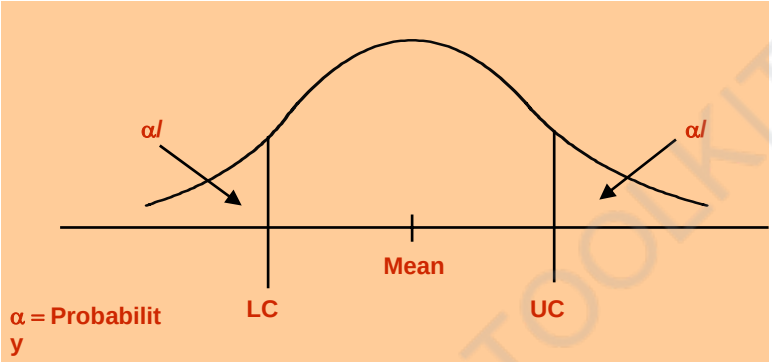
In this lecture we will learn to:

1. Use and interpret control charts.
2. Use of run tests to check for non randomness in process output.

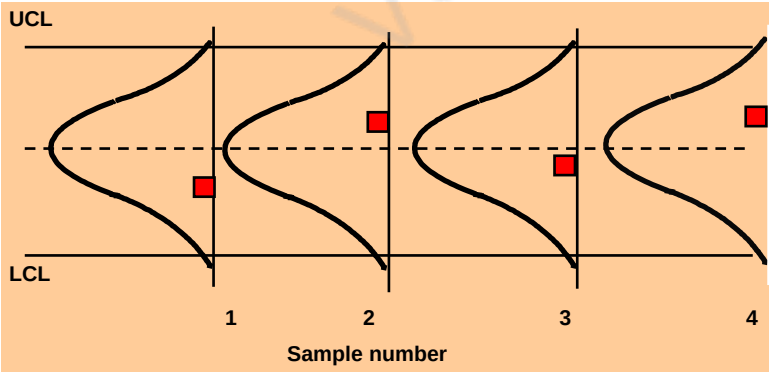
SPC Errors

- Type I error: Concluding a process is not in control when it actually is or concluding that no randomness is present when it is only randomness that is present.
- Type II error: Concluding a process is in control when it is not that no randomness is not present when it is present.

Type I Error



Observations from Sample Distribution



Control Charts for Variables

- Mean control charts
- Used to monitor the central tendency of a process.
- X bar charts
- Range control charts
- Used to monitor the process dispersion
- R charts

MEAN AND RANGE CHARTS

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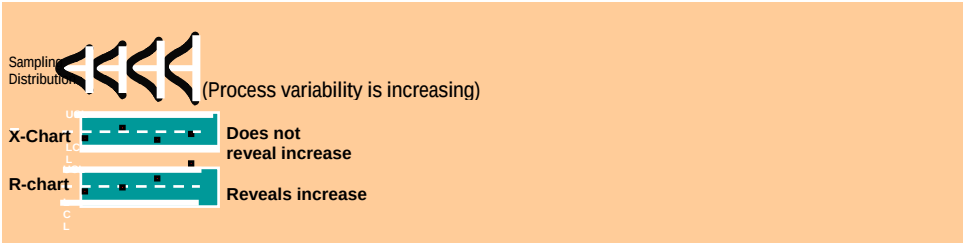

CONTROL CHART FOR ATTRIBUTES

- p-Chart - Control chart used to monitor the proportion of defectives in a process
- c-Chart - Control chart used to monitor the number of defects per unit

Use of p-Charts

- When observations can be placed into two categories.
- Good or bad
- Pass or fail
- Operate or don't operate
- When the data consists of multiple samples of several observations each

Use of c-Charts

- Use only when the number of occurrences per unit of measure can be counted; non-occurrences cannot be counted.
- Scratches, chips, dents, or errors per item
- Cracks or faults per unit of distance
- Breaks or Tears per unit of area
- Bacteria or pollutants per unit of volume
- Calls, complaints, failures per unit of time

Use of Control Charts

- At what point in the process to use control charts
- What size samples to take
- What type of control chart to use
    1. Variables
    2. Attributes

Run Tests

- *Run test* – a test for randomness
- Any sort of pattern in the data would suggest a non-random process
- All points are within the control limits - the process may not be random

Nonrandom Patterns in Control charts

- Trend
- Cycles

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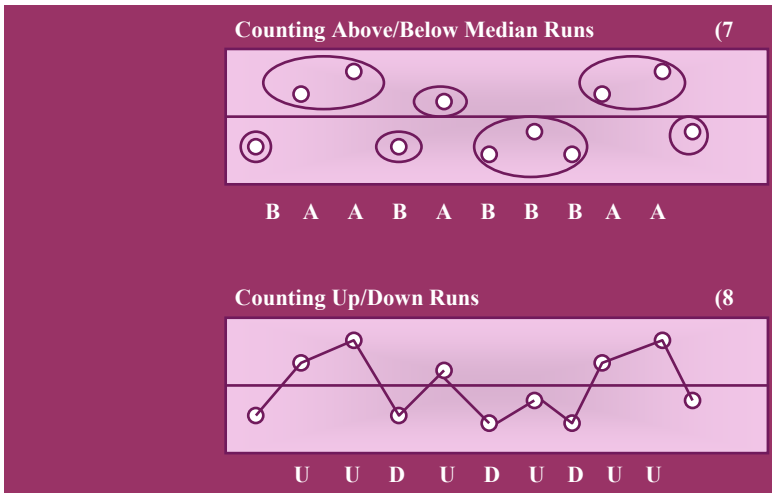
- Bias
- Mean shift
- Too much dispersion

Counting Runs



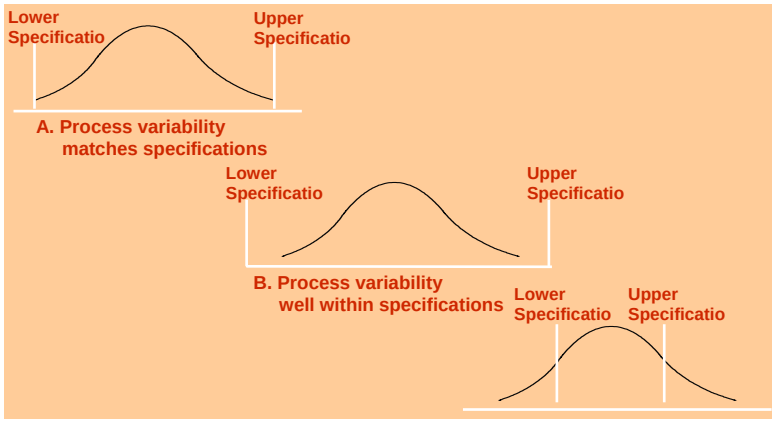
◆Underlining each runs helps in counting
◆IN case of Ups and Down the first value does not receives either a U or D because nothing precedes it.

PROCESS CAPABILITY

- Tolerances or specifications is the range of acceptable values established by engineering design or customer requirements
- Process variability: is the natural variability in a process
- Process capability: is the process variability relative to specification

Process Capability is thus more importantly related to our discussion of Quality Control and Quality Assurance and we will take up three cases in detail to understand this important concept.

1. In Case A we observe that process specifications and output are matched.
2. In Case B process variability is well within the process specification and output.
3. In Case C, we need to check whether a process is capable of meeting specifications and not just use a control chart.



Process Capability

Case C, A manager in case C can take the following steps.

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1. Redesign the process to obtain the desired output.
2. Use an alternative process to obtain the desired output.
3. Retain the current process but attempt to eliminate output using 100 percent inspection
4. Examine the specifications to see if they are necessary or can be relaxed

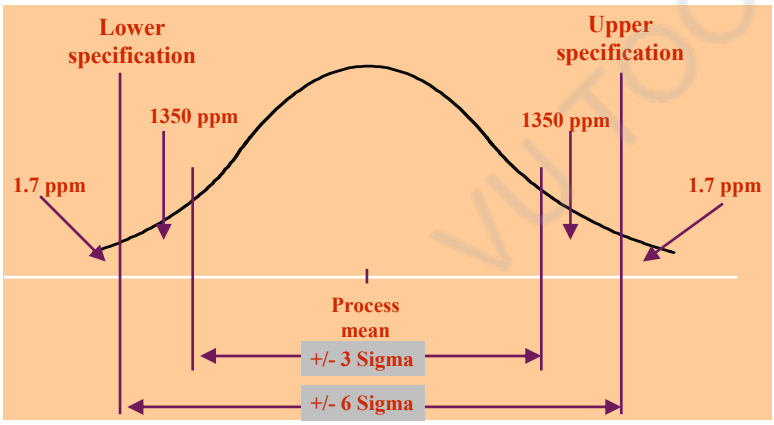
Process Variability is the key factor in Process Capability. It is measured in terms of process standard deviation. Process capability is considered to be ± 3 Standard Deviations from the process mean. E.g. An insurance company provides a service of registering a new membership (filling of form) in 10 mins, acceptable range of variation around the time is ± 1 minute, the process has a standard deviation of 0.5min.It would not be capable because ± 3 SDs would be ± 1.5 Mins, exceeding the specification of ± 1 minute.

Process Capability Ratio

Process capability ratio, Cp = Specification width / Process width

$$Cp = \frac{\text{Upper specification} - \text{lower specification}}{6\sigma}$$

3 SIGMA AND 6 SIGMA QUALITY



Improving Process Capability

1. Simplify
2. Standardize
3. Mistake-proof (Poka Yoke)
4. Upgrade equipment
5. Automate

Taguchi Loss Function

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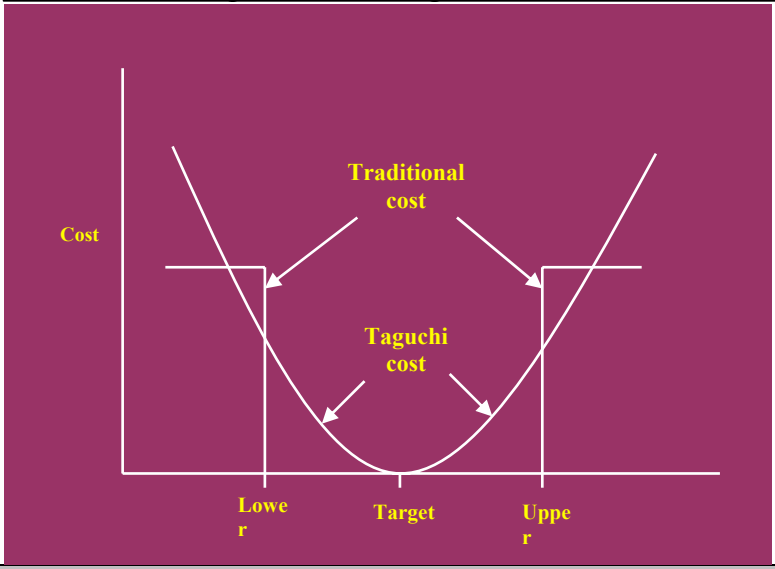

Limitations of Capability Indexes

1. Process may not be stable
2. Process output may not be normally distributed
3. Process not centered but C_p is used

Operations Strategy WRT Q/C

- It is neither necessary nor desirable to use Control charts for every production process.
- Some processes are highly stable and do not require Control Charts.
- Managers should use Control Charts on processes that go out of control.
- Use control Charts for new processes till they obtain stable results.
- Judicious use of SPC will ensure detection of departures from randomness in a process.

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Lesson 29

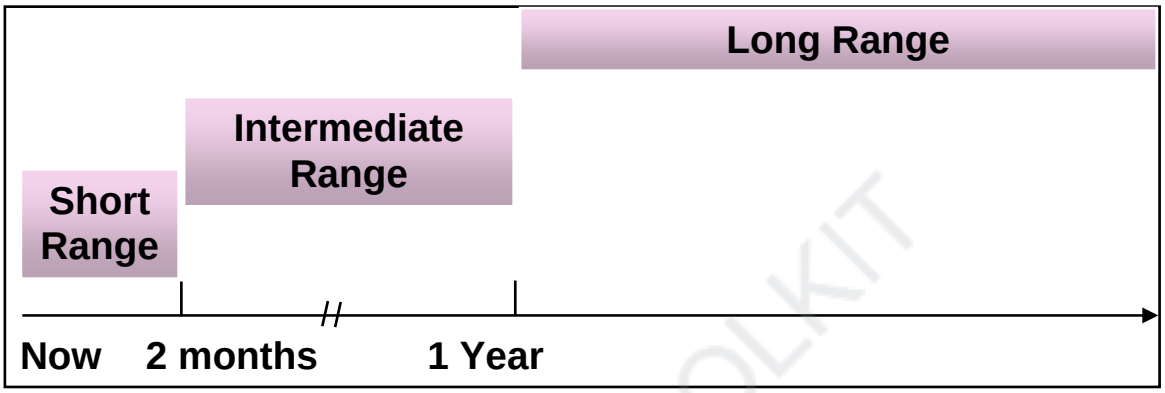
AGGREGATE PLANNING

Learning Objectives

- Explain the working and usefulness of Aggregate Planning.
- Identify the variable decision makers to work with in aggregate planning and some of the possible strategies they can use.
- Describe some of the graphical and quantitative techniques planners use.
- Prepare aggregate plans and compare their costs.

Planning Horizon

Aggregate planning: Intermediate-range capacity planning, usually covering 2 to 12 months.



As Operations Manager we should be able to understand and identify the various Planning Levels which are Short Range Plans, Intermediate Plans and Long Range Plans.

Short-range plans (Detailed plans)
1. Machine loading
2. Job assignments

Intermediate plans (General levels)
1. Employment
2. Finished Good inventories
3. Subcontracting, Backorders
4. Output

Long-range plans
1. Long term capacity
2. Location / layout

Planning Sequence

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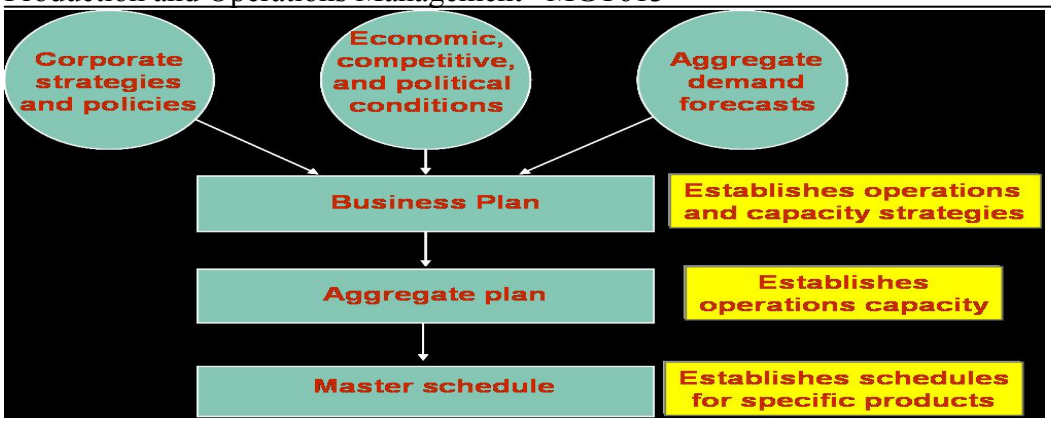

Aggregate Planning Inputs

- Resources
  1. Workforce
  2. Facilities
- Demand forecast
- Policies
  1. Subcontracting
  2. Overtime
  3. Inventory levels
  4. Back orders
- Costs
  1. Inventory carrying
  2. Back orders
  3. Hiring/firing
  4. Overtime
  5. Inventory changes
  6. subcontracting

Aggregate Planning Outputs

1. Total cost of a plan
2. Projected levels of inventory
3. Inventory
4. Output
5. Employment
6. Subcontracting
7. Backordering

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Aggregate Planning Strategies

- Proactive Strategy: Strategies that alter demand to match capacity are known as Proactive Strategy.
- Reactive Strategy: Strategies that alter capacity to match demand are known as Reactive Strategy.
- Mixed. Strategies that make use of qualities from both Proactive and Reactive Strategy are known as Mixed Strategies.

Demand and Capacity Options

Demand Options: The four common demand options primarily focus on market aspects apart from backorders which is strictly operational management in nature. The operations manager should know all four demand options but should be more interested in back order option.

1. Pricing
2. Promotion
3. Back orders
4. New demand

Capacity Options: The common capacity options primarily focus on.

1. Hire and layoff workers
2. Overtime/slack time
3. Part-time workers
4. Inventories
5. Subcontracting
6. Maintain a level workforce
7. Maintain a steady output rate
8. Match demand period by period
9. Use a combination of decision variables

An important point to be noted is that Demand options are short range in nature while Capacity options are long duration (term or range).

Which Strategy to Use

The organization needs to consider two factors before choosing a strategy

1. Costs
2. Company/Corporate Policy
   - Policy can set constraints on available options. E.g. Layoffs, subcontracting/Outsourcing (PIA subcontracting its databases) to protect secrecy.
   - As a rule of thumb, aggregate planners seek to match supply and demand within in constraints by policies and minimum costs.

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AGGREGATE PLANNING (Contd.)

Learning Objectives

In this lecture we will cover the basic aggregate planning strategies, Assumptions for Aggregate Planning, different Aggregate Planning Relationships, Master Schedule and Master Scheduler. We will study desegregating the aggregate plans for production control. This discussion would prepare us to take a deeper look into Inventory Management and MRP/ERP. All this would allow us to become effective operations manager to work for improving the operations as well as the systems of the organizations we will work for.

Basic Strategies

- Level capacity strategy: Maintaining a steady rate of regular-time output while meeting variations in demand by a combination of options.
- Chase demand strategy: Matching capacity to demand; the planned output for a period is set at the expected demand for that period.

Chase Approach

- Advantages

1. Investment in inventory is low
2. Labor utilization in high

- Disadvantages
    1. The cost of adjusting output rates and/or workforce levels

Level Approach

- Advantages
    1. Stable output rates and workforce
- Disadvantages
    1. Greater inventory costs
    2. Increased overtime and idle time
    3. Resource utilizations vary over time

Techniques for Aggregate Planning

1. Determine demand for each period
2. Determine capacities for each period
3. Identify policies that are pertinent
4. Determine units costs
5. Develop alternative plans and costs
6. Select the best plan that satisfies objectives. Otherwise return to step 5.

Assumptions for Aggregate Planning

1. The regular output capacity is the same for all periods.
2. Cost (Back Order, Inventory, Subcontracting etc) is a linear function composed of unit cost and number of units. (In reality cost is more of a step function)
3. Plans are feasible (There is sufficient inventory exists to accommodate a plan, subcontractors would provide quality products and outsourcers would be secure)
4. Assumptions for Aggregate Planning
5. All costs associated with a decision option can be represented by a lump sum or by unit costs that are independent of the quantity involved.
6. Cost figures can be reasonably estimated and are constant over the planning horizon.

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7. Inventories are built up and draw down at a uniform rate and output occurs at a uniform rate throughout each period. Backlogs are treated as if they exist for the entire period, even though in reality they tend to build up towards the end of the period

Aggregate Planning Relationships

1. Number of workers in a period equals Number of Workers at the end of the previous period PLUS Number of new Workers at the start of the current period - Number of laid off Workers at the start of the current period
2. NOTE: SINCE the organization would not hire and layoff simultaneously, so at least one of the last two terms will be "0".
3. Inventory at the end of a (current) period equals Inventory at the end of the previous period PLUS Production in the current period – Amount used to satisfy the demand in the current period
4. NOTE :The average Inventory for a period is equal to (Beginning Inventory Plus Ending Inventory)/2

Average Inventory
Aggregate Planning Relationships
•Cost for a (current) period equals Output Cost (Regular +OT+ Subcontract) + Hire/Layoff Cost+ Inventory Cost + Backorder Cost
NOTE
The cost of a particular plan for a given period can be determined by summing the appropriate costs

Aggregate Planning Relationships

Type of Costs	How to Calculate
Output	
Regular	Regular Cost per Unit X Quantity of Regular Output
Overtime	Overtime Cost per Unit X Overtime Quantity
Subcontract	Subcontract Cost per Unit X Subcontract Quantity
Hire/Layoff	
Hire	Cost Per Hire X Number Hired
Layoff	Cost per Layoff X Number laid off
Inventory	Carrying Cost per Unit X Average Inventory
Back Order	Back Order Cost Per Unit X Number of Backorder Units

Mathematical Techniques

Linear programming: Methods for obtaining optimal solutions to problems involving allocation of scarce resources in terms of cost minimization.
Linear decision rule: Optimizing technique that seeks to minimize combined costs, using a set of cost-approximating functions to obtain a single quadratic equation.

Summary of Planning Techniques

Technique	Solution	Characteristics
Graphical /charting	Trial and error	Intuitively appealing, easy to understand; solution not necessarily optimal.
Linear programming	Optimizing	Computerized; linear assumptions not always valid.
Linear decision rule	Optimizing	Complex requires considerable effort to obtain pertinent cost information and to construct model; cost assumptions not always valid.
Simulation	Trial and error	Computerized models can be examined under a variety of conditions.

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Aggregate Planning in Services

1. Services occur when they are rendered .Unlike most manufacturing output, most services cannot be inventoried. Services such as financial planning, tax counseling and oil changes cant be inventoried/stockpiled. This removes the option of building up the inventories during a slow period in anticipation of future demand.
2. Demand for service can be difficult to predict .The volume of demand for services is often variable. In some situations, customers may need prompt service . e.g. police, fire, medical emergency while in others they may not need prompt service and may be willing to find some other service provider.
3. Capacity Availability can be difficult to predict. Processing requirements for services can sometimes be quite variable, similar to the variability of work in a job shop setting.
4. Demand for service can be difficult to predict It is difficult to measure the capacity of a person rendering a service, a dentist, a Montessorian, a bank teller in anticipation of future demand).
5. Labor Flexibility can be advantage in Services Labor often comprises a significant portion of service compared to manufacturing. That coupled with the fact that service providers are often able to handle a fairly wide variety of service requirements means that to some extent, planning is easier than manufacturing

Aggregate Plan to Master Schedule

Disaggregating the Aggregate Plan

The Aggregate Plan is broken down into Master Schedules and Rough Cut Capacity Planning charts respectively.

- *Master schedule*: The result of disaggregating an aggregate plan; shows quantity and timing of specific end items for a scheduled horizon.
- *Rough-cut capacity planning*: Approximate balancing of capacity and demand to test the feasibility of a master schedule.
- WE WILL DISCUSS IT IN DETAIL WHEN WE COVER OUR MRP LECTURE
- E.g. Suppose the organization is making 500 aggregate units of Air conditioners for the month of March and April with breakup being 200 for window types, 300 type split units with further tonnage capacities.
- A master schedule shows the planned output for individual products rather than an entire product group, along with the timing of production.
- With Rough cut capacity planning we can check capacities of production and warehouses constraints exist. This means checking capacities of production and warehouse facilities, labor and

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vendors to ensure that no gross deficiencies exist that will render master schedule unworkable. The master schedule then serves as the basis for short range planning.

- MS is disaggregated in stages or phases, which may cover weeks or months.
- Master schedule: Determines quantities needed to meet demand
- Interfaces with
  1. Marketing
  2. Capacity planning
  3. Production planning
  4. Distribution planning

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Master Scheduling

- A Master schedule indicates the quantity and timing (i.e. delivery times) for a product, or a group of products, but it does not show planned production. For a master schedule may call for delivery of 500 Air conditioners on April 1. But it may not require any production because of availability of 1000 air conditioners in inventory. Or if there are only 400 Air conditioners, 100 would be planned for production.

Master Scheduler

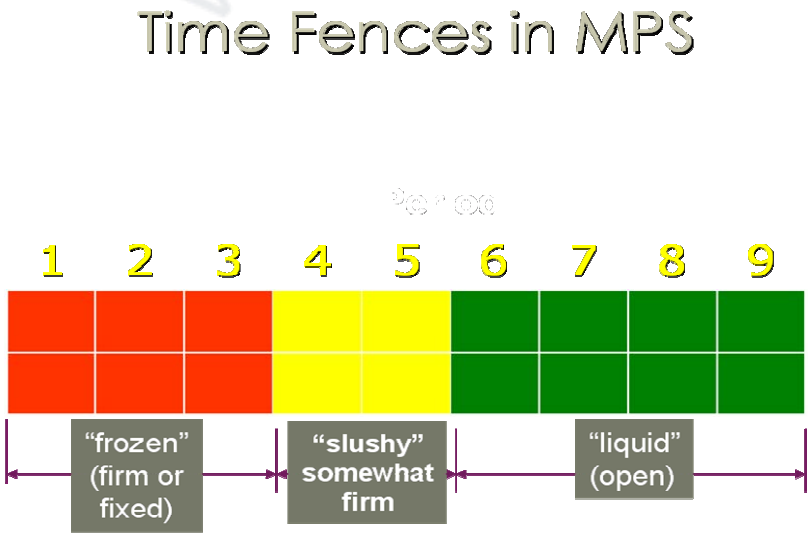
- Evaluates impact of new orders
- Provides delivery dates for orders
- Deals with problems
- Production delays
- Revising master schedule
- Insufficient capacity

Projected On-hand Inventory

Stabilizing the Master Schedule

- Changes to a master schedule can be disruptive, particularly changes to the early, or near, portions of the schedule.
- Typically the further out in the future a change is, the less the tendency to cause problems.
- Master Production Schedules are often divided into 4 stages or phases. The dividing lines between phases are sometimes referred to as time fences.

Time Fences in MPS



- In the first phase, usually the first few periods of the schedule, changes can be quite disruptive.

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- Consequently, once established, that portion of the schedule is generally frozen, which implies that all but the most critical changes cannot be made without permission from the highest levels in an organization. This helps in achieving high degree of stability in the production system.
- In the next stage, perhaps the next two days or three periods, changes are still disruptive, but not to that extent that they are in first phase.
- Management views the schedule as firm and only exceptional changes are made which helps an organization gain some competitive advantage.
- In the third stage, management views the schedule as full, meaning that all available capacity has been allocated.
- Although changes do impact the schedule, their effect is less dramatic and they are usually made if there is good reason for doing so.
- IN the final phase, management views the schedule as open, meaning that not all capacity has been allocated. This is where new orders are usually in the Schedule.

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INVENTORY MANAGEMENT

Learning Objectives

Our discussion on Inventory Management would be complete only when we are able to learn and understand the types of Inventories and objectives of Inventory Control. This would ensure that we are able to understand the major reasons for holding inventories. We would be able to differentiate between independent and dependent demand. We will also learn the requirements of an effective inventory management system. We will review both periodic as well as perpetual Inventory systems. We will discuss in detail the ABC approach with a suitable example. Since our discussion would extend over three lectures we will also discuss the objectives of inventory management, describe the basic EOQ model, Economic Run Size, Quantity Discount Model with solved examples.

Types of Inventories

The five common types of inventories are:

1. Raw materials & purchased parts.
2. Partially completed goods called *work in progress.*
3. Finished-goods inventories:
    a. (*manufacturing firms*) or
    b. merchandise, (*retail stores*)
4. Goods-in-transit to warehouses or customers.
5. Replacement parts, tools, & supplies.

Objective of Inventory Control

To achieve satisfactory levels of customer service while keeping inventory costs within reasonable bounds. Operations Managers are well aware of the fact that customer services with respect to Inventory takes into account both the internal customers as well as external customers.

1. Level of customer service.
2. Costs of ordering and carrying inventory.

Functions of Inventory

A manufacturing organization has one or more of the following functions of inventory in mind when it tries to set up a pragmatic and effective inventory management system.

1. To meet anticipated demand.
2. To smooth production requirements.
3. To decouple operations.
4. To protect against stock-outs.
5. To take advantage of quantity discounts.
6. To permit operations.
7. To help hedge against price increases.
8. To take advantage of order cycles.

Requirements of Effective Inventory Control

Management has two basic functions concerning Inventory.

1. To make decisions about how much and when to order.
2. To establish a system of keeping track of items in an inventory.

Effective Inventory Management

An Inventory Management System would be called Effective if it is able to fulfill the following requirements.

1. A system to keep track of inventory.
2. A reliable forecast of demand.

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3. Knowledge of lead times.
4. Reasonable estimates of:
    a. Holding costs
    b. Ordering costs
    c. Shortage costs
5. A classification system.

Inventory Counting Systems

There are two famous types of Inventory Counting Systems

1. *Periodic System*
2. *Perpetual Inventory System(CONTINUAL)*

Periodic System: Physical count of items made at periodic intervals.
Perpetual Inventory System(CONTINUAL): System that keeps track of removals from inventory continuously, thus monitoring current levels of each item. Perpetual Inventory Systems can be simple or complex, the two common perpetual Inventory systems found in Pakistan are the:

- *Two-Bin System* - Two containers of inventory; reorder when the first is empty.
- *Universal Bar Code* - Bar code printed on a label that has information about the item to which it is attached.

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INVENTORY MANAGEMENT (Contd.)

Learning Objectives

Inventory Management is the procurement, use and distribution of Inventory; some text books use the work Inventory control for the same concept. The word control ensures that inputs, the process itself and the outputs are all manageable. This inventory control concept helps us to understand two important concepts of Operations Management i.e. Supply Chain Management and Just In Time Production Systems. In this lecture we will study the ABC classification System, Inventory Ordering and Holding Costs and Economic Order Quantity Model.

Key Inventory Terms

The Key Inventory Terms we should know are Lead time, Holding (carrying) costs, Ordering (Set up) Costs and Shortage(Stock out) costs

1. Lead time: Time interval between ordering and receiving the order.
2. Holding (carrying) costs: Cost to carry an item in inventory for a length of time, usually a year. Costs include Interest, insurance, taxes, depreciation, obsolescence, deterioration, pilferages, breakage, warehousing costs and Opportunity costs. Holding (carrying) costs: Holding costs are stated in two ways
    a. Percentage of unit price or
    b. Rupee
3. Ordering costs: Costs of ordering and receiving inventory. These are the actual costs that vary with the actual placement of the order.
4. Shortage costs: Costs when demand exceeds supply.

ABC Classification System

An important aspect of Inventory Management is that items held in inventory are not of equal importance in terms of rupees invested, profit potential, sales or usage volume.
ABC Classification System controls inventories by dividing items into 3 groups A, B and C respectively.

1. Group A consists of High Rupee (Monetary) Value, which account for a small portion about 10% of the total inventory usage.
2. Group B consists of Medium Rupee (Monetary) Value, which account for about 20% of the total inventory usage.
3. Group C consists of Low Rupee (Monetary) Value, which account for a large portion about 70% of the total inventory usage.
4. The level of control reflects cost benefit concerns.
5. Group A items are reviewed on a regular basis.
6. Group B items are reviewed at a less frequency than Group A items but more than Group C items.
7. Group C items are not reviewed and order is placed directly.

Example.

Item	Demand	Unit Cost	Annual Value (Rupees)	Classification
PC	10	Rs.20,000	200,000	B (up to Rs. 500,000)
Monitor	5	5000	25,000	C(Up to Rs. 50,000)
Processor	25	5000	125,000	B
RAM	1000	2000	2,000,000	A

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Classify inventory according to ABC classification system, Rupee value up to 50K and 500K represent C and B respectively.

Cycle Counting

1. A physical count of items in inventory.
2. Cycle counting management:
3. How much accuracy is needed?
4. When should cycle counting be performed?
5. Who should do it?

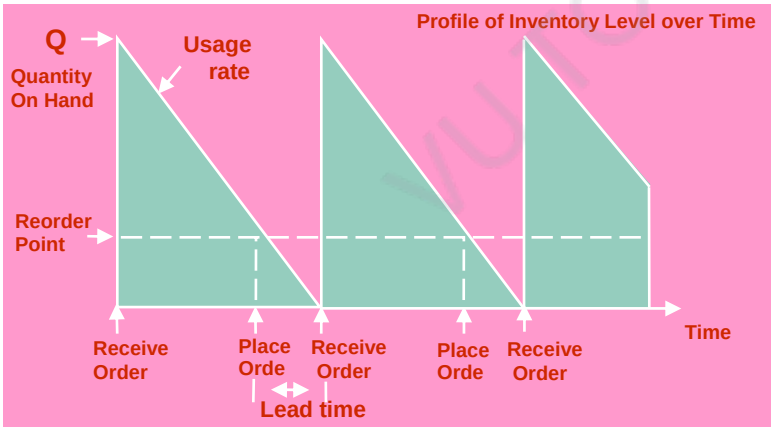
Economic Order Quantity Models

1. Economic order quantity model
2. Economic production model
3. Quantity discount model

Assumptions of EOQ Model

1. Only one product is involved.
2. Annual demand requirements known.
3. Demand is even throughout the year.
4. Lead time does not vary.
5. Each order is received in a single delivery.
6. There are no quantity discounts.

The Inventory Cycle



Total Cost

$$\text{Total cost} = \text{Annual carrying cost} + \text{Annual ordering cost}$$

$$TC = \frac{Q}{2}H + \frac{D}{Q}S$$

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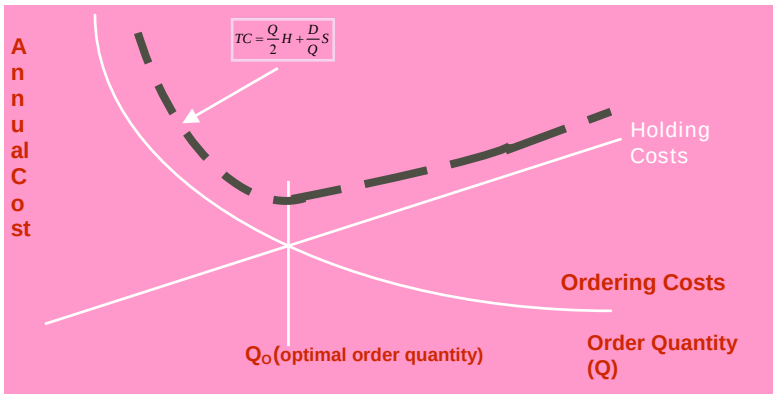
Cost Minimization Goal



Deriving the EOQ

Using calculus, we take the derivative of the total cost function and set the derivative (slope) equal to zero and solve for Q.

$$Q_{OPT} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(\text{Annual Demand})(\text{Order or Setup Cost})}{\text{Annual Holding Cost}}}$$

Minimum Total Cost
The total cost curve reaches its minimum where the carrying and ordering costs are equal.

Example 2

A local distributor for an international aerobic exercise machine manufacturer expects to sell approximate 10,000 machines. Annual carrying cost is Rs. 2500 per machine and Order cost is Rs. 10,000. The distributor Operates 300 days a year.

1. Find EOQ?
2. The number of times the store will reorder?
3. Length of an Order Cycle?
4. Total Annual Cost if EOQ is ordered?

Given Data

D=10,000 machines.
H= Annual carrying cost is Rs. 2500 per machine.
S=Order cost is Rs. 10,000.
No of The distributor Operates 300 days a year.

Calculation of EOQ

Q_0= Sq Root of (2 DS)/H=
Sq Root (2 X 10,000 X 10,000)/2500
=Sq Root (80,000)
=283 machines per year

The number of times the store will reorder?
D/Q_0=10,000/283=35.34
= 35 Times

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The Length of an Order Cycle

$Q_0/D=283/10.000=0.0283$ of a year= 0.0283 X 300= 8.49 days

The Total Annual Cost, if EOQ is ordered

TC= Carrying Cost + Ordering Cost
$=Q_0/2$ (H) + D/Q_0 (S)
=283/2 (2500) + 10.000/283 (10,000)
=353,750 + 353,353
= Rs. 707,107

Summary

Inventory Management is simply the procurement, use and distribution of Inventory. In our subsequent discussions on Inventory as well as Supply Chain Management we will find some similarities between the two important concepts of Inventory Management and Supply Chain Management. When we combine Inventory Management (Control) with Production and Purchasing we are more or less focusing on the Japanese Philosophy of Just In Time Production. Also, the basic EOQ Model minimizes the sum of carrying or holding costs as well as setup or ordering cost.

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INVENTORY MANAGEMENT (Contd.)

Learning Objectives

Our discussion on Inventory Management would be complete only when we are able to learn and understand the types of Inventories and objectives of Inventory Control. This would ensure that we are able to understand the major reasons for holding inventories. We would be able to differentiate between independent and dependent demand. We will also learn the requirements of an effective inventory management system. We will review both periodic as well as perpetual Inventory systems. We will discuss in detail the ABC approach with a suitable example. Our discussion has focused on the objectives of inventory management, basic EOQ model, Economic Run Size, Quantity Discount Model with solved examples.

Example (In terms of Percentage)

CNG-LPG company in Karachi, purchases 5000 compressors a year at Rs.8,000 each. Ordering costs are Rs. 500 and Annual carrying costs are 20 % of the purchase price. Compute the Optimal price and the total annual cost of ordering and carrying the inventory.

Data

D=Demand =5,000

S=Ordering= Rs. 500

H=Holding/Carrying Cost=0.2 X 8,000=Rs.1600

Example 3 (In terms of Percentage)

Q_0= Sq Root of (2(5,000)(500)/(1600))

= 55.9=56 Compressors

TC= Carrying costs + Ordering Costs

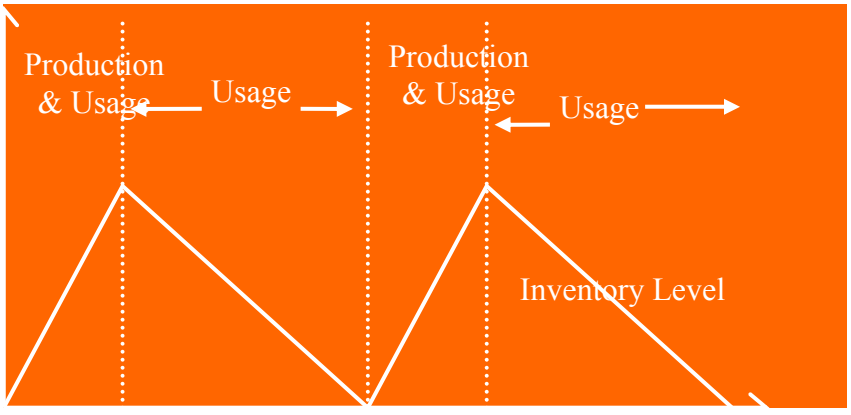
$=Q_0/2$ (H) + D/Q_0 (S)

= 56/2 (1600) + 5000/56 (500)

= 28 (1600)+ 44,643

=44,800+44,643=Rs. 89,443

Economic Production Quantity (EPQ)



Economic Production Quantity (EPQ) Assumptions

Production done in batches or lots

Capacity to produce a part exceeds the part's usage or demand rate.

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Assumptions of EPQ are similar to EOQ except orders are received incrementally during production.

Economic Production Quantity Assumptions

1. Only one item is involved
2. Annual demand is known
3. Usage rate is constant
4. Usage occurs continuously
5. Production rate is constant
6. Lead time does not vary
7. No quantity discounts

Finer Points of Economic Production Quantity Model

- The basic EOQ model assumes that each order is delivered at a single point in time.
- If the firm is the producer and user, practical examples indicate that inventories are replenished over time and not instantaneously.
- If usage and production (delivery) rates are equal, then there is no buildup of inventory.
- Set up costs in a way our similar to ordering costs because they are independent of lot size.
- The larger the run size, the fewer the number of runs needed and hence lower the annual setup.
- The number of runs is D/Q and the annual setup cost is equal to the number of runs per year times the cost per run (D/Q)S.
- Total Cost is

TC_{min}= Carrying Cost+ Setup Cost

$= (I_{max}/2)H + (D/Q_0)S$

Where I_{max}= Maximum Inventory

Economic Run Size

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$$

Economic Production Quantity Assumptions

Where p= production rate

U = usage rate

Economic Production Quantity Assumptions

The Run time (the production phase of the cycle) is a function of the run size and production rate

Run time = Q_0/p

The maximum and average inventory levels are

$I_{max} = Q_0/p\ (p-u)$

$I_{average} = I_{max}/2$

Example (Economic Run Size)

Example for Economic Run Size

A firm in Sialkot produces 250,000 each world class footballs for both domestic and international markets . It can make footballs at a rate of 2000 per day. The footballs are manufactured uniformly

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over the whole year. Carrying cost is Rs. 100 per football and Setup cost for a production run is Rs. 2500. The manufacturing unit operates for 250 days per year.

Determine the

1. Optimal Run Size.
2. Minimum total annual cost for carrying and setup cost.
3. Cycle time for the Optimal Run Size.
4. Run time by using the formula

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$$

Solution

1. Optimal Run Size.
= Sq Root (2 X 250,000 X 2500/100)(Sq Root (2 000 /2000-1000))
= 2500(sq.root2X2) =5000 footballs.

2. Minimum total annual cost for carrying and setup cost.
= Carrying Cost + Set up Cost
=(I max/2)H+ (D/Q0)S
Where I max= Q0/p ((p-u))=5000/2000(1000)
=2500 footballs
Now TC= 2500/2 X 100 + (250,000/5000) (2500)
=1250 X 100 + 125,000
=125,000+ 125,000
= Rs. 250,000.

3. Cycle time for the Optimal Run Size.
Q0/U=5000/1000= 5 days

4. Run time
Q0/p=5000/2000= 2.5 days

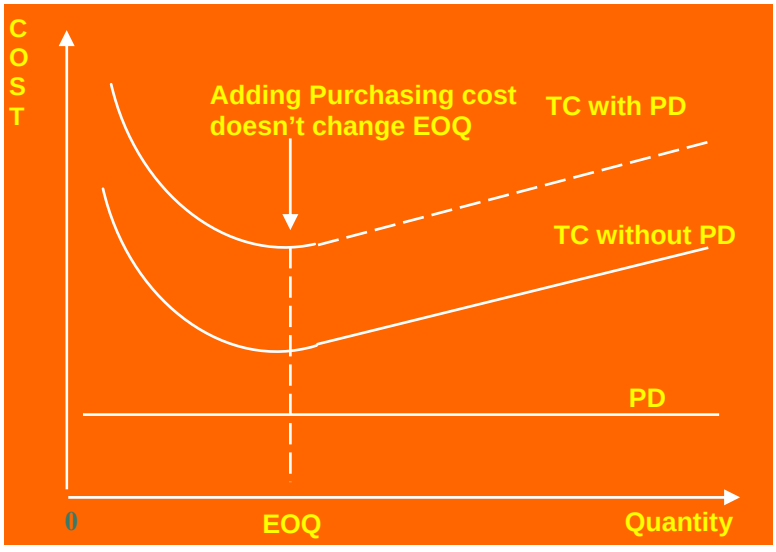
Quantity Discount: Price reductions for large orders are called Quantity Discounts.

Total Costs with Purchasing Cost

$$TC = \text{Annual carrying cost} + \text{Annual ordering cost} + \text{Purchasing cost}$$

$$TC = \frac{Q}{2}H + \frac{D}{Q}S + PD$$

Total Costs with PD



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Example for Optimal Order Quantity and Total Cost

The maintenance department of a large cardiology hospital in Islamabad uses about 1200 cases of corrosion removal liquid, used for maintenance of hospital. Ordering costs are Rs 100, carrying cost are Rs 20 per case, and the new price schedule indicates that orders of less than 50 cases will cost Rs 1250 per case, 50 to 79 cases will cost Rs 1150 per case , 80 to 99 cases will cost Rs 1050 per case and larger costs will be Rs 1000 per case.
Determine the Optimal Order Quantity and the Total Cost.
Given Data

D=1200 case.
S= Rs. 100 per case
H=Rs.20 per case

Range	Price
1 to 49	Rs 1250
50 to 79	Rs 1150
80 to 99	Rs 1050
100 or more	Rs 1000

Compute the Common EOQ=Sq Root (2DS/H)
= Sq Root (2 X 100 X 1200/20)
=Sq Root (12000)
=109.5=110 cases which would be brought at 1000 per order
The total Cost to Purchase 1200 cases per year would be
TC= Carrying Cost+ Order Cost+ Purchase Cost
$=(Q/2)H+(D/Q_0)S+PD$
=(110/2)20+(1200/110)100+1200X 1000
=1100+1091+12000,000
=Rs. 1,202,191
When to Reorder with EOQ Ordering
Reorder Point - When the quantity on hand of an item drops to this amount, the item is reordered.
Safety Stock - Stock that is held in excess of expected demand due to variable demand rate and/or lead time.
Service Level - Probability that demand will not exceed supply during lead time.

Example for Reorder Point

An apartment complex in Quetta requires water for its home use.
Usage= 2 barrels a day
Lead time= 5 days
ROP= Usage X Lead Time
= 2 barrels a day X 5 = 10 barrels

Determinants of the Reorder Point

1. The rate of demand
2. The lead time
3. Stock out risk (safety stock)
4. Demand and/or lead time variability

Example
An owner of a Montessori equipment firm in Karachi, determined from historical records that demand for wood required for Montessori equipment averages 25 tones per anum. His operations management expertise allowed him to determine the demand during lead that could be described by a normal distribution that has a mean of 25 tons and a standard deviation of 2.5 tons, with a stock out risk not limited to 6 percent.
a. Appropriate value of Z? Please use the table given on the next page (9)

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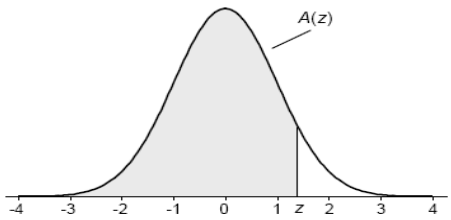
b. Safety stock level?
c. Reorder Point?
d. Expected weight of wood short for any order cycle, if he wants to maintain a service level of 80% Use the attached service level table. Please use the table given on page (10)
e. Annual Service Level, if service level =80

Area under the standardizes normal curve from -∞ to –z

A(z) is the integral of the standardized normal distribution from ∞−to z (in other words, the area under the curve to the left of z). It gives the probability of a normal random variable not being more than z standard deviations above its mean. Values of z of particular importance:



z	A(z)	
1.645	0.9500	Lower limit of right 5% tail
1.960	0.9750	Lower limit of right 2.5% tail
2.326	0.9900	Lower limit of right 1% tail
2.576	0.9950	Lower limit of right 0.5% tail
3.090	0.9990	Lower limit of right 0.1% tail
3.291	0.9995	Lower limit of right 0.05% tail

Cumulative Standardized Normal Distribution

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	0.9994	0.9995	0.9995	0.9995
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	0.9996	0.9996	0.9996	0.9997
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	0.9998
3.5	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998	0.9998

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Normal Distribution Service Levels and Unit Normal Loss Function

Z	S.L.	E(z)	Z	S.L.	E(z)	Z	S.L.	E(z)
-2.40	0.0082	2.4030	0.00	0.5000	0.3990	2.44	0.9927	0.0020
-2.36	0.0091	2.3630	0.04	0.5160	0.3790	2.48	0.9934	0.0020
-2.32	0.0102	2.3230	0.08	0.5319	0.3600	2.52	0.9941	0.0020
-2.28	0.0113	2.2840	0.12	0.5478	0.3420	2.56	0.9948	0.0020
-2.24	0.0125	2.2440	0.16	0.5636	0.3240	2.60	0.9953	0.0010
-2.20	0.0139	2.2050	0.20	0.5793	0.3070	2.64	0.9959	0.0010
-2.16	0.0154	2.1650	0.24	0.5948	0.2900	2.68	0.9963	0.0010
-2.12	0.0170	2.1260	0.28	0.6103	0.2750	2.72	0.9967	0.0010
-2.08	0.0188	2.0870	0.32	0.6255	0.2560	2.76	0.9971	0.0010
-2.04	0.0207	2.0480	0.36	0.6406	0.2370	2.80	0.9974	0.0008
-2.00	0.0228	2.0080	0.40	0.6554	0.2300	2.84	0.9977	0.0007
-1.96	0.0250	1.9690	0.44	0.6700	0.2170	2.88	0.9980	0.0006
-1.92	0.0274	1.9300	0.48	0.6844	0.2040	2.92	0.9982	0.0005
-1.88	0.0301	1.8920	0.52	0.6985	0.1920	2.96	0.9985	0.0004
-1.84	0.0329	1.8530	0.56	0.7123	0.1800	3.00	0.9987	0.0004
-1.80	0.0359	1.8140	0.60	0.7257	0.1690	3.04	0.9988	0.0003
-1.76	0.0392	1.7760	0.64	0.7389	0.1580	3.08	0.9990	0.0003
-1.72	0.0427	1.7370	0.68	0.7517	0.1480	3.12	0.9991	0.0002
-1.68	0.0465	1.6990	0.72	0.7642	0.1380	3.16	0.9992	0.0002
-1.64	0.0505	1.6610	0.76	0.7764	0.1290	3.20	0.9993	0.0002
-1.60	0.0548	1.6230	0.80	0.7881	0.1200	3.24	0.9994	0.0001
-1.56	0.0594	1.5860	0.84	0.7995	0.1120	3.28	0.9995	0.0001
-1.52	0.0643	1.5480	0.88	0.8106	0.1040	3.32	0.9995	0.0001
-1.48	0.0694	1.5110	0.92	0.8212	0.0970	3.36	0.9996	0.0001
-1.44	0.0749	1.4740	0.96	0.8315	0.0890	3.40	0.9997	0.0001
-1.40	0.0808	1.4370	1.00	0.8413	0.0830			
-1.36	0.0869	1.4000	1.04	0.8508	0.0770			
-1.32	0.0934	1.3640	1.08	0.8599	0.0710			
-1.28	0.1003	1.3280	1.12	0.8686	0.0660			
-1.24	0.1075	1.2920	1.16	0.8770	0.0610			
-1.20	0.1151	1.2560	1.20	0.8849	0.0560			
-1.16	0.1230	1.2210	1.24	0.8925	0.0520			
-1.12	0.1314	1.1860	1.28	0.8997	0.0480			
-1.08	0.1401	1.1510	1.32	0.9066	0.0440			
-1.04	0.1492	1.1170	1.36	0.9131	0.0400			
-1.00	0.1587	1.0830	1.40	0.9192	0.0370			
-0.96	0.1685	1.0490	1.44	0.9251	0.0340			
-0.92	0.1788	1.0170	1.48	0.9306	0.0310			
-0.88	0.1894	0.9840	1.52	0.9357	0.0280			
-0.84	0.2005	0.9520	1.56	0.9406	0.0260			
-0.80	0.2119	0.9200	1.60	0.9452	0.0230			
-0.76	0.2236	0.8890	1.64	0.9495	0.0210			
-0.72	0.2358	0.8580	1.68	0.9535	0.0190			
-0.68	0.2483	0.8280	1.72	0.9573	0.0170			
-0.64	0.2611	0.7980	1.76	0.9608	0.0160			
-0.60	0.2743	0.7690	1.80	0.9641	0.0140			
-0.56	0.2877	0.7400	1.84	0.9671	0.0130			
-0.52	0.3015	0.7120	1.88	0.9699	0.0120			
-0.48	0.3156	0.6840	1.92	0.9726	0.0100			
-0.44	0.3300	0.6570	1.96	0.9750	0.0090			
-0.40	0.3446	0.6300	2.00	0.9772	0.0080			
-0.36	0.3594	0.5970	2.04	0.9793	0.0080			
-0.32	0.3745	0.5760	2.08	0.9812	0.0070			
-0.28	0.3897	0.5550	2.12	0.9830	0.0060			
-0.24	0.4052	0.5300	2.16	0.9846	0.0050			
-0.20	0.4207	0.5070	2.20	0.9861	0.0050			
-0.16	0.4364	0.4840	2.24	0.9875	0.0040			
-0.12	0.4522	0.4620	2.28	0.9887	0.0040			
-0.08	0.4681	0.4400	2.32	0.9898	0.0030			
-0.04	0.4840	0.4190	2.36	0.9909	0.0030			
			2.40	0.9918	0.0030			

Expected Shortage per cycle:
E(n) = E(z) * s.d. dLT

Expected Shortage per year:
E(N) = E(n) * D/Q

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SOLUTION

a. Expected Lead Time Demand= 25 tonnes, also σ_{dLT}= 2.5 tonnes, Risk= 6%. Using the given table values, 1-0.06=.9400 therefore + Z=1.1.55

b. The safety stock = $Z\sigma_{dLT}$= 1.55 x 2.50 tonnes= 3.875 tonnes

c. Reorder Point = Expected Lead Time Demand + Safety Stock
= 25 tonnes + 3.875=28.875 tonnes

d. From the Service Level Table, Lead time Service Level z=0.8 therefore E(z)=0.7881,using the formula E(n)=E(z) X σ_{dLT}
Now Since σ_{dLT}= 2.5 tonnes
Therefore E(n)=0.7881(2.50)=39.41 tonnes= 1.97025 tonnes

e. SL_{annual}= 1-E(z) σ_{dLT}/Q

Now Since Q= 25 tonnes, E(z)=

We can calculate the Annual Service Level by substituting values in the formula above

SL_{annual}= 1-0.7881(2.5)/25
=1-0.7881(0.1)
=1-0.07881
=0.921

Fixed-Order-Interval Model

1. Orders are placed at fixed time intervals.
2. Order quantity for next interval?
3. Suppliers might encourage fixed intervals.
4. May require only periodic checks of inventory levels.
5. Risk of stock out.

Summary

In this lecture we studied various important concepts relating to Inventory Management. Most importantly we learnt how to make use of statistical tables to calculate lead points and service levels. This lecture forms the basis for Supply Chain Management and Just In Time Production Systems.

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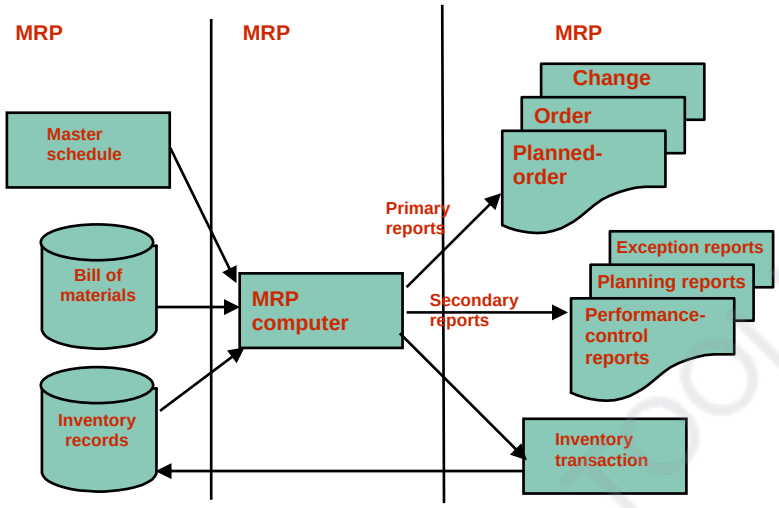
MATERIAL REQUIREMENTS PLANNING / ENTERPRISE RESOURCE PLANNING

Learning Objectives

- Describe the conditions under which MRP is most appropriate.
- Describe the inputs, outputs and nature of MRP processing.
- Explain how requirements in a Master Production Schedule are translated into material requirements for lower level items.
- Discuss benefits and requirements of MRP.

MRP

Material requirements planning (MRP): Computer-based information system that translates master schedule requirements for end items into time-phased requirements for subassemblies, components, and raw materials.



Independent and Dependent Demand

Dependent demand: Demand for items that are subassemblies or component parts to be used in production of finished goods. Once the independent demand is known, the dependent demand can be determined.

Cumulative lead time: The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

MPR Inputs

MRP has three Inputs

- Master Schedule Plan
- Bill of Materials
- Inventor Records

Master Production Schedule

- Time-phased plan specifying timing and quantity of production for each end item.
- Material Requirement Planning Process

Master Schedule

Master schedule: One of three primary inputs in MRP; states which end items are to be produced, when these are needed, and in what quantities.

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Cumulative lead time: The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

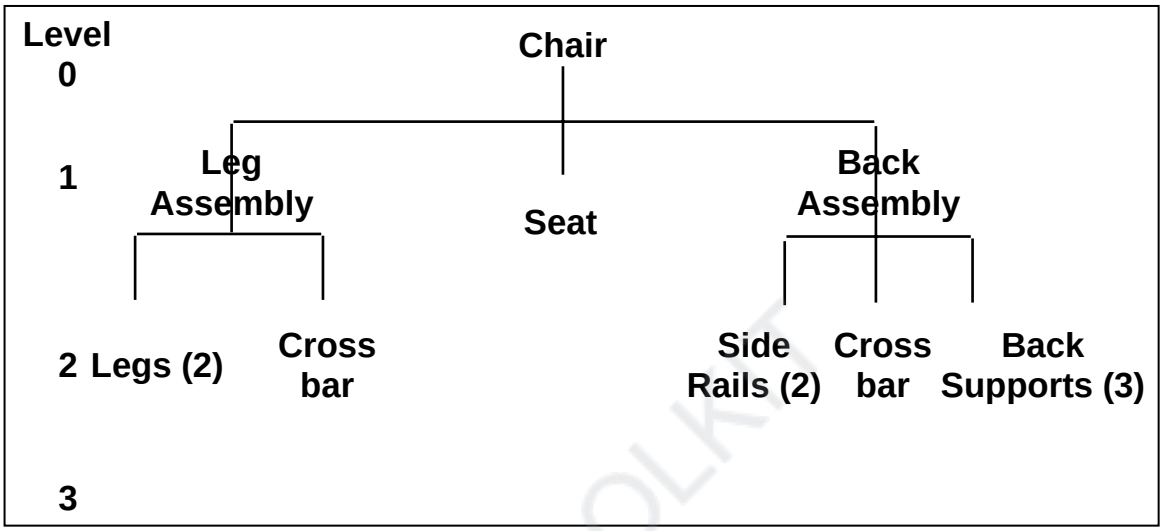
Planning Horizon

Bill-of-Materials

Bill of materials (BOM): One of the three primary inputs of MRP; a listing of all of the raw materials, parts, subassemblies, and assemblies needed to produce one unit of a product.

Product Structure Tree

Product structure tree: Visual depiction of the requirements in a bill of materials, where all components are listed by levels.



Inventory Records

- One of the three primary inputs in MRP
- Includes information on the status of each item by time period
- Gross requirements
- Scheduled receipts
- Amount on hand
- Lead times
- Lot sizes
- And more …
- Assembly Time Chart
- *Cumulative lead time*: The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

MRP Processing

1. Gross requirements
2. Schedule receipts
3. Projected on hand
4. Net requirements
5. Planned-order receipts
6. Planned-order releases

Updating the System

1. Regenerative system
2. Updates MRP records periodically

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3. Net-change system
4. Updates MPR records continuously

MRP Outputs

1. Planned orders - schedule indicating the amount and timing of future orders.
2. Order releases - Authorization for the execution of planned orders.
3. Changes - revisions of due dates or order quantities, or cancellations of orders.

MRP Secondary Reports

1. Performance-control reports
2. Planning reports
3. Exception reports

Other Considerations

- Lot sizing is the Choosing of a lot size for ordering or production.
- For dependant demand, managers have variety of methods available as there is no clear cut advantage associated with anyone particular method. They can use
    1. Lot for Lot Ordering.
    2. Economic Order Quantity Model
    3. Fixed Period Ordering
    4. Part Period Model.
- Lot-for-lot ordering
    1. Simplest method
    2. The order or run size for EACH period is set equal to demand for that period.
    3. Eliminates holding costs for parts carried over to other periods.
    4. Minimizes investment in inventory.
    5. It involves different order sizes (can not make use of fixed order size , standard containers and standardized procedures) and requires a new setup for each run.
    6. If set up costs can be reduced this would be ideal to approximate the minimum cost lot size.
- Economic order quantity models tend to be less ideal.
- Fixed Period Ordering provides coverage for some predetermined number of periods.
- Rule of thumb being to order to cover a two period interval.
- Part-Period Model represents an attempt to balance set up and holding costs.
- The part period term refers to holding part or parts over a number of periods, e.g. if a business holds 20 parts for 3 periods this would be a 20 X 3= 60 parts period.
- Economic Part Period (EPP) is the ratio of setup costs to the cost of hold a unit for one period.
- Part-Period Model
- Various order sizes are examined for planning horizon and each one\s number of part period is determined.
- The one that is closet to the EPP is selected as the best lot size.

Example for Part Period Method

Use part-period method to determine order sizes for the demand schedule of a Montessori equipment manufacturer in Karachi. The setup cost is Rs. 8000 per run for this item and unit holding cost is Rs. 100 per period.
Data.

PERIODS								
	1	2	3	4	5	6	7	8
DEMAND	60	40	20	2	30	-	70	50
CUMULATIVE DEMAND	60	100	120	122	152	152	222	272

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•STEP I : First compute EPP which is 8000/100=80

PERIODS					
Period when order is placed	**Lot Size**	**Extra Inventory carried**	**Multiplied by Periods carried**	**Part Periods**	**Cumulative Part Periods**
1	60	0	0	0	0
	100	40	1	40	40
	120	**20**	**2**	**40**	**80**
	122	**2**	**3**	**6**	**86**
5	**30**	**0**	**0**	**0**	**0**

- Our calculations show that we need to order 122 units to be available at period 1 and 100 units should be ordered available at period 5.
- The effect of lumpy demands set in period 5 and period 8.

Benefits of MRP

- Low levels of in-process inventories
- Ability to track material requirements
- Ability to evaluate capacity requirements
- Means of allocating production time

VU TOOLKIT

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Lesson 35

MATERIAL REQUIREMENTS PLANNING - II/ ENTERPRISE RESOURCE PLANNING

Learning Objectives

- Discuss benefits and requirements of MRP.
- Explain how an MRP system is useful in Capacity Requirements
- Benefits and shortcomings of MRP
- MRP II and MRP.

MRP: A Recap

1. **Material Requirements Planning (MRP)** is software focusing on production planning and inventory control system used to manage manufacturing processes.
2. An MRP system is intended to simultaneously meet three objectives:
    1. Ensure materials and products are available for production and delivery to customers.
    2. Maintain the lowest possible level of inventory.
    3. Plan manufacturing activities, delivery schedules and purchasing activities.

MRP Processing

1. Gross requirements
    a. Total expected demand.
2. Scheduled receipts
    a. Open orders scheduled to arrive.
3. Planned on hand
    a. Expected inventory on hand at the beginning of each time period.
4. Net requirements
    a. Actual amount needed in each time period.
5. Planned-order receipts
    a. Quantity expected to be received at the beginning of the period.
    b. Offset by lead time.
6. Planned-order releases
    a. Planned amount to order in each time period.

Updating the MRP Systems

1. Regenerative system
    a. Updates MRP records periodically.
2. Net-change system
    a. Updates MPR records continuously.

MRP in Services

1. Food catering service
2. End item => catered food
3. Dependent demand => ingredients for each recipe, i.e. bill of materials
4. Hotel renovation
5. Activities and materials “exploded” into component parts for cost estimation and scheduling

Benefits of MRP

1. Low levels of in-process inventories
2. Ability to track material requirements
3. Ability to evaluate capacity requirements
4. Means of allocating production time

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Requirements of MRP

1. Computer and necessary software
2. Accurate and up-to-date
3. Master schedules
4. Bills of materials
5. Inventory records
6. Integrity of data

MRP II

1. Expanded MRP with emphasis placed on integration
2. Financial planning
3. Marketing
4. Engineering
5. Purchasing
6. Manufacturing

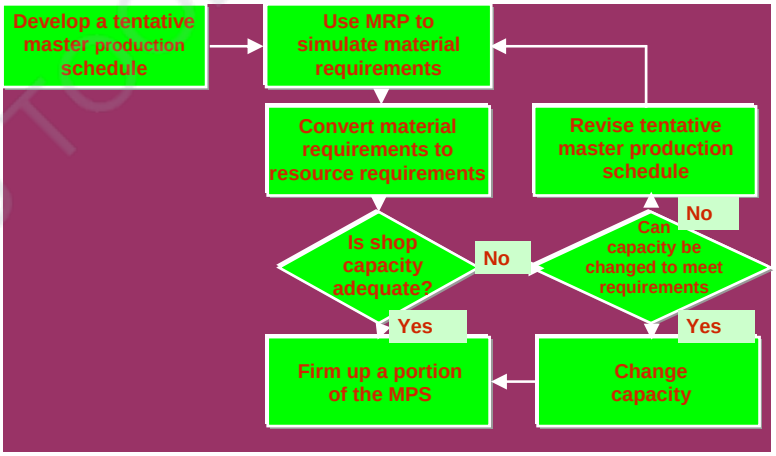
Capacity Planning

Capacity requirements planning: The process of determining short-range capacity requirements.
Load reports: Department or work center reports that compare known and expected future capacity requirements with projected capacity availability.
Time fences: Series of time intervals during which order changes are allowed or restricted.

As an operations manager we should be able to identify the process of Capacity Planning. Infact the Capacity requirements planning process determines short-range capacity requirements. The necessary inputs are:

1. Planned order releases for MRP
2. The current shop load
3. Routing information
4. Job times

Outputs include load reports for each work center.



Load reports: Department or work center reports that compare known and expected future capacity requirements with projected capacity availability.
An organization generates a Master Schedule in terms of what is needed and not in terms of what is possible or available.

An over view of the capacity planning process includes the following.

1. The Master schedule is first tested for feasibility and possibly adjusted before it becomes permanent.
2. The proposed schedule is processed using MRP to ascertain the materials requirements the schedule would generate.
3. These are then translated into capacity requirements in the form of load reports for each departments or work centers.

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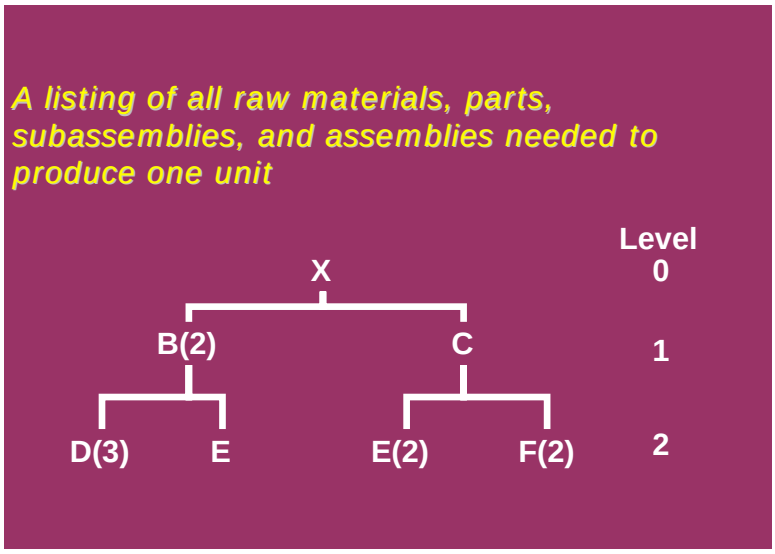
The initial schedule may or may not be feasible given the limits of production or availability of materials. Also, with the aid of Time fences (the series of time intervals during which order changes are allowed or restricted) a feasible schedule may be finalized.



MRP II

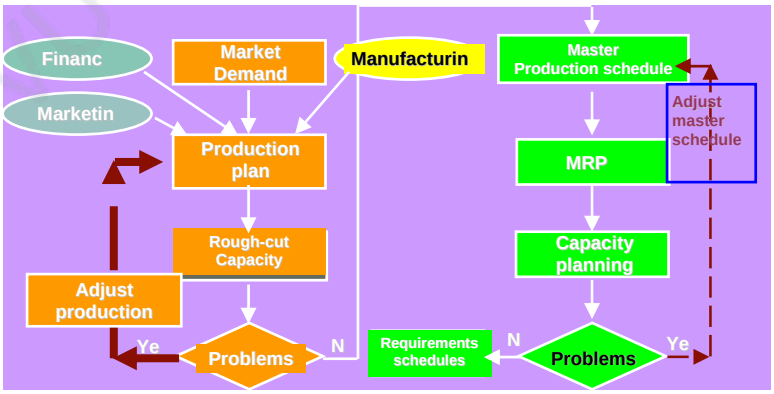
Manufacturing Resource Planning (**MRP II**) is defined and accepted by professionals as a method for the effective planning of all resources of a manufacturing company.

Ideally, it should answer operational planning in units, financial planning in rupees, and has a simulation capability to answer "what-if" questions. and extension of closed-loop MRP.

This is not exclusively a software function, but a merger of people skills, dedication to data base accuracy, and computer resources. It is a total company management concept for using human resources more productively.

Accounting and finance departments get accurate costs and predict cash flows. Operations and Engineering departments audit and feed in accurate data on production methods in detail, such as:

1. Bill of Materials
2. Quality Control based operational and functional data.



ERP

Enterprise resource planning (ERP): often called the rightful next step in an evolution that began with MPR and evolved into MRPII. Integration of financial, manufacturing, and human resources on a single computer system.

ERP Strategy Considerations

1. High initial cost
2. High cost to maintain

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3. Future upgrades
4. Training

Summary

- Materials Requirements Planning (MRP) is an information Systems used to handle ordering of dependent demand items (components of assembled products)
- The planning process begins with customer orders, which are used along with any back orders to develop a Master Schedule that indicates timing and quantity of finished goods.
- The end items are exploded using the bill of materials; Material Requirement Plans are developed show quantity and timing for ordering or producing components.
- The main features of MRP are the time phasing of requirements, calculating component requirements and planned order releases.
- To be successful MRP requires a computer program and accurate master production schedules, bills of materials and inventory data.
- Firms can only implement MRP if they have accurate records
- MRP II links business planning, production planning and the MPS. ERP's are more refined as well as comprehensive versions of MRP.

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JUST IN TIME PRODUCTION SYSTEM

Just In Time Production or Lean Production systems focus on the efficient delivery of products or services. Some of the distinguishing elements of the JIT systems are a pull method to manage material flow, consistently high quantity, small lot sizes, uniform work station loads. The JIT systems provide an organizational structure for improved supplier coordination by integrating the logistics, production and purchasing processes. When Operations Manager focuses on their organization's competitive advantage they aim for low cost of production, consistent quality with reductions in inventory, space requirements, paperwork and increases in productivity, employee participation and effectiveness.

JIT/Lean Production

Lean Manufacturing: is a management philosophy focusing on reduction of the seven wastes.

1. Over-production (Capacity exceeding demand)
2. Waiting time
3. Transportation
4. Processing
5. Costs
6. Inventory
7. Motion (Lack of coordination of body movements)

JIT/Lean Production Features

- By eliminating waste (muda), quality is improved, production time is reduced and cost is reduced.
- "Pull" production (by means of Kanban).
- While some believe that Lean Manufacturing is a set of problem solving tools.
- In addition, experts in this field believe that philosophy-based Lean Manufacturing strategy is the most effective way to launch and sustain lean activities.

Key lean manufacturing principles

1. Key lean manufacturing principles include:
2. Perfect first-time quality - quest for zero defects
3. Waste minimization
4. Continuous improvement
5. Pull processing: products are pulled from the consumer end, not pushed from the production end.
6. Flexibility
7. Building and maintaining a long term relationship with suppliers through collaborative risk sharing, cost sharing and information sharing arrangements.

Applications of Lean Manufacturing

1. Lean Healthcare Systems
2. Lean Software Manufacturing
3. Systems Engineering
4. Lean Systems in Defense Industry

Generic Strategy for Implementation of a Lean program

1. Top Management to agree and discuss their lean vision.
2. Management brainstorm to identify project leader and set objectives.
3. Communicate plan and vision to the workforce.

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4. Ask for volunteers to form the Lean Implementation team.
5. Appoint members of the Lean Manufacturing Implementation Team.
6. Train the Implementation Team in the various lean tools.

Organizational and Operational Strategies

1. Organizations aiming for JIT system should focus on the Human Resource Management with proper system of incentives, rewards, labor classification, cooperation and trust in place.
2. Organizations should concentrate on effective management of inventory, purchasing, logistics and scheduling.
3. Organizations should develop a demand base system so less waste is generated and good management of high quality, small lot sizes, good quality, standardized components and work methods is ensured.
4. Lean or JIT Systems are effective only if they are designed to produce or deliver the right product or the right services in the right quantities just in time to serve subsequent processes or customers.
5. Organizations who design their Operations on JIT philosophy need to encourage partnership concept whether it's between organizations's purchasing department and supplier or partnership between management and labor.

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JUST IN TIME PRODUCTION SYSTEM (Contd.)

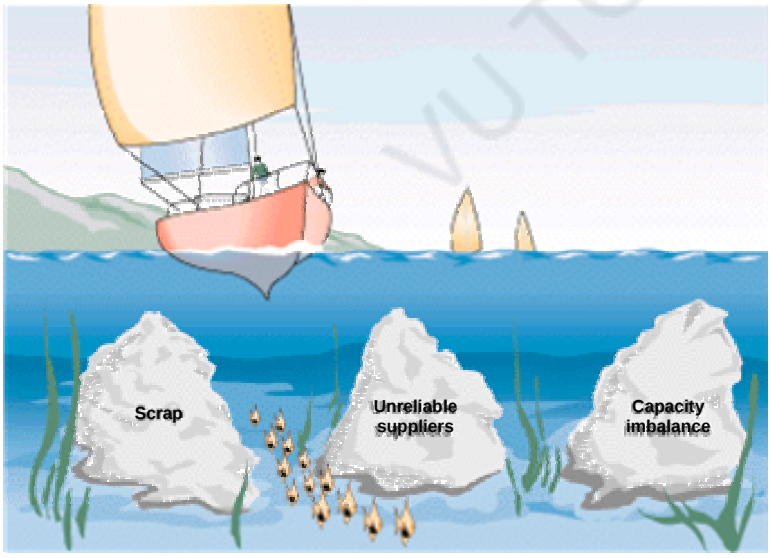
We have progressed our discussion on Lean Production Systems and Just In Time Systems and we will now focus our attention upon Lean Systems in Services, Operational Benefits associated with JIT. We will also note some of the common Implementation Issues along which the Organizational face while implementing JIT. We also need to know what single Kanban System is and solve some examples.

Characteristics of Lean Systems: Just-in-Time

Continuous Improvement with the help of Lean Systems is possible if Operations Managers are able to focus on some of the common characteristics of Lean Systems, which include:

1. Pull method of materials flow
2. Consistently high quality
3. Small lot sizes
4. Uniform workstation loads
5. Standardized components and work methods
6. Close supplier ties
7. Flexible workforce
8. Line flows
9. Maintenance
10. Automated production
11. Preventive maintenance

The figure below of a ship sailing through waters is a great representation of an organization carrying its business with hidden rocks (barriers) like scrap, unreliable suppliers and capacity imbalance, carrying the threat of sinking the ship. With proper and effective lean production system philosophy in place, this can be avoided and organization can continue to sail through smooth and calm waters.



Lean Systems in Services

1. Consistently high quality
2. Uniform facility loads
3. Standardized work methods
4. Close supplier ties
5. Flexible workforce
6. Automation

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7. Preventive maintenance
8. Pull method of materials flow
9. Line flows

Operational Benefits

1. Reduce space requirements
2. Reduce inventory investment
3. Reduce lead times
4. Increase labour productivity
5. Increase equipment utilization
6. Reduce paperwork and simple planning systems
7. Valid priorities for scheduling
8. Workforce participation
9. Increase product quality

Implemental Issues

1. Organizational considerations
    a. Human cost of JIT systems
    b. Cooperation and trust
    c. Reward systems and labour classifications
2. Process considerations
3. Inventory and scheduling
    a. MPS stability
    b. Setups
    c. Purchasing and logistics

Kanban Production Control System

Kanban: Card or other device that communicates demand for work or materials from the preceding station.
Kanban is the Japanese word meaning "signal" or "visible record".
Paperless production control system.
Authority to pull, or produce comes from a downstream process.
Kanbans also govern the assembly or Parts' movement authorization

Kanban Formula

We can mathematically construct the Kanban Formula, If we designate the following alphabets
N = Total number of containers (Or Kanban Cards)
D = Planned usage rate of using work center
T = Average waiting time for replenishment of parts
plus average production time for a
container of parts
X = Policy variable set by management
- possible inefficiency in the system often called Alpha
C = Capacity of a standard container

$$N = \frac{DT(1+X)}{C}$$

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Often the same formula above is used with the following parameters in mind

N= # cards
D= usage
T = wait + process time
X = efficiency rating
C = bin capacity

Example

A company in Gujranwala is making rubber tyres and tubes. The operations manager has just completed his MBA from VU and has observed the that factory has inefficient machine group. He records that the daily demand for 21" tube is 1000 units. The average waiting time for a container of the same part is 0.5 day. The processing time for the tyre tube container is 0.25 day. A container can hold 500 units, currently there are 20 containers for this item.

Calculate

1. What is the value of policy variable ALPHA?
2. What is the total planned inventory (work in process and finished goods) for the tyre tube?
3. Suppose that the policy variable Alpha is 0, how many containers would be needed? what is the effect of policy variable in this problem?

Solution

The given data is

- d is 1000 units, w bar = 0.5 day.
- P bar= 0.25 day. K= 500 units and Alpha is to be calculated.

We use the equation and substitute values

$$k = \frac{d(\bar{w} + \bar{p})(1 + \alpha)}{c}$$

Then with 20 containers in the system and since each container can hold 500 units, the total planned inventory is 20 (500)= 10,000 units

If Alpha is 0 then on substituting values we have

$$500 = \frac{1000(0.5 + 0.25)(1 + \alpha)}{20}$$

(1 + *a*)=500 X 20 / 1000 (0.75)
(1 + *a*)=10,000/750=13.33
a =12.33

- Then with 20 containers in the system and since each container can hold 500 units, the total planned inventory is 20 (500)= 10,000 units
- If Alpha is 0 then on substituting values we have

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$$k = \frac{1000(0.5 + 0.25)(1 + 0)}{500}$$

$$k \frac{1000(0.75)(1)}{500}$$

K= 750/500= 1.5 or more correctly 2 containers.

Single-Card Kanban System

1. Each container must have a card.
2. Assembly always withdraws from fabrication (pull system).
3. Containers cannot be moved without a kanban.
4. Containers should contain the same number of parts.
5. Only good parts are passed along.
6. Production should not exceed authorization.

Summary

Organizations use different methods and means to signal the need for material replenishment and production, in this lecture we studied the effective kanban system and learnt how a single card Kanban, JIT System can be used to control production flow.

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JUST IN TIME PRODUCTION SYSTEM (Contd.)

Just In Time system provides an organization a robust structure by improving the relationship between the organization and the supplier by constituting a strategic alliance network between the organization and the suppliers. At the intra organization level, JIT forms a healthy alliance between the management and the workforce, all this contributes in elimination of waste.

JUST IN TIME

- Just-In-Time (JIT): JIT can be defined as an integrated set of activities designed to achieve high-volume production using minimal inventories (raw materials, work in process, and finished goods).
- JIT also involves the elimination of waste in production effort.
- JIT also involves the timing of production resources (i.e., parts arrive at the next workstation "just in time").

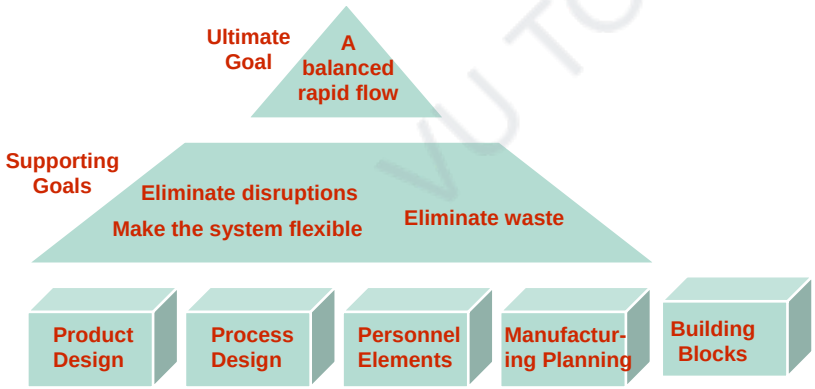
Just-in-time (JIT): A highly coordinated processing system in which goods move through the system, and services are performed, just as they are needed. As operations managers we should remember this point onwards that

1. JIT is also known as lean production
2. JIT is the true pull (demand) system
3. JIT operates with very little "fat"

.

Summary JIT Goals and Building Blocks

Goal of JIT: The ultimate goal of JIT is a balanced system. JIT achieves a smooth, rapid flow of materials through the system. The ultimate as well as supporting goals are represented below in the form of a pyramid.



We need to pay special attention on building blocks along with secondary blocks as absence of one or more objectives can seriously harm the JIT production structure for any manufacturing or service based organization.

Secondary Goals

1. Eliminate disruptions
2. Make system flexible
3. Eliminate waste, especially excess inventory

Big vs. Little JIT

1. Big JIT – broad focus (Includes Internal as well as External)
   a. Vendor relations

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b. Human relations
c. Technology management
d. Materials and inventory management

2. Little JIT – narrow focus Internal to organization
   a. Scheduling materials
   b. Scheduling services of production

JIT Building Blocks

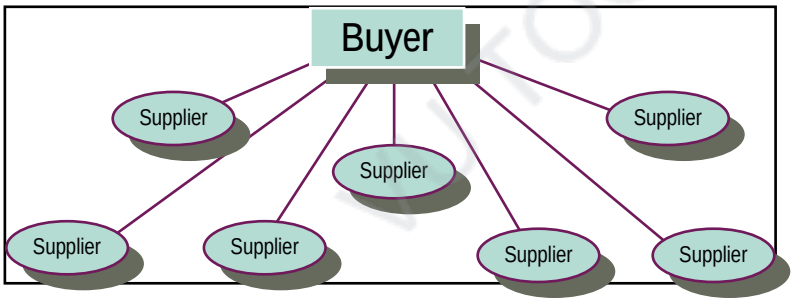
1. Product design
2. Process design
3. Personnel/organizational elements
4. Manufacturing planning and control

The Lean Production System
Based on two philosophies:
1. Elimination of waste

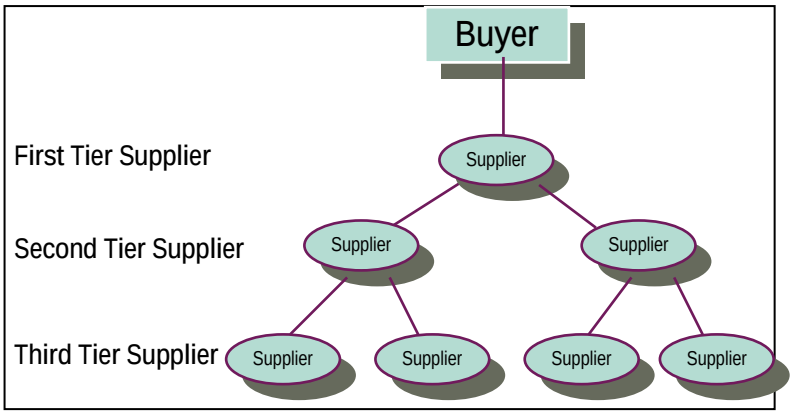
2. Respect for people

Traditional Supplier Network

1. The organizations make its suppliers compete against each other.
2. Also the suppliers can supply the same component or raw material to the organizations competitors thus harming the organizations business.
3. Organizations tend to waste resources and a lot of time looses its suppliers to the competitors.
4. Suppliers too end up absorbing poor order placement from the organizations.
5. The whole network faces sluggishness or inertia.



Tiered Supplier Network



1. The suppliers work as a strategic alliance to provide components to the organization.
2. Inventory costs as well as the overall time involved are reduced.

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3. Order execution is improved and organizations do not face the challenge of loosing its suppliers to the competitors.
4. There is little or no rivalry between the suppliers

Transitioning to a JIT System

1. Get top management commitment
2. Decide which parts need most effort
3. Obtain support of workers
4. Try to reduce scrap material
5. Start by trying to reduce setup times
6. Incorporate quality
7. Gradually convert operations
8. Convert suppliers to JIT
9. Prepare for obstacles

Obstacles to Conversion

1. Management may not be committed
2. Workers/management may not be cooperative
3. Suppliers may resist

JIT in Services

The basic goal of the demand flow technology in the service organization is to provide optimum response to the customer with the highest quality service and lowest possible cost.

1. Eliminate disruptions
2. Make system flexible
3. Reduce setup and lead times
4. Eliminate waste
5. Simplify the process

JIT in Services (Examples)

1. Upgrade Quality
2. Clarify Process Flows
3. Develop Supplier Networks
4. Introduce Demand-Pull Scheduling
5. Reorganize Physical Configuration
6. Eliminate Unnecessary Activities
7. Level the Facility Load

JIT II

JIT II: a supplier representative works right in the company's plant, making sure there is an appropriate supply on hand.

Benefits of JIT Systems

1. Reduced inventory levels
2. High quality
3. Flexibility
4. Reduced lead times
5. Increased productivity

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Summary

JIT systems allow an organization to achieve a balanced smooth flow of production, more system flexibility with reduction in wastes and lead time. Proper emphasis on the process and product design along with personnel management can provide the necessary control and reward of achievement of JIT or Lean Production systems.

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SUPPLY CHAIN MANAGEMENT

Supply Chain: The sequence of organization's facilities, functions, and activities that are involved in producing and delivering a product or service.

Need for Supply Chain Management

1. Improve operations
2. Increasing levels of outsourcing
3. Increasing transportation costs
4. Competitive pressures
5. Increasing globalization
6. Increasing importance of e-commerce
7. Complexity of supply chains
8. Manage inventories

Benefits of Supply Chain Management

1. Lower inventories
2. Higher productivity
3. Greater agility
4. Shorter lead times
5. Higher profits
6. Greater customer loyalty

Elements of Supply Chain Management

Element	Typical Issues
Customers	Determining what customers want
Forecasting	Predicting quantity and timing of demand
Design	Incorporating customer wants, mfg., and time
Processing	Controlling quality, scheduling work
Inventory	Meeting demand while managing inventory costs
Purchasing	Evaluating suppliers and supporting operations
Suppliers	Monitoring supplier quality, delivery, and relations
Location	Determining location of facilities
Logistics	Deciding how to best move and store materials

Logistics

The goal of logistic work is to manage the completion of project life cycles, supply chains and resultant efficiencies. Often Logistics is termed as the art and science of managing and controlling the flow of goods, energy, information and other resources like products, services, and people, from the source of production to the marketplace.

It also refers to the movement of materials and information within a facility and to incoming and outgoing shipments of goods and materials in a supply chain.

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Logistics is the time related positioning of resources and is commonly seen as a branch of engineering which creates "people systems" rather than "machine systems. It involves the integration of information, transportation, inventory, warehousing, material handling, and packaging.

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Important Characteristics of Logistics

1. Movement within the facility
2. Bar coding
3. Incoming and outgoing shipments
4. EDI (Electronic Data Interchange)
5. Distribution
6. JIT Deliveries

Logistics: Evaluating Shipping Alternatives

- A situation that arises frequently in some businesses in making a choice between quicker(expensive) shipping alternatives such as overnight or 2 day air and slower but cheaper alternatives. The decision in such cases often focuses on the cost savings of alternatives versus the increased holding cost that result from using slower alternative.
- Often the supplier gets paid on delivery of the product through EDI the very same time the order reaches its destination.
- The Incremental Holding cost incurred by using the slower alternative is computed as follows:
  Incremental Holding Cost= H (d/365)
  Where H=Annual Holding cost for the item.
  d = Time savings in days and d/365 is fraction of year saved.

Logistics Example

Determine the shipping alternative (with in Pakistan) for a Karachi based Montessori toy manufacturer,1 days or 5 days are best when the holding cost of the item is Rs. 100,000 per year and the 1 day shipping cost is Rs 1500. and 3 day shipping cost is
Rs. 600
Rs. 500

Solution

H= Rs. 100,000 per year
Time savings = 2 days using 1 day alternative
Holding cost for additional 2 days
= 100,000 X (2/365)
= Rs. 547.95=548.
Or Holding cost per day = Rs. 274

Alternative A

Cost savings = Rs. (1500-600)= Rs. 900, because the actual cost of savings of Rs 900 is more than the holding cost of Rs. 548, use the 3 day option.
Cost savings = Rs. (1500-500)= Rs. 1000, because the actual cost of savings of Rs 1000 is greater than the holding cost of Rs.548, use the 3 day option.

Distribution Requirements Planning

Distribution requirements planning (DRP) is a system for inventory management and distribution planning. Extends the concepts of MRPII.

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Uses of DRP

Management uses DRP to plan and coordinate:

1. Transportation
2. Warehousing
3. Workers
4. Equipment
5. Financial flows

Electronic Data Interchange

EDI is the direct transmission of inter-organizational transactions, computer-to-computer, including purchase orders, shipping notices, and debit or credit memos.
Electronic Data Interchange gives an organization the following benefits and advantages.

1. Increased productivity
2. Reduction of paperwork
3. Lead time and inventory reduction
4. Facilitation of just-in-time systems
5. Electronic transfer of funds
6. Improved control of operations
7. Reduction in clerical labor
8. Increased accuracy

Efficient Consumer Response

Efficient consumer response (ECR) is a supply chain management initiative specific to the food industry. ECR reflects companies' efforts to achieve quick response using EDI and bar codes.

E-Commerce: is the use of electronic technology to facilitate business transactions.

Successful Supply Chain

1. Trust among trading partners
2. Effective communications
3. Supply chain visibility
4. Event-management capability
    a. The ability to detect and respond to unplanned events
5. Performance metrics

Summary

Supply Chain Management is primarily the flow of information which ensures the effective flow of materials throughout the value chain. The chain extends from the Suppliers to the organization and from the organization to the customers. Operations Managers should be able to identify that the strength of the Supply Chain is the strength of its weakest link. If an organization fails to make use of the customer feed back it not only looses its customer base but also weakens its supply chain and loses its business to its customers. Suppliers normally come at the upstream of the organization and customers at the downstream to complete the Supply Chain. Many Software are available to ensure that Supply chain is managed effectively by the organization. Supply Chain Management is now gaining popularity in Pakistan.

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SUPPLY CHAIN MANAGEMENT (Contd.)

Learning Objective

In this lecture we will focus on certain important parameters of Supply Chain Management. We will discuss the Supply Chain Operational Reference Metrics and Collaborative Planning Forecasting and Replenishment Process, which would help us analyze the Supply chains. This would also help us an operation manager to design effective supply chains. We will try to understand the concepts of Velocity and Bullwhip effect and how they pose a serious challenge to the effectiveness of the Supply Chain.

Supply Chain Operational Reference (SCOR) Metrics

Perspective	Metrics
Reliability	On-time delivery Order fulfillment lead time Fill rate (fraction of demand met from stock) Perfect order fulfillment
Flexibility	Supply chain response time Upside production flexibility Agility to obtain competitiveness
Expenses	Supply chain management costs Warranty cost as a percent of revenue Value added per employee
Assets/utilization	Total inventory days of supply Cash-to-cash cycle time Net asset turns

Supply chain response time often makes or breaks a supply chain.

CPFR

CPFR is an acronym derived from the first letters of the following phrase: Collaborative Planning, Forecasting and Replenishment.

1. Focuses on information sharing among trading partners.
2. Forecasts can be frozen and then converted into a shipping plan.
3. Eliminates typical order processing.

CPFR Process consists of the following steps.

Step 1 – Front-end agreement
Step 2 – Joint business plan
Steps 3-5 – Sales forecast
Steps 6-8 – Order forecast collaboration
Step 9 – Order generation/delivery execution

Creating an Effective Supply Chain

1. Develop strategic objectives and tactics.
2. Integrate and coordinate activities in the internal supply chain.
3. Coordinate activities with suppliers with customers.
4. Coordinate planning and execution across the supply chain.
5. Form strategic partnerships.

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Supply Chain Performance Drivers

1. Quality
2. Cost
3. Flexibility
4. Velocity
5. Customer service

Velocity

1. Inventory velocity: The rate at which inventory (material) goes through the supply chain.
2. Information velocity: The rate at which information is communicated in a supply chain.

Challenges to an Effective Supply Chain Management

1. Barriers to integration of organizations
2. Getting top management on board
3. Dealing with trade-offs
4. Small businesses
5. Variability and uncertainty
6. Long lead times

Trade-offs

1. Cost-customer service
    a. Disintermediation
2. Lot-size-inventory
    a. Bullwhip effect
3. Inventory-transportation costs
    a. Cross-docking
4. Lead time-transportation costs
5. Product variety-inventory
    a. Delayed differentiation

- Bullwhip effect represents the real life time situation that Inventories are progressively larger moving backward through the supply chain.
- Cross-docking represents the fact that the goods arriving at a warehouse from a supplier are unloaded from the supplier's truck and loaded onto outbound trucks. Avoids warehouse storage.
- Delayed differentiation relates to the Production of standard components and subassemblies, which are held until late in the process to add differentiating features.
- Disintermediation is reducing one or more steps in a supply chain by cutting out one or more intermediaries.

Supply Chain Issues

Strategic Issues	Tactical Issues	Operating Issues
Design of the supply chain, partnering	Inventory policies Purchasing policies Production policies Transportation policies Quality policies	Quality control Production planning and control

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Supply Chain Benefits and Drawbacks

Problem	Potential Improvement	Benefits	Possible Drawbacks
Large inventories	Smaller, more frequent deliveries	Reduced holding costs	Traffic congestion Increased costs
Long lead times	Delayed differentiation Disintermediation	Quick response	May not be feasible. May need absorb functions
Large number of parts	Modular	Fewer parts Simpler ordering	Less variety
Cost Quality	Outsourcing	Reduced cost, higher quality	Loss of control
Variability	Shorter lead times, better forecasts	Able to match supply and demand	Less variety

Supplier Partnerships

Ideas from suppliers could lead to improved competitiveness

1. Reduce cost of making the purchase
2. Increase Revenues
3. Enhance Performance

Critical Issues

1. Technology management
    a. Benefits
    b. Risks
2. Strategic importance
    a. Quality
    b. Cost
    c. Agility
    d. Customer service
    e. Competitive advantage

Operations Strategy

1. SCM creates value through changes in time, location and quantity.
2. SCM creates competitive advantage by integrating and streamlining the diverse range of activities that involve purchasing, internal inventory, transfers and physical distribution.

Summary

Supply Chain Management dynamics allow an Operations Manager to evolve an effective strategy that creates value. Logistics and purchasing alone can allow an operations manager to effectively control the flow of information and materials with in and to and fro from the organization. Organizations aiming for SCM implementation often fail because of lack of training of their employees as well as top managements commitment.

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SCHEDULING

Learning Objectives

After completing the introductory discussion on Scheduling, the students would be able to understand what scheduling is and how important it is to high volume and intermediate volume systems. It would also help them to learn how to address scheduling needs in Job shops. The students would also learn the use and interpretation of Gantt Charts. They would also use Assignment method for loading along with common Priority Rules. They would also learn the common and unique scheduling problems in Service Systems.

Scheduling

Scheduling: Scheduling is an important tool for manufacturing and service industries where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility what to make, when, with which staff, and on which equipment. Similarly, scheduling in service industries, such as airlines and public transport, aim to maximize the efficiency of the operation and reduce costs.

Scheduling

Modern computerized scheduling tools greatly outperform older manual scheduling methods. This provides the production scheduler with powerful graphical interfaces which can be used to visually optimize real-time work loads in various stages of the production, and pattern recognition allows the software to automatically create scheduling opportunities which might not be apparent without this view into the data. For example, an airline might wish to minimize the number of airport gates required for its aircraft, in order to reduce costs, and scheduling software can allow the planners to see how this can be done, by analyzing time tables, aircraft usage, or the flow of passengers.

Scheduling

Companies use backward and forward scheduling to plan their human and material resources. Backward scheduling is planning the tasks from the due date to determine the start date and/or any changes in capacity required, whereas forward scheduling is planning the tasks from the start date to determine the shipping date or the due date.

Benefits of Scheduling

Scheduling: Establishing the timing of the use of equipment, facilities and human activities in an organization

1. Effective scheduling can yield
2. Cost savings
3. Increases in productivity

The benefits of production scheduling include:

1. Process change-over reduction
2. Inventory reduction, leveling
3. Reduced scheduling effort
4. Increased production efficiency
5. Labor load leveling
6. Accurate delivery date quotes
7. Real time information

High-Volume Systems

1. Flow system: High-volume system with Standardized equipment and activities
2. Flow-shop scheduling: Scheduling for high-volume flow system

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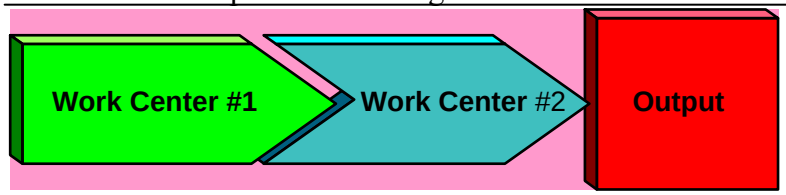

Scheduling Manufacturing Operations

- High-volume
- Intermediate-volume
- Low-volume
- Service operations

High-Volume Success Factors

Process and product design
Preventive maintenance
Rapid repair when breakdown occurs
Optimal product mixes
Minimization of quality problems
Reliability and timing of supplies
Intermediate-Volume Systems
Outputs are between standardized high-volume systems and made-to-order job shops
Run size, timing, and sequence of jobs
Economic run size:

$$Q_0 = \sqrt{\frac{2DS}{H}}\sqrt{\frac{p}{p-u}}$$

Scheduling Low-Volume Systems

Loading - assignment of jobs to process centers
Sequencing - determining the order in which jobs will be processed

- Job-shop scheduling
- Scheduling for low-volume systems with many variations in requirements

Gantt Load Chart

Gantt chart - used as a visual aid for loading and scheduling

Load Chart

Load chart – A type of Gantt Chart that shows the loading and idle times for a group of machines or list of departments

Work Center	Mon.	Tues.	Wed.	Thurs.	Fri.
1	Job 3			Job 4	
2		Job 3	Job 7		
3	Job 1			Job 6	Job 7
4	Job 10				

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Schedule chart – A type of Gantt Chart that shows the orders or jobs in progress and whether they are on schedule or not.

Input/Output Control Chart – A type of Control Chart that shows management of work flow and queues at the work centers

Loading Types

The common types of loading include the following

1. Infinite loading
2. Finite loading
3. Vertical loading
4. Horizontal loading
5. Forward scheduling
6. Backward scheduling
7. Schedule chart

We now briefly discuss this type of Loading

1. Infinite loading. Jobs are assigned to work centers without regard to the capacity of the work center.
2. Finite loading Jobs are assigned to work centers with regard to the capacity of the work center and job processing times.
3. Vertical loading: Loading jobs at a work center, job by job, usually according to some priority criterion, using infinite loading i.e. Jobs are assigned to work centers without regard to the capacity of the work center.
4. Horizontal loading: Loading each job on all work centers it will require, then the next job on all work centers, according to some priority, using finite loading i.e. Jobs are assigned to work centers with regard to the capacity of the work center and job processing times.
5. Forward scheduling: Scheduling ahead, from some point in time
6. Backward scheduling: Scheduling by working backwards from the due date
7. Schedule chart A Gantt chart that shows the orders or jobs in progress and whether they are on schedule or not.

Assignment Method of Linear Programming

Assignment Model is a type of linear programming model for optimal assignment of tasks and resources
Hungarian method is the method of assigning jobs by a one for one matching to identify the lowest cost solution
Let's take a step by step approach to understand and make use of Hungarian Method

Hungarian Method

- First of all, acquire the relevant cost information and arrange it in tabular form
- Second, obtain the Row Reduction; this is obtained by subtracting the smallest number in each row from every number in the row. Enter the results in a new table.
- Third, Obtain the Column Reduction by subtracting the smallest number in each column of the new table from every number in the column.
- Fourth, test whether an optimum assignment can be made. You do this by determining the minimum number of lines needed to cover (i.e.) cross out all zeros. If the number of lines equal the numbers of row, an optimum assignment is possible. IN that case move to final step.
- Fifth, if the numbers of lines is less than the number of rows, modify the table in the following manner

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- Subtract the smallest uncovered number from every uncovered number in the table.
- Add the smallest uncovered number to the numbers at the intersections of covering lines
- Numbers crossed out but not at intersections of cross out lines carry over unchanged to the next table.

- Sixth, Repeat steps fourth and fifth unless an Optimal table is obtained
- Seventh, make the assignments. Begin with rows or columns with only one zero. Match items that have zeros, using only one match for each row and each column. Cross out both the row and column for each row.

Hungarian Method Example

Please refer to the matrix which shows Jobs 1,2,3 and 4 with Machines A, B, C and D.

JOBS	A	B	C	D
1	8	6	2	4
2	6	7	11	10
3	3	5	7	6
4	5	10	12	9

Please apply the Hungarian Method to make appropriate assignments.

Select the Row Minimum

MACHINE					
JOBS	A	B	C	D	ROW MIN
1	8	6	2	4	2
2	6	7	11	10	6
3	3	5	7	6	3
4	5	10	12	9	5

Subtract the smallest number in reach row
To form a new table and select column minimum

MACHINE				
JOBS	A	B	C	D
1	6	4	0	2
2	0	1	5	4
3	0	2	4	3
4	0	5	7	4
COL MIN	0	1	0	2

Subtract the smallest number in reach column & Enter the results to form a new table

MACHINE				
JOBS	A	B	C	D
1	6	3	0	0
2	0	0	5	2
3	0	1	4	1
4	0	4	7	2

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Determine the minimum number of lines needed to cross Out all zeros. Here we have three lines only and rows are 4, so the solution is not optimal

Hungarian Method Example

Subtract the smallest value that has not been crossed out from every number that has not been crossed out (1 here) and add this to numbers that are at intersections of covering lines

MACHINE				
JOBS	A	B	C	D
1	6	3	0	0
2	0	0	5	2
3	0	1	4	1
4	0	4	7	2

MACHINE				
JOBS	A	B	C	D
1	6+1=7	3	0	0
2	0+1=1	0	5	2
3	0	0	3	0
4	0	3	6	1

Determine the minimum number of lines needed to cross Out all 0 (4), since this equals the number of rows, we obtain the optimum assignment.

MACHINE				
JOBS	A	B	C	D
1	7	3	0	0
2	1	0	5	2
3	0	0	3	0
4	0	3	6	1

Make the assignments, start with rows and columns with only one 0. Match jobs with machines that have 0 costs.

MACHINE				
JOBS	A	B	C	D
1	7	3	0	0
2	1	0	5	2
3	0	0	3	0
4	0	3	6	1

The assignment according to Hungarian Method is therefore

A4, 2B,1C AND 3D

Sequencing

Sequencing: Determine the order in which jobs at a work center will be processed.

Workstation: An area where one person works, usually with special equipment, on a specialized job.

Summary

Scheduling is the timing and coordination of Operations. Scheduling problems differ in nature because of the system being designed for high volume, intermediate or low volume flow. In our next lecture we will discuss its complementary and supplementary concept of Sequencing.

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SEQUENCING

Learning Objectives

After completing today's lecture, the students should be able to develop a comprehensive understanding of scheduling and sequencing operations with the help of Hungarian Methods and Johnson Rules. The students would be able to understand the priority rules along with the need of effective scheduling and sequencing. The students would be able to develop an Operations Strategy with respect to both Scheduling and Sequencing.

Sequencing

Sequencing: Determine the order in which jobs at a work center will be processed.
Requires order for sequencing at all work centers as well as sequencing at individual work centers.

Workstation: An area where one person works, usually with special equipment, on a specialized job.
Sequencing

Job time: Time needed for setup and processing of a job.

Priority rules: Simple heuristics (Commonsense rules) used to select the order in which jobs will be processed.

1. Local Rules (pertaining to single workstation)
2. Global Rules(pertaining to multiple workstation)
3. Job processing times and due dates are important pieces of information.
4. Job time consists of processing time and setup times

Priority Rules

1. FCFS - First Come, First Served: Jobs are processed in the order in which they arrive at a machine or work center.
2. SPT- Shortest Processing Time: Jobs are processed according to processing time at a machine or work center, shortest job first.
3. DD - Due Date: Jobs are processed according to due date, earliest due date first.
4. CR - critical ratio: Jobs are processed according to smallest ratio of time remaining until due date to processing time remaining.
5. S/O - slack per operation: Jobs are processed according to average slack time (time until due date minus remaining time to process). Compute by dividing slack time by dividing slack time by number of remaining operations including the current one.
6. Rush – emergency: Emergency or Preferred Customers first.

Assumptions to Priority Rules

1. The set of jobs is known, no new jobs arrive after processing begins and no jobs are canceled.
2. Setup time is deterministic
3. Processing times are deterministic rather than variables.
4. There will be no interruptions in processing such as machine breakdowns , accidents or worker illnesses.

Definitions

Job Flow Time: The length of time a job is in the shop at a particular workstation or work center.

Job Lateness: This is the length of time the job completion date is expected to exceed the date the job was due or promised to a customer.

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Makespan: This is the total time needed to complete a group of jobs. It is the length of time between the start of the first job in the group and the completion of the last job in the group.

Average Number of Jobs: Jobs that are considered in a shop are considered to be work in process inventory. Mathematically
Average Number of Jobs= Total Flow Time / Makespan.

Example

Determine the sequence of jobs, average time flow, average days late and average number of jobs at the work center, for each of these rules
FCFS
SPT
DD
CR
Example Data

JOB	Processing Time	Due Date
A	2	7
B	8	16
C	4	4
D	10	17
E	5	15
F	12	18

Part A. FCFS

Assume Jobs arrived in the following order 1. A-B-C-D-E-F

JOB Sequences	Processing Time (1)	Flow Time (cumulative processing time) (2)	Due Date (3)	(2)-(3)
A	2	2	7	0
B	8	10	16	0
C	4	14	4	10
D	10	24	17	7
E	5	29	15	14
F	12	41	18	22
	41	120		54

Part A. FCFS
Average Flow time= Total Flow Time/Number of Jobs=120/6=20 days
Average Tardiness=54/6=9
The makespan =41 days
Average Number of Jobs at workstation=
120/41=2.93 jobs per workstation
SPT, the sequence is A-C-E-B-D-F

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Part B SPT rule

JOB Sequences	Processing Time (1)	Flow Time (cumulative processing time) (2)	Due Date (3)	(2)-(3)
A	2	2	7	0
C	4	6	4	2
E	5	11	15	0
B	8	19	16	3
D	10	29	17	12
F	12	41	18	23
	41	108		40

Average Flow time= Total Flow Time/Number of Jobs=108/6=18 days
Average Tardiness=40/6=6.67days
The makespan =41 days
Average Number of Jobs at workstation=
108/41=2.63 jobs per workstation
Summary Part A,B,C and D

JOB Sequences Rule	Average Flow Time (Days)	Average Lateness (Days)	Average Number of Jobs of the Work Center
FCFS	20.00	9.00	2.93
SPT	18.00	6.67	2.63
DD	18.33	6.33	2.68
CR	26.67	14.17	3.9

Summary Part A,B,C and D

1. Generally Speaking FCFS and CR rule seems to be the least effective.
2. CR is the worst in each aspect of measurement.
3. The primary limitation of FCFS is that long jobs will tend to delay other jobs.
4. However in scheduling of service systems, the FCFS has the advantage of simplicity, inherent fairness (first come first served) but also due to non availability of realistic estimates of processing times for individual jobs.

Johnson's Rule (Two Work Center Sequencing)

Johnson's Rule: technique for minimizing completion time for a group of jobs to be processed on two machines or at two work centers.

1. Minimizes total idle time
2. Several conditions must be satisfied

Johnson's Rule Conditions

1. Job time must be known and constant
2. Job times must be independent of sequence
3. Jobs must follow same two-step sequence
4. Job priorities cannot be used
5. All units must be completed at the first work center before moving to second

Johnson's Rule Optimum Sequence

1. List the jobs and their times at each work center

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2. Select the job with the shortest time
3. Eliminate the job from further consideration
4. Repeat steps 2 and 3 until all jobs have been scheduled

Johnson's Rule Example

	PROCESSING TIMES (HOURS)	
JOB	Work Center 1	Work Center2
A	5	5
B	4	3
C	8	9
D	2	7
E	6	8
F	12	15

1. Select the job with shortest processing time. In our case it is Job D
2. Eliminate the row of JOB D & proceed further to select the next job with shortest processing time which is B in our case and that too at work center2
3. Similarly sequencing other jobs at work centers, we follow that if there is tie of no of hours, we can sequence it at the beginning or the end.
4. Construct a chart to determine the throughput time and idle times at the work centers. We have
5. 1st D,2nd E,3rd C,4th F,5th A and 6th B

Scheduling Difficulties

1. Variability in
    a. Setup times
    b. Processing times
    c. Interruptions
    d. Changes in the set of jobs
2. No method for identifying optimal schedule
3. Scheduling is not an exact science
4. Ongoing task for a manager

Minimizing Scheduling Difficulties

1. Set realistic due dates
2. Focus on bottleneck operations
3. Consider lot splitting of large jobs

Scheduling Service Operations

1. Appointment systems
    a. Controls customer arrivals for service
2. Reservation systems
    a. Estimates demand for service
3. Scheduling the workforce
    a. Manages capacity for service
4. Scheduling multiple resources
    a. Coordinates use of more than one resource

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Cyclical Scheduling

1. Hospitals, police/fire departments, restaurants, supermarkets
2. Rotating schedules
3. Set a scheduling horizon
4. Identify the work pattern
5. Develop a basic employee schedule
6. Assign employees to the schedule

Service Operation Problems

1. Cannot store or inventory services
2. Customer service requests are random
3. Scheduling service involves
    a. Customers
    b. Workforce
    c. Equipment

Maintenance

Maintenance: All activities that maintain facilities and equipment in good working order so that a system can perform as intended
Breakdown maintenance: Reactive approach; dealing with breakdowns or problems when they occur
Preventive maintenance: Proactive approach; reducing breakdowns through a program of lubrication, adjustment, cleaning, inspection, and replacement of worn parts

Maintenance Reasons

Reasons for keeping equipment running
1. Avoid production disruptions
2. Not add to production costs
3. Maintain high quality
4. Avoid missed delivery dates

Breakdown Consequences

Some of the important consequences are:
1. Production capacity is reduced : Orders are delayed
2. No production: Overhead continues
3. Cost per unit increases: Quality issues
4. Product may be damaged
5. Safety issues
    a. Injury to employees
    b. Injury to customers

Total Maintenance Cost

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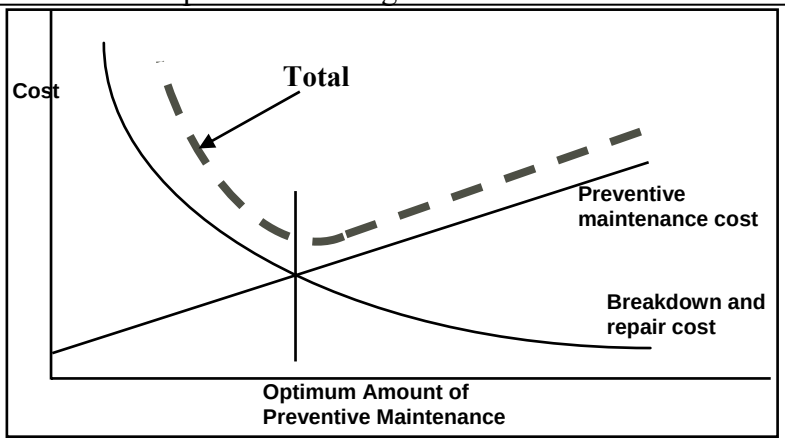

Preventive Maintenance

Preventive maintenance: goal is to reduce the incidence of breakdowns or failures in the plant or equipment to avoid the associated costs

1. Preventive maintenance is periodic
2. Result of planned inspections
3. According to calendar
4. After predetermined number of hours

Example 1
Frequency of breakdown

Number of breakdowns	0	1	2	3
Frequency of occurrence	.20	.30	.40	.10

If the average cost of a breakdown is Rs.10,000, and the cost of preventative maintenance is Rs.12,500 per month, should we use preventive maintenance?
Example 1 Solution

Number of Breakdowns	Frequency of Occurrence	Expected number of Breakdowns
0	.20	0
1	.30	.30
2	.40	.80
3	.10	.30
	1.00	1.40

Expected cost to repair = 1.4 breakdowns per month X Rs.10,000
= Rs.14,000
Preventive maintenance = Rs.12,500.
PM results in savings of Rs.1500 per month

Predictive Maintenance

Predictive maintenance: An attempt to determine when best to perform preventive maintenance activities
Total productive maintenance: JIT approach where workers perform preventive maintenance on the machines they operate

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Breakdown Programs

1. Standby or backup equipment that can be quickly pressed into service
2. Inventories of spare parts that can be installed as needed
3. Operators who are able to perform minor repairs
4. Repair people who are well trained and readily available to diagnose and correct problems with equipment

Replacement

1. Trade-off decisions
2. Cost of replacement vs. cost of continued maintenance
3. New equipment with new features vs. maintenance
4. Installation of new equipment may cause disruptions
5. Training costs of employees on new equipment
6. Forecasts for demand on equipment may require new equipment capacity
7. When is it time for replacement?

Operations Strategy

1. Scheduling can hinder or help the Operations Strategy.
2. An on time delivery of a product or service is only possible if the Operations Managers is able to do effective scheduling.
3. An ineffective scheduling would result in inefficient use of resources and possible dissatisfied customers.
4. Scheduling as an Operations Strategy can provide an organization a competitive advantage over its competitors.
5. Time based competition depends on good scheduling.
6. Good design, superior quality and other elements of a well run organization are meaningless if effective scheduling is absent from Operations Management Strategy.
7. Scheduling is that bank balance which may seem great in numbers but if not used effectively would not make any sense.

Summary

Scheduling involves timing and coordination of operations. Scheduling is different for high volume, intermediate volume and low volume. Scheduling for job shops is very complex, because of variety jobs that need to be processed. The two major problems in Scheduling is the assigning of jobs to the machines (work centers) and sequence of operations at a machine.

Gantt Load charts are used to help managers visualize the work load situation.
Scheduling of service systems require appointment or reservation systems, although all systems are not amenable to this. When multiple resources are involved, the balancing can be difficult. Maintenance Activities ensure that sequence activities are completed on time and as per schedule. Maintenance adds to revenue and not to costs.

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PROJECT MANAGEMENT

Learning Objectives

After completing our lectures 43 and 44, we should be able to understand the Behavioral aspects of projects in terms of project personnel and the project manager. We should be able to appreciate the nature and importance of work breakdown structure in Project Management. We should develop a working knowledge of PERT/CPM techniques.
Construct simple network diagrams and try to assimilate the kind of information that a PERT or CPM analysis can provide. And last but not the least we should be able to analyze networks with probabilistic times and describe activity "crashing" and solve some problems.

Projects

Projects are unique, one-time (temporary) operations designed to accomplish a specific set of objectives in a limited time frame.

This property of being a temporary and a one-time venture contrast with operations, which are permanent or semi-permanent ongoing functional work to create the same product or service over-and-over again.

The management of these two systems is often very different and requires varying technical skills and philosophy, hence requiring the development of project management

Project Management

Project Management is the organizing and managing resources in such a way that these resources deliver all the work required to complete a project within defined scope, time, and cost constraints. A project is a temporary and one-time endeavor undertaken to create a unique product or service.
Distinguishing characteristics of Project Management

1. How is it different?
   - Limited time frame
   - Narrow focus, specific objectives
   - Less bureaucratic
2. Why is it used?
   - Special needs
   - Pressures for new or improves products or services
3. Project Management has the following important key metrics
   - Time
   - Cost
   - Performance objectives

Key Success Factors

What are the Key Success Factors?

1. Top-down commitment
2. Having a capable project manager
3. Having time to plan
4. Careful tracking and control
5. Good communications

Project Management has certain major administrative issues, such as

1. Executive responsibilities
2. Project selection
3. Project manager selection
4. Organizational structure

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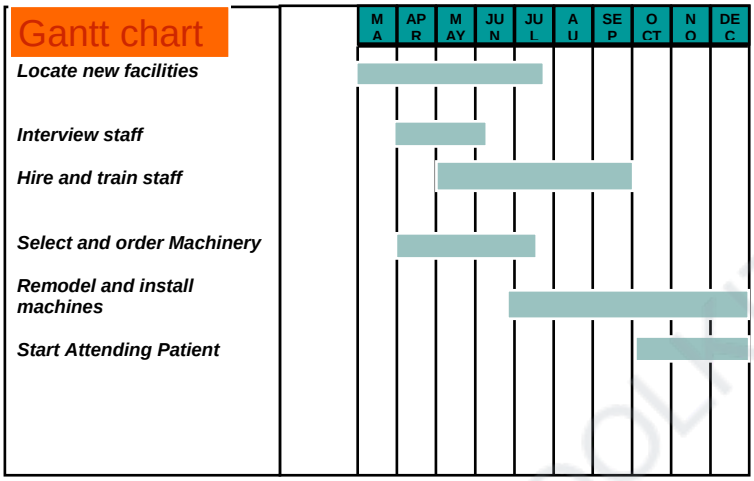
5. Organizational alternatives
6. Manage within functional unit
7. Assign a coordinator
8. Use a matrix organization with a project leader

Project Management normally involves the knowledge of Project management tools, Work breakdown structure, Network diagram, Gantt charts and Risk management.

Project Management: Hospital

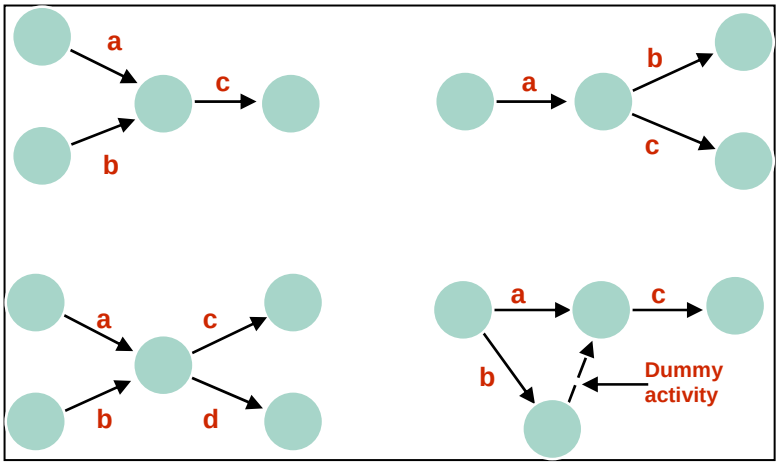
We are given the task of setting up a hospital facility in our community. The plan is to set up both medicine and surgery facilities related to all important fields of medicine and surgery. The project Managers are required to list the possible activities in the form of
Planning and Scheduling (Gantt Chart) and Network Diagram AON and AOA Activities



Project Management: Hospital Construction and Operation Activities include:

- Locate new facilities
- Interview staff
- Hire and train staff
- Select and order Machinery
- Remodel and install phones
- Start Patient Examination/startup

Network Diagrams and Conventions



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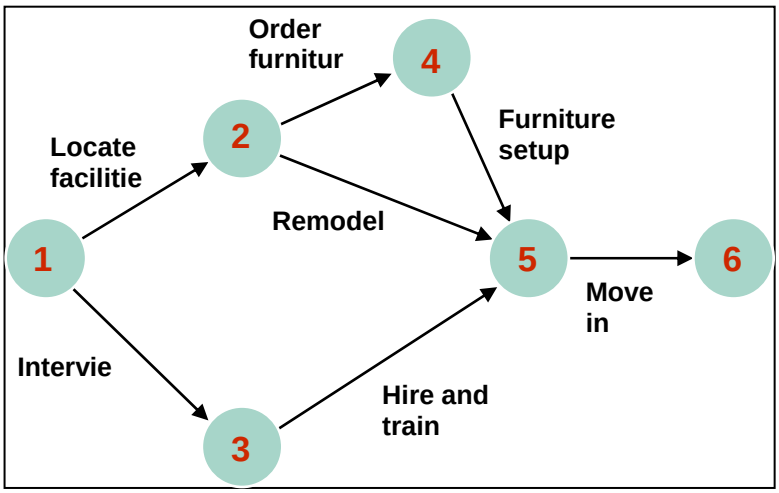
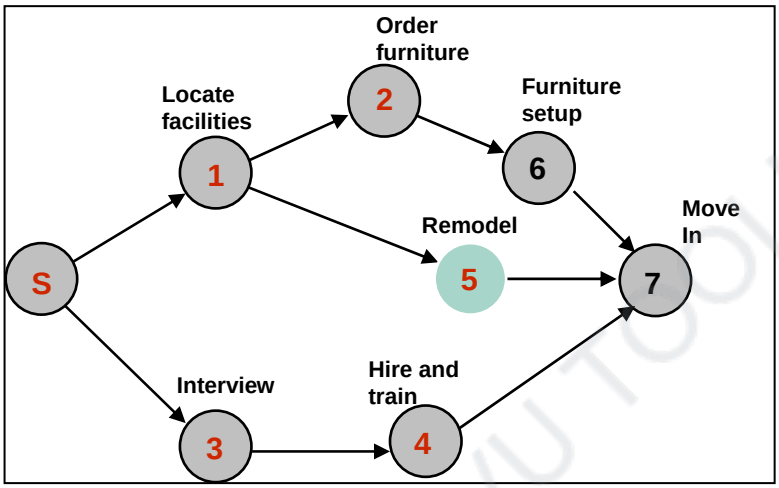
Project Network – Activity on Arrow



Project Network – Activity on Node



- Activity on Arrow: The Network diagram convention in which arrows designate activities.
- Activity on Node: The Network diagram convention in which the nodes designate the activities.
- Activities: Project steps that consume or utilize resources (and or time).
- Events: The starting and finishing of activities designated by nodes in the Activity on Arrow notation.
- Path: Sequence of activities that leads from the starting node to the finishing node
- Critical path: The longest path; determines expected project duration
- Critical activities: Activities on the critical path
- Slack: Allowable slippage for path; the difference the length of path and the length of critical path

Critical

Path	Length (weeks)	Slack
1-2-3-4-5-6	18	2
1-2-5-6	20	0
1-3-5-6	14	6

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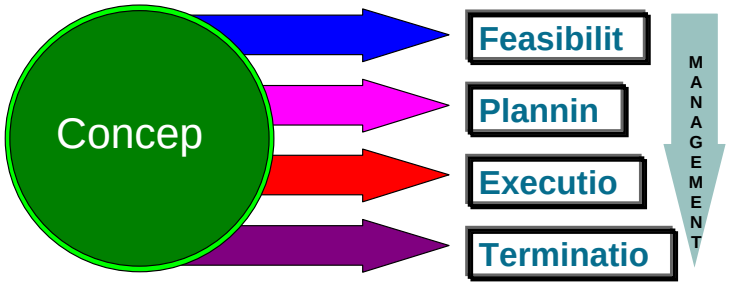
Project Life Cycle

The Project Life Cycle comprises of a new concept idea for a unique activity which is then evaluated through feasibility reports, planned with certain sequence of activities, execution of activities and terminated after the project has been completed or shelved due to certain unavoidable. What is important is to note that all stages of Project Life Cycle are administered and handled by competent Project Management team or Project Managers.



Planning and Scheduling involves the following key decisions:

- Deciding which projects to implement
- Selecting a project manager
- Selecting a project team
- Planning and designing the project
- Managing and controlling project resources
- Deciding if and when a project should be terminated

Responsibilities of a Project Manager

Project Manager is normally considered responsible for:

- Project Management
- Responsible for: Technical and Financial Analysis

Project Manager is normally considered to have qualification such as

- PMP certification
- CFM, CFA and CFP certification

Project Manager should be skilled enough to carryout or supervise the calculation of

- Financial Evaluation and Investment Analysis
- Cost Benefit Analysis

Project Managers should be able to focus on Ethical Issues and avoid:

- Temptation to understate costs
- Withhold information
- Misleading status reports
- Falsifying records
- Compromising workers' safety
- Approving substandard work

Work Breakdown Structure

A project is different that operations due to its unique nature. A good project management practice is to breakdown the project into sublevel or group of similar activities. These sublevel or group of similar activities is called Work Breakdown Structure.

The work breakdown structure usually represents a Parent Child Activity with the relationship between a parent and child level being easily identifiable. The work break down structure allows a project manager to incorporate more administrative control over the project activities.

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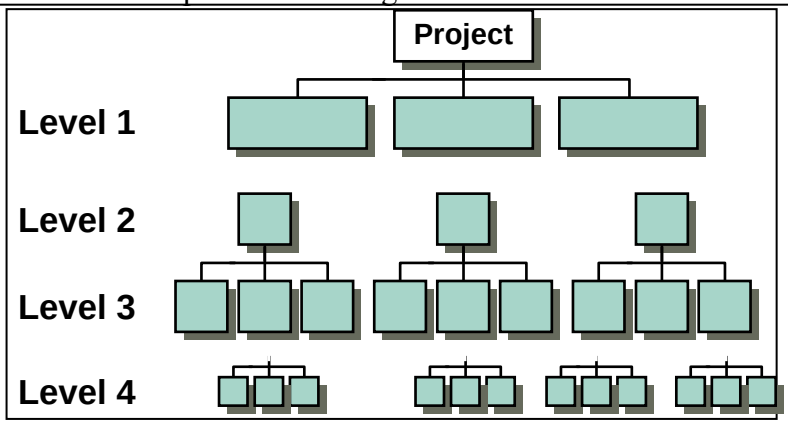

PERT and CPM

PERT: Program Evaluation and Review Technique
CPM: Critical Path Method

1. Graphically displays project activities
2. Estimates how long the project will take
3. Indicates most critical activities
4. Show where delays will not affect project

Advantages of PERT

1. Forces managers to organize
2. Provides graphic display of activities
3. Identifies
4. Critical activities
5. Slack activities

Limitations of PERT

1. Important activities may be omitted
2. Precedence relationships may not be correct
3. Estimates may include a fudge factor
4. May focus solely on critical path

Project Scope and Scope Creep

Project Scope refers to the total work needed out of a project. The primary tool required to describe Project Scope is the Work Breakdown Structure. Often projects suffer from an irritant known as scope creep. Scope creep is the unnecessary extension of project scope which does not allow the project to be completed within budget and with in the time limits. Organizations incorporate special management techniques to isolate and eliminate scope creep. Senior Management is advised and trained by outside consultants to avoid decisions which lead to increase in business scope creep or technical scope creep. Technical Scope creep (like Gold plating) is the unfortunate tendency of technical side to add certain avoidable and costly features in their products (services or softwares) to make their product or service more powerful and attractable to the customers. Business Scope creep (often called customer pleasing) is the tendency of the business managers to over do the customer relationship with their customers. A pragmatic strategy to avoid scope creep is to be judicious to the original project scope and religiously avoid uncalled for business or technical additions that may incorporate scope creep.

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Summary

We learnt the Project Management concept to be different and unique from operations side. Operations represent a repetition of same activities while projects represent execution of unique activities. However there exist similarities which include administration of activities by project manager in a similar fashion to the activities performed by the operations manager. We discussed the Network Diagrams, an Hospital example Project in terms of Gantt Chart, Work Breakdown Structure and job responsibilities of a Project Manager.

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PROJECT MANAGEMENT (Contd.)

Learning Objectives

After learning about the network diagrams, the project life cycle and the responsibilities of project manager. We will now learn the important concept of time estimates (which is based on computing algorithms of Early Start, Early Finish, Late Start and Late Finish) and variances which are used to control the project activities. We will consider important aspects like the forward and backward path time estimates, Project Crashing, Time Cost Trade Offs, Project Management Software, Risk Management and develop a project management based Operations Strategy.

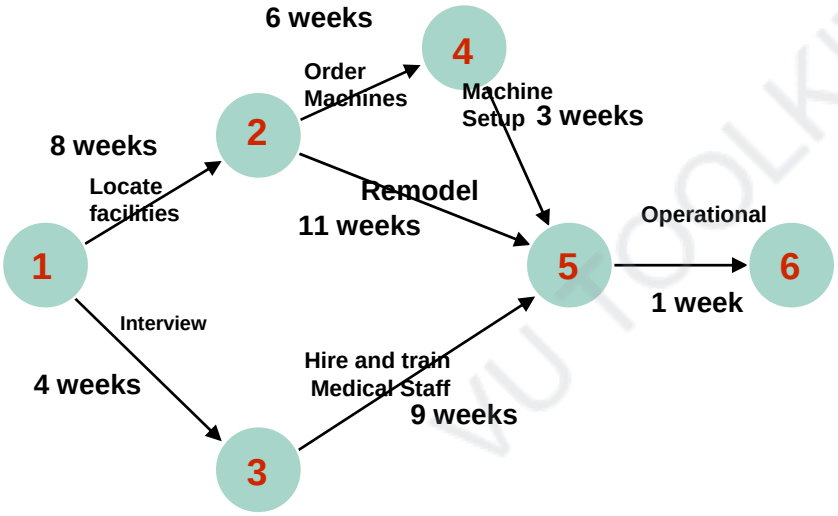
Time Estimates

There are two common types of time estimates namely

1. Deterministic: Time estimates that are fairly certain
2. Probabilistic: Estimates of times that allow for variation

Example: Hospital

We take the same hospital example and now place the time dimension to it .



The activities from locating the facility to making the hospital fully are represented in the form of a network diagram. The student should try to write down the activities along with the activity description then try to draw the network diagram using both the activity on node and activity on arrow as practice.

Computing Algorithm

Network activities

1. ES: early start
2. EF: early finish
3. LS: late start
4. LF: late finish

Used to determine

1. Expected project duration
2. Slack time
3. Critical path

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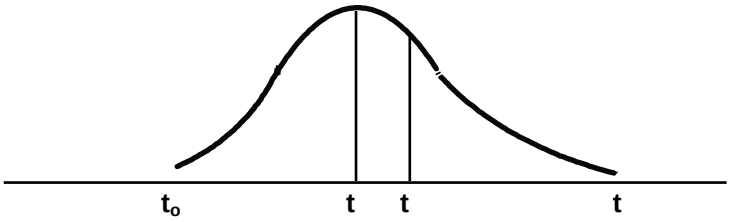
Probabilistic Time Estimates

1. Optimistic time : Time required under optimal conditions
2. Pessimistic time: Time required under worst conditions
3. Most likely time: Most probable length of time that will be required

Probabilistic Estimates require two important parameters like Expected Time and Variance represented by t_e and σ respectively.



Activity Start | **Optimistic Time** | **Most Likely Time** | **Pessimistic Time**

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

where

t_e = expected time
t_o = optimistic time
t_m = most likely time
t_p = pessimistic time

Variance

The word variance reflects the square of standard deviation of activities on a path and represented by σ^2. The size of variance reflects the degree of uncertainty associated with activity's time, the larger the variance the larger the uncertainty.

$$\sigma^2 = \frac{(t_p - t_o)^2}{36}$$

σ^2 = variance
t_o = optimistic time
t_p = pessimistic time

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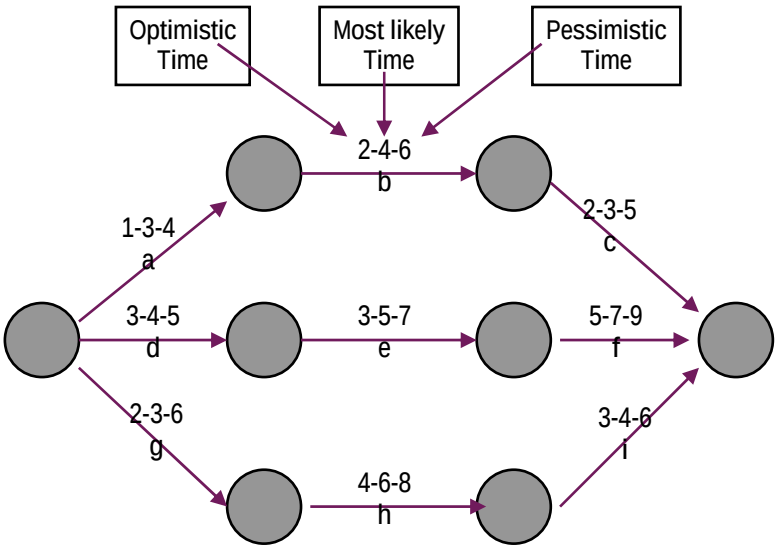
Example



Path Probabilities

$$Z = \frac{\text{Specified time} - \text{Path mean}}{}$$

Z indicates how many standard deviations of the path distribution the specified tine is beyond the expected path duration. If the value of "z" is +2.50 or more, treat the probability of path completion by the specified time as 100 percent.

Time-cost Trade-offs: Crashing

Crash is the shortening activity duration
Procedure for crashing

- Crash the project one period at a time
- Only an activity on the critical path
- Crash the least expensive activity

Multiple critical paths: find the sum of crashing the least expensive activity on each critical path

Project Crashing

Crashing a project involves paying more money to complete a project more quickly.
Since the critical path determines the length of a project, it makes sense to reduce the length of activities on the critical path.
Critical Path activities should be reduced until the project is reduced to the desired length or you are paying more per day than you save.
If you have multiple Critical Paths, they should be shortened simultaneously.
Time-Cost Trade-Offs: Crashing
Time-Cost Trade-Offs: Crashing

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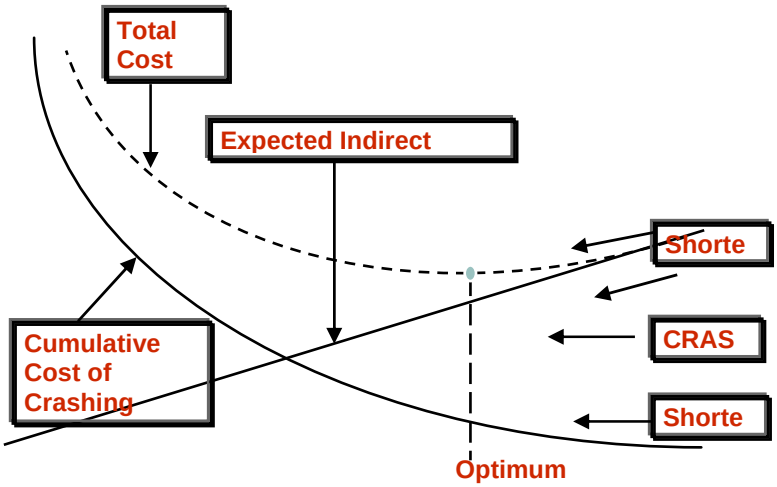


Example

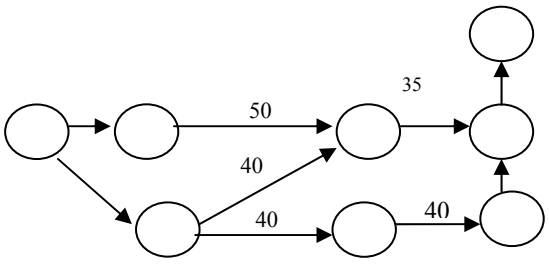
The manager of a PHA is about to undertake a reforestation project throughout Pakistan. He is first asked to carryout a pilot project. The project will involve the following six activities:

SR. #	ACTIVITY	PRECEEDS	TIME ESITIMATES (DAYS)		
			OPTIMISTIC " a"	MOST LIKELY" m"	PESSIMISTIC " b"
	START	U,V			
	U	W	35	50	65
	V	W,X	28	40	52
	W	Z	26	35	44
	X	Y	28	40	52
	Y	Z	26	29	38
	Z	END	36	60	84

Solution: First of all, we construct network diagram based on Activity on Node followed by calculating the probabilistic time "t" and standard deviation "σ" using the formulas given below and then the ES,EF and LS, LF using the forward pass (progression) and backward pass (progression) respectively.

$t = (a+4m+b)/6$ and $\sigma = (b-a)/6$

The denominator of "6" reflects the concept of area under the curve that the range of data lies to + 3 Standard Deviations from mean also it shows the weighted average.



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ACTIVITY	TIME ESITIMATES (DAYS)					FORWARD		BACKWARD		SLACK
	" a"	" m"	" b"	t	σ	ES	EF	LS	LF	n
START										
U	35	50	65	50	5	0	50	25	75	25
V	28	40	52	40	4	0	40	0	40	0
W	26	35	44	35	3	50	85	75	110	25
X	28	40	52	40	4	40	80	40	80	0
Y	26	29	38	30	2	80	110	80	110	0
Z	36	60	84	60	8	110	170	110	170	0

I. Time "t" = (a+4m+b)/6

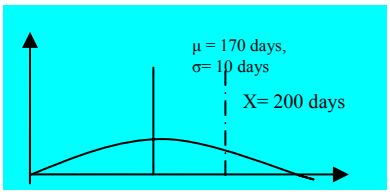
Activity U = (35+4(50) +65)/6= (100+200)/6= 300/6= 50 days
Activity V = (28+4(40) +52)/6= (80+160)/6= 240/6= 40 days
Activity W = (26+4(35) +44)/6= (70+140)/6= 210/6= 35 days
Activity X = (28+4(40) +52)/6= (80+160)/6= 240/6= 40 days
Activity Y = (26+4(29) +38)/6= (64+116)/6= 180/6= 30 days
Activity Z = (36+4(60) +84)/6= (120+240)/6= 360/6= 60 days

Standard Deviation "σ" = (b-a)/6

Activity U = (65-35)/6= (30)/6= 5 days
Activity V = (52-28)/6= (24)/6= 4 days
Activity W = (44-26)/6= (18)/6= 3 days
Activity X = (52-28)/6= (24)/6= 4 days
Activity Y = (38-26)/6= (12)/6= 2 days
Activity Z = (84-36)/6= (48)/6= 8 days

Critical Path

The critical path is the longest path taken for the project to complete.
From Start to End there are three possible paths as from the Network Diagram
Start –U-W-Z-End = 50 + 35+60 = 145 days (logically incorrect)
Start-V-X-Y-Z-End= 40+40+30+60 = 170 days
Start-V-W-Z-End= 40+35+60 = 135 days (logically incorrect)
For the Critical Path, we also calculate the standard deviation of Project portfolio
Start-V-X-Y-Z-End=σ2= [(4)2+(4)2+(2)2+(8)2]= (16+16+4+64)= (100)
Then σ = Square Root (100) = 10 days
Also individual sum of standard deviations = 4+4+2+8 = 18 days
Since portfolio project σ = 10 days is less than individual sum of 18 days, it shows our value of portfolio σ is correct
Normal Distribution
"z" = (X-μ)/σ , now since X= 200 days μ = 170 days,
σ= 10 days



Also Using the Normal Probability Curve

Z= (X – μ)/σ
= (200-170)/10= 30/10= 3.0
According to the standard normal table, the area at z = 3 is 0.4987. Adding 0.5 for left hand side of the standard normal curve, we get 0.9987.

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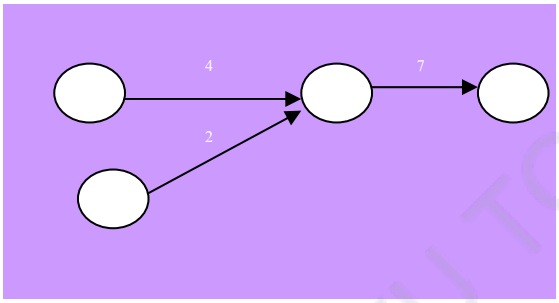
Q.3: What is the estimated expected (mean) time for Project Completion?
135 days
145 days
170 days
180 days
255 days
The answer is 170 Days (Choice C)

Q.4: What is the estimated slack time for activity W?
0 days
25 days
35 days
45 days
85 days
The answer is 25 Days (Choice B)

Q.5: What is the probability that the critical path for this project will be completed with in 200 days?
0.8413
0.9544
0.9772
0.9974
0.9987
Based on the calculations of critical path "σ" above, the answer comes out to be 0.9987 (**Choice E**).



Given the portion of the network shown above, what is the earliest finish time for activity 10-11, if the earliest start time of 8-10 is "12" and the earliest start time of 9-10 is "13"?
22
23
24
25
26

Q.1: What is the estimated expected (mean) time for activity Y?
30 days
29 days
38 days
26 days
35 days
The answer is 30 Days (Choice A)

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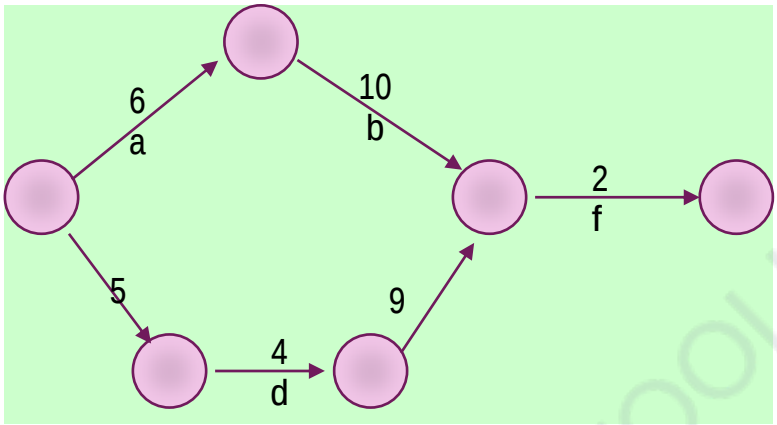
ACTIVITY		FORWARD		BACKWARD		SLACK
	t	ES	EF	LS	LF	n
START						
8 to 10	4	12	16	12	16	0
9 to 10	2	13	15	14	16	1
10 to 11	7	16	**23**	16	23	0

Q.2: What is the estimated standard deviation in the time for activity Z?
3 days
2 days
4 days
8 days
5 days
The answer is 8 Days (Choice D)



Solved Examples

You have been hired as the Chief Project Manager, by your city's Kabbadi Association for construction, renovation and repairs of the city Kabbadi Stadium. The Kabbadi Associations President had in the past hired an Indian Consultant to help him carry out the task of expanding and improving the hockey stadium. The Indian Consultant left the work after collecting the time (in days) associated with the activities and developing the forward path network diagrams.

TIME ESTIMATES

ACTIVITY	OPTIMISTIC	MOST LIKELY	PESSIMISTIC	IMMEDIATE PREDECESSOR
A	1	4	7	-
B	2	6	7	-
C	3	3	6	B
D	6	13	14	A
E	3	6	12	A,C
F	6	8	16	B
G	1	5	6	E,F

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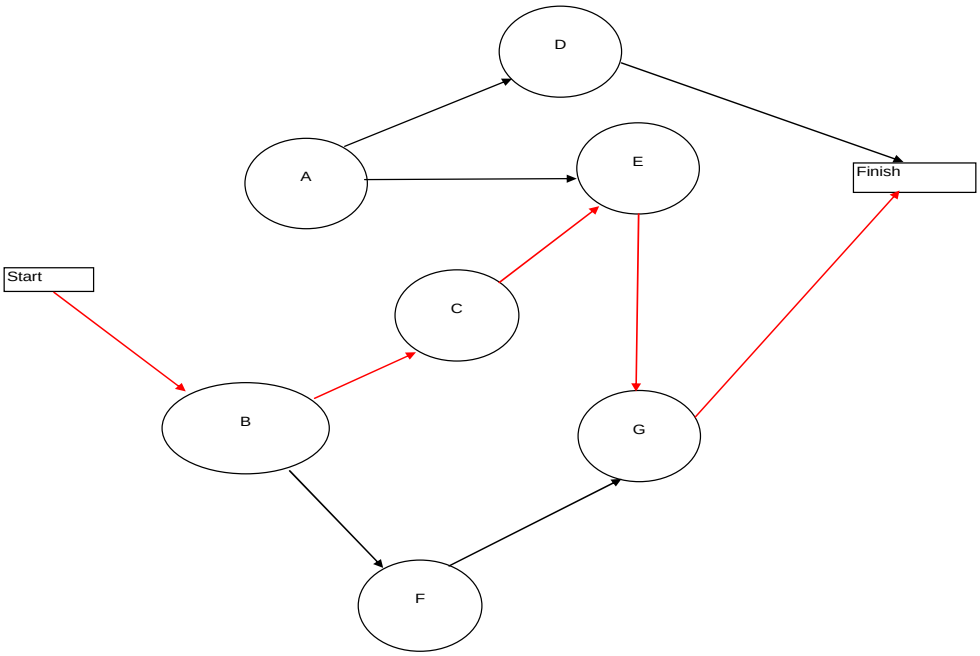

The Association President has asked you to calculate the following:

a. Calculate the expected time and variance for each activity.
b. Calculate the activity slacks and determine critical path using expected activity times?
c. What is the probability of completing the project with in 550 days?

Solution
We first of all calculate the Expected times and variances for each activity using the formulae respectively

$t_e = (a+4m+b)/6$

$\sigma^2 = ((b-a)/6)^2$

The results are presented in the form of the table

ACTIVITY	EXPECTED TIME	VARIANCE
A	4.00	1.00
B	5.50	0.69
C	3.50	0.25
D	12.00	1.78
E	6.50	2.25
F	9.00	2.78
G	4.50	0.69

f. We need to calculate the Earliest Start, Latest Start, Earliest Finish, Latest Finish represented by the symbols ES, LS, EF and LF respectively. We use the forward path network diagram as provided by the hockey association's president.

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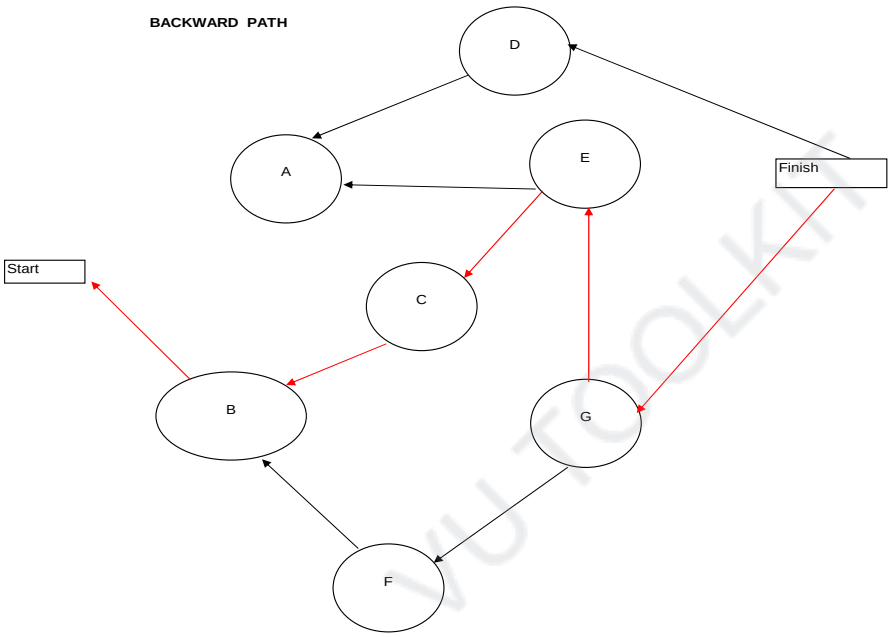
ACTIVITY	ES	EF	t
A	0.00	4.00	4.00
B	0.00	5.50	5.50
C	5.50	9.00	3.50
D	4.00	16.00	12.00
E	9.00	15.50	6.50
F	5.50	14.50	9.00
G	15.50	20.00	4.50

As we can see from the table above the earliest time by which Activity G would finish is 20 days and requires 4.5 days of time to complete. We need to know calculate values of Latest Start and Latest Finish using the backward path. Please refer to the backward path diagram below, the direction of arrows have been reversed indicating that we are actually back tracing the activities with the same times as calculated above using forward path.



ACTIVITY	LS	LF	t
G	15.50	20.00	4.50
F	6.50	15.50	9.00
E	9.00	15.50	6.50
D	8.00	20.00	12.00
C	5.50	9.00	3.50
B	0.00	5.50	5.50
A	4.00	8.00	4.00

	Start		Finish			
ACTIVITY	ES	LS	EF	LF	SLACK	CRITICAL PATH
A	0.00	4.00	4.00	8.00	4.00	NO
B	0.00	0.00	5.50	5.50	0.00	YES
C	5.50	5.50	9.00	9.00	0.00	YES
D	4.00	8.00	16.00	20.00	4.00	NO
E	9.00	9.00	15.50	15.50	0.00	YES
F	5.50	13.00	14.50	15.50	1.00	NO
G	15.50	15.50	20.00	20.00	0.00	YES

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PATH	EXPECTED TIME	VARIANCE
A-D	16.00	2.78
A-E-G	15.00	3.94
B-C-E-G	20.00	3.89
B-F-G	19.00	4.17

The critical path is B-C-E-G with total expected time of 20 days.

c. We first calculate the z value

$$Z = (t-t_e)/\sqrt{\sigma^2}$$
$$= (23-20)/\sqrt{3.89}$$
$$= 3/1.972$$
$$= 1.5210$$

Using the Normal Distribution table, we calculate the probability of completing the project in 23 days to be 0.9357.

Project Management Software Tools

1. Computer aided design (CAD)
2. Groupware (Lotus Notes)
3. Project management software
    a. CA Super Project
    b. Harvard Total Manager
    c. MS Project
    d. Sure Track Project Manager
    e. Time Line

Advantages of PM Software

1. Imposes a methodology
2. Provides logical planning structure
3. Enhances team communication
4. Flag constraint violations
5. Automatic report formats
6. Multiple levels of reports
7. Enables what-if scenarios
8. Generates various chart types

Project Risk Management

Risk: occurrence of events that have undesirable consequences

1. Delays
2. Increased costs
3. Inability to meet specifications
4. Project termination

Risk Management

1. Identify potential risks
2. Analyze and assess risks
3. Work to minimize occurrence of risk

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4. Establish contingency plans

Operations Strategy

1. Many Organizations have setup a separate Project Management department or cell to administer unique and non repetitive activities.
2. The scope of the project decides whether to use a project management software tool or not.
3. Project teams normally operate as a matrix team with employees from different functional departments working with the project team. In such situations the organizations device a strategy that project manger should lead the team as he or she is more aware of the situation being faced by the whole organization as well as the constituent functional departments.

Summary

1. Projects are unique set of activities established to given set of objectives in a limited time span.
2. PERT and CPM two commonly used techniques for developing and monitoring projects.
3. Two slightly different conventions can be used for constructing a network diagram.
4. The task of developing and updating project networks quickly becomes projects of even moderate size or PC applications.
5. A deterministic approach is useful for estimating the duration of the project, when activity times can be fairly well established.
6. In some instances, it may be possible to shorten or crash the length of a project by shortening one or more of the project activities.
7. Often Projects are shortened to the point where the cost of additional reduction would exceed the benefit of additional reduction to a specified time.

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WAITING LINES

Learning Objectives

After completing the lecture, we should be able to explain the formation of waiting lines in unloaded systems, identify the goal of queuing (waiting line) analysis, list the measures of system performance that are used in queuing analysis. We should be able to understand the importance of simulation and at the same time we should look beyond the Production Operations Management class as business graduate professionals adding value to the society.

Visit to a Cricket Stadium

1. Waiting in lines does not add enjoyment
2. Waiting in lines does not generate revenue
3. Waiting Lines
4. Waiting lines are non-value added occurrences
5. Are formed at airports, cricket stadiums, post offices.
6. Formed due to non scheduled random arrivals
7. Often regarded as poor service quality

Waiting Line Examples

1. Orders waiting to be filled
2. Trucks waiting to be loaded or unloaded
3. Job waiting to be processed
4. Equipment waiting to be loaded
5. Machines waiting to be repaired.

Service Station as a Waiting Line Example

Service station is usually designed to provide service on average service time. At macro level system is unloaded at micro level the system is overloaded a Paradox
Customers arrive at random rate
Service requirements vary only oil change or even tuning or maintenance activity in order to change oil

Waiting Lines

Queuing theory: Mathematical approach to the analysis of waiting lines.

1. Goal of queuing analysis is to minimize the sum of two costs Customer waiting costs and Service capacity costs.
2. Waiting lines are non-value added occurrences

Implications of Waiting Lines

1. Cost to provide waiting space
2. Loss of business
    a. Customers leaving
    b. Customers refusing to wait
3. Loss of goodwill
4. Reduction in customer satisfaction
5. Congestion may disrupt other business operations

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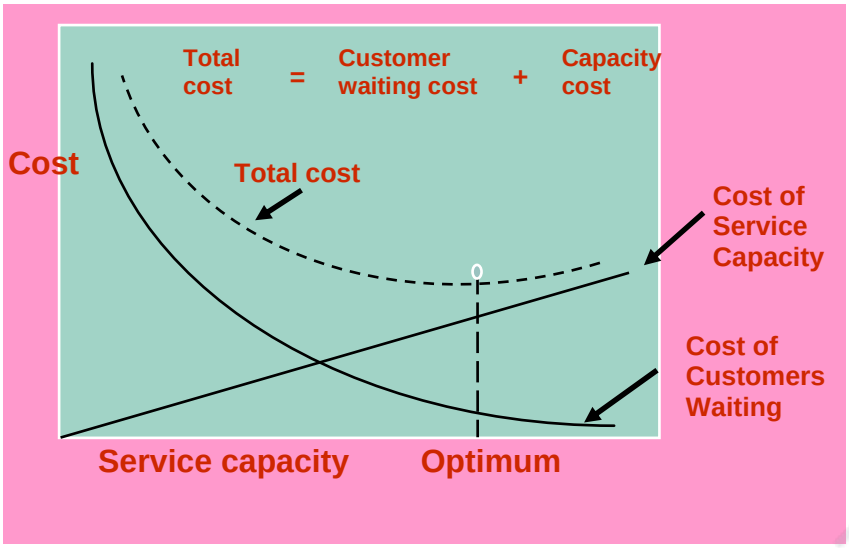
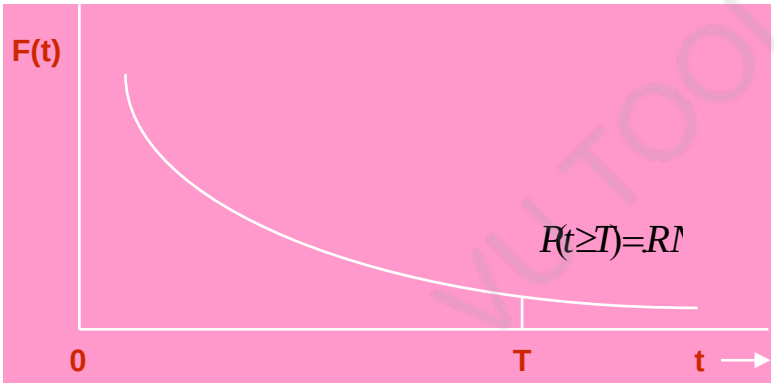
Queuing Analysis

Organizations carry out queuing analysis to ensure that they are able to balance the service levels with costs which the organization can incur. The ultimate goal of queuing analysis is to minimize the sum of two costs that is the service capacity cost (represented on x axis) and customer waiting costs.



Negative Exponential Distribution: Another example of Common Queuing System



Queue discipline is considered to be a primary requirement in service systems. However hospital emergency rooms, rush orders in a factory and main frame computer processing of jobs do not follow Queue Discipline.

System Characteristics

1. Population Source
    a. Infinite source: customer arrivals are unrestricted
    b. Finite source: number of potential customers is limited
2. Number of observers (channels)
3. Arrival and service patterns
4. Queue discipline (order of service)

Elements of Queuing System

Population Source, Arrivals, Waiting Lines, Processing Order, Service, System and Exit are the common identifiable elements of a Queuing System.

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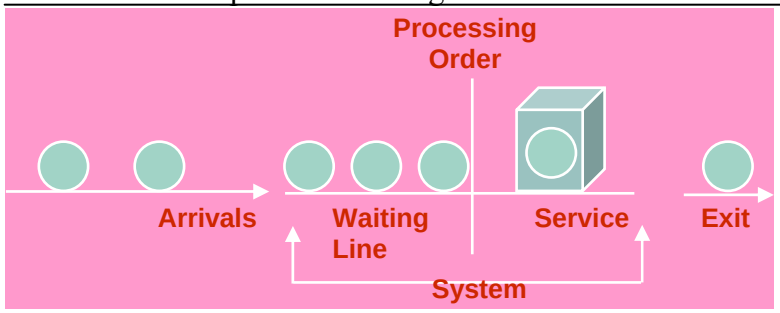
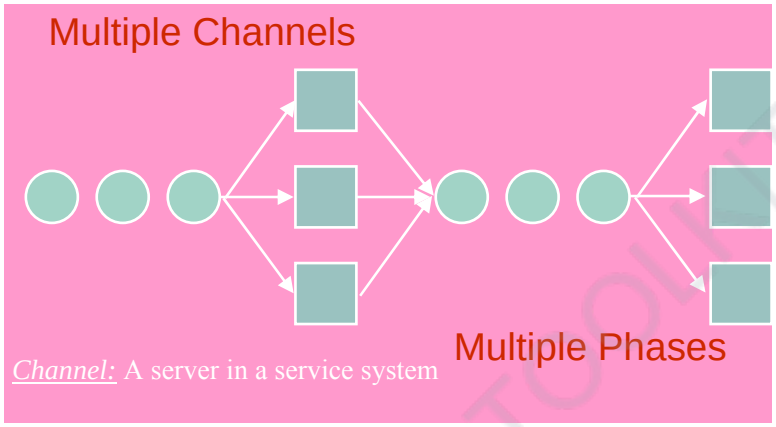


Queuing Systems

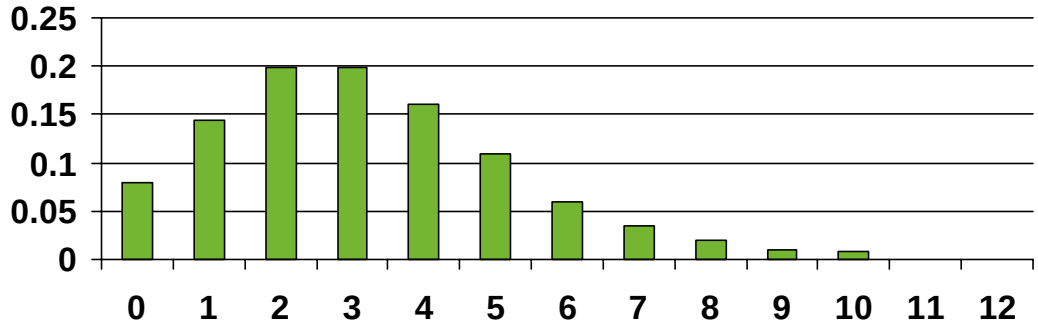
The System characteristics are

1. Population Source
2. Number of Servers(Channels)
3. Arrival and Service Patterns
4. Queue Discipline



Poisson Distribution

Poisson distribution is a discrete probability distribution and expresses the probability of a number of events occurring in a fixed period of time if these events occur with a known average rate, and are independent of the time since the last event.



Waiting Line Models

As a student of Operations Management we can identify the following types of Waiting Line Models in our day to day routine activities.

1. Patient :Customers enter the waiting line and remain until served
2. Reneging: Waiting customers grow impatient and leave the line

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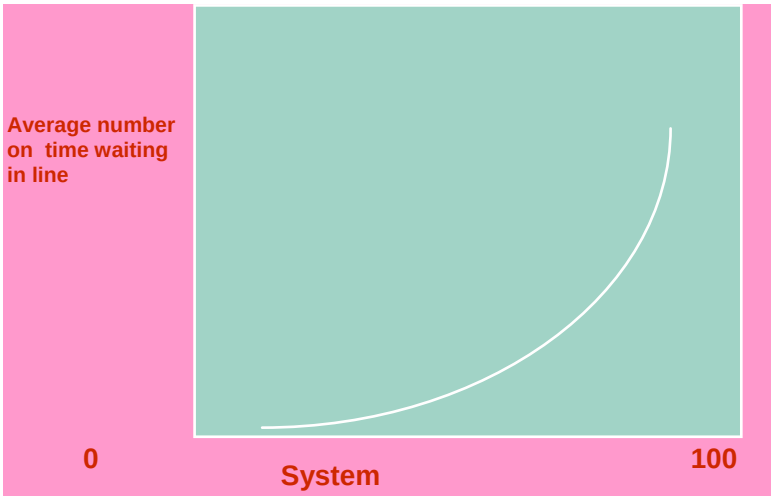
3. Jockeying: Customers may switch to another line
4. Balking: Upon arriving, decide the line is too long and decide not to enter the line

Waiting Time vs. Utilization

The figure represents an increase in system utilization at the expense of increase in both length of the waiting line and average waiting time. These values increase as the utilization approaches 100 percent. The implication is that under normal circumstances, 100 percent utilization is not a realization goal.



Waiting Time vs. Utilization

System Performance

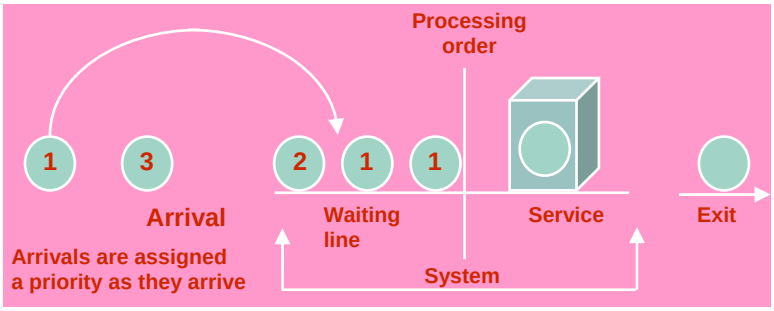
1. Average number of customers waiting
2. Average time customers wait
3. System utilization
4. Implied cost
5. Probability that an arrival will have to wait

Example Service Station

Queuing Models: Infinite-Source

1. Single channel, exponential service time
2. Single channel, constant service time
3. Multiple channel, exponential service time
4. Multiple priority service, exponential service time

Priority Model



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Finite-Source Formulas

$$Service\ Factor\ X = \frac{T}{T+U}$$

$$Average\ Number\ Waiting\ L = N(1-F)$$

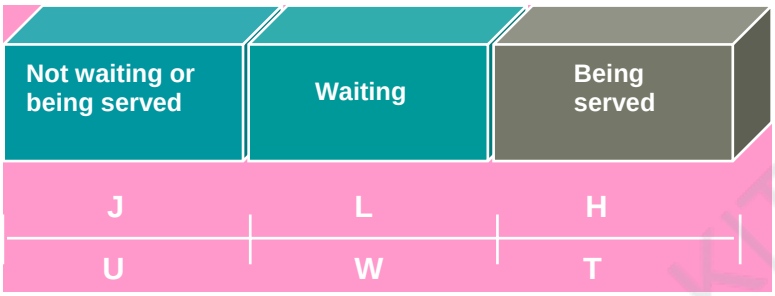
$$Average\ Waiting\ Time\ W = \frac{L(T+U)}{N-L} = \frac{T(1-F)}{XF}$$

$$Average\ Number\ Running\ J = NF(1-X)$$

$$Average\ Number\ being\ Served\ H = FNX$$

$$Number\ in\ Population\ N = J + L + H$$

Finite-Source Queuing



Where we use the formula

Other Approaches Non Mathematical Approaches

1. Reduce perceived waiting time $F = \frac{J+H}{J+L+H}$
2. Magazines in waiting rooms
3. Radio/television
4. In-flight movies
5. Filling out forms
6. Derive benefits from waiting
7. Place impulse items near checkout
8. Advertise other goods/services

Simulation

Simulation: a descriptive technique that enables a decision maker to evaluate the behavior of a model under various conditions.

1. Simulation models complex situations
2. Models are simple to use and understand
3. Models can play "what if" experiments
4. Extensive software packages available

Simulation Process

1. Identify the problem
2. Develop the simulation model
3. Test the model
4. Develop the experiments
5. Run the simulation and evaluate results

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6. Repeat 4 and 5 until results are satisfactory

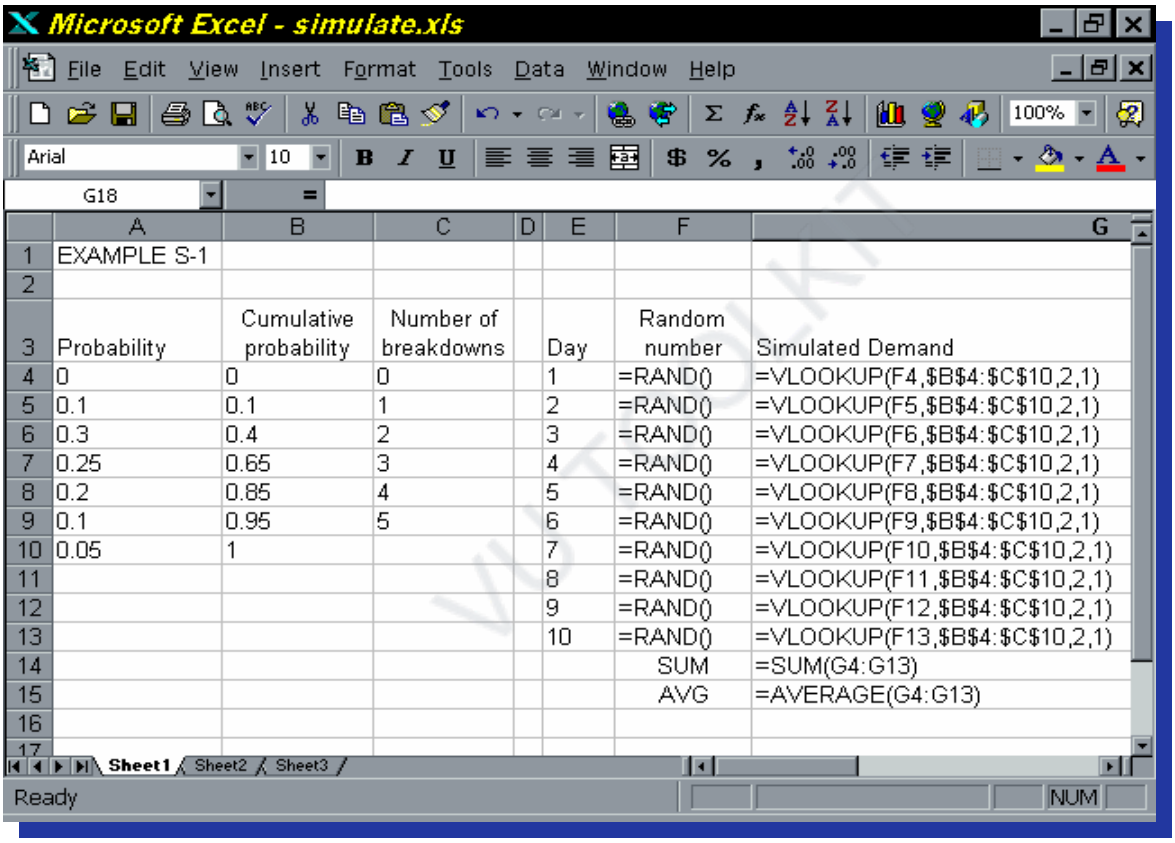
Monte Carlo Simulation

Monte Carlo method: Probabilistic simulation technique used when a process has a random component

1. Identify a probability distribution
2. Setup intervals of random numbers to match probability distribution
3. Obtain the random numbers
4. Interpret the results

Example Showing the use of Microsoft Excel

An Operations Manager makes best use of the power of Microsoft Excel by carrying out simulation. The first picture below shows a snapshot which carries the formulae and the second picture represents the actual values.



	A	B	C	D	E	F	G
1	EXAMPLE S-1						
2							
3	Probability	Cumulative probability	Number of breakdowns		Day	Random number	Simulated Demand
4	0	0	0		1	=RAND()	=VLOOKUP(F4,$B$4:$C$10,2,1)
5	0.1	0.1	1		2	=RAND()	=VLOOKUP(F5,$B$4:$C$10,2,1)
6	0.3	0.4	2		3	=RAND()	=VLOOKUP(F6,$B$4:$C$10,2,1)
7	0.25	0.65	3		4	=RAND()	=VLOOKUP(F7,$B$4:$C$10,2,1)
8	0.2	0.85	4		5	=RAND()	=VLOOKUP(F8,$B$4:$C$10,2,1)
9	0.1	0.95	5		6	=RAND()	=VLOOKUP(F9,$B$4:$C$10,2,1)
10	0.05	1			7	=RAND()	=VLOOKUP(F10,$B$4:$C$10,2,1)
11					8	=RAND()	=VLOOKUP(F11,$B$4:$C$10,2,1)
12					9	=RAND()	=VLOOKUP(F12,$B$4:$C$10,2,1)
13					10	=RAND()	=VLOOKUP(F13,$B$4:$C$10,2,1)
14						SUM	=SUM(G4:G13)
15						AVG	=AVERAGE(G4:G13)
16							
17							

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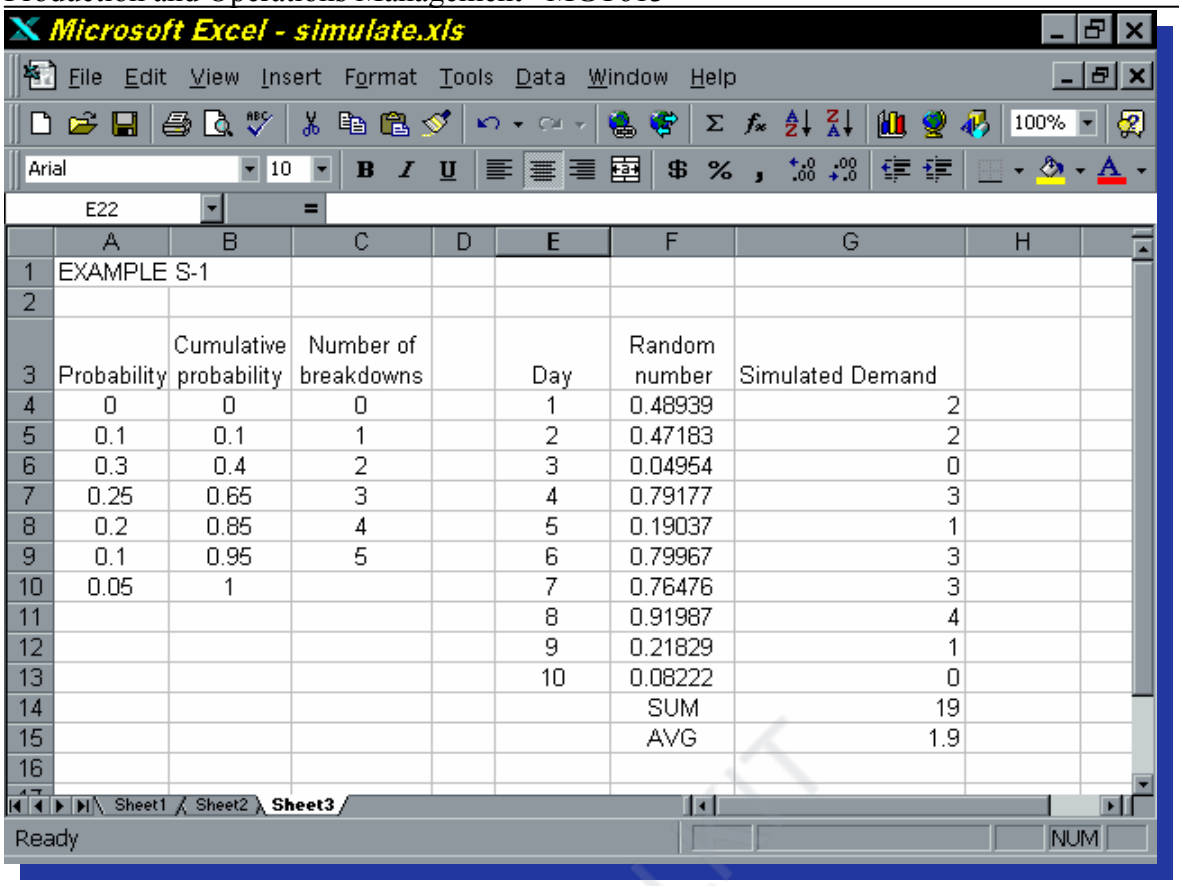
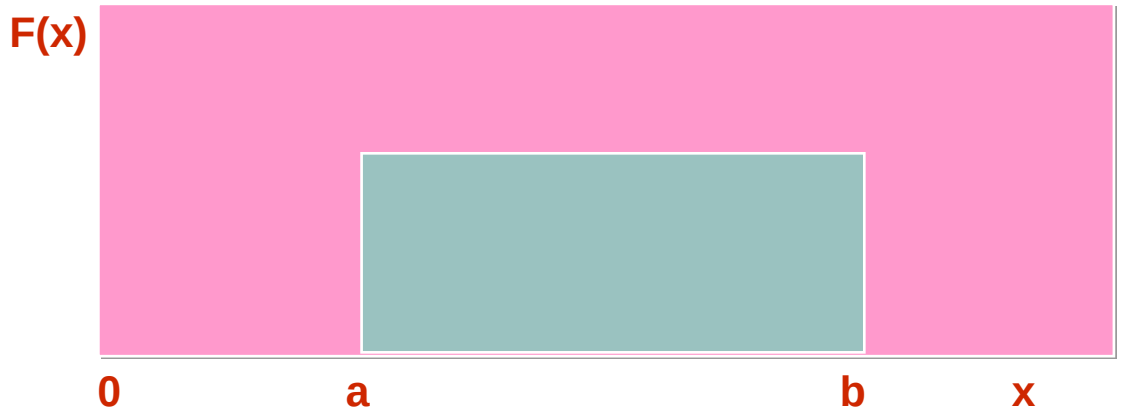


	A	B	C	D	E	F	G	H
1	EXAMPLE S-1							
2								
3	Probability	Cumulative probability	Number of breakdowns		Day	Random number	Simulated Demand	
4	0	0	0		1	0.48939	2	
5	0.1	0.1	1		2	0.47183	2	
6	0.3	0.4	2		3	0.04954	0	
7	0.25	0.65	3		4	0.79177	3	
8	0.2	0.85	4		5	0.19037	1	
9	0.1	0.95	5		6	0.79967	3	
10	0.05	1			7	0.76476	3	
11					8	0.91987	4	
12					9	0.21829	1	
13					10	0.08222	0	
14						SUM	19	
15						AVG	1.9	
16								

Simulating Distributions commonly used are the Poisson and Normal Distributions.
Poisson distribution: Mean of distribution is required
Normal Distribution: Need to know the mean and standard deviation

Stimulated Value= Mean + Random Number X Standard Deviation

Uniform Distribution



Stimulated Value= a+ (b-a)(Random number as a percentage)

Computer Simulation

Simulation languages

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1. SIMSCRIPT II.5
2. GPSS/H
3. GPSS/PC
4. RESQ

Advantages of Simulation

1. Solves problems that are difficult or impossible to solve mathematically
2. Allows experimentation without risk to actual system
3. Compresses time to show long-term effects
4. Serves as training tool for decision makers

Limitations of Simulation

1. Does not produce optimum solution
2. Model development may be difficult
3. Computer run time may be substantial
4. Monte Carlo simulation only applicable to random systems

Why Simulation is necessary

1. Mathematics involved is too complicated
2. Easier to manipulate than reality
3. Software and hardware permit modeling

Simulation Steps

1. Problem formulation
2. Model building
3. Data acquisition
4. Model translation
5. Verification & validation
6. Experiment planning & execution
7. Analysis
8. Implementation & documentation

Operations Strategy

1. The central idea for formulating an Operations Strategy for Waiting Line concept is designing a service system to achieve a balance between service capacity and customer waiting time.
2. The operations strategy should be able to identify an appropriate and acceptable level of service capacity as well as quality so waiting lines are not formed or formed which are manageable and acceptable to the customers.
3. Often Organizations when challenged by lack of practical solutions or space constraints opt for a more tangible quality based solutions by engaging the waiting customers in activities which give the customers not only an opportunity to make use of the time but also to make the waiting time less painful and more pleasant.

Summary

Analysis of waiting lines can be an important milestone in the design of improved service systems. Waiting lines have a tendency to form in even those systems which in a macro sense are under loaded or unloaded.

The arrival of customers at random times and variability of service times combine to create temporary overloads. When this happens, waiting lines appear.

A major consideration in the analysis of the queuing systems is whether the number of potential customers is limited (finite source) or whether entry to the system is unrestricted (infinite source).Of the 5 models we studied, 4 dealt with infinite source and 1 with finite source population.

As a rule, the models assume that customer arrival rates are described by Poisson distribution and service time can be described by a negative exponential distribution.

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POMA Strategies beyond the final exam

1. In the long run (when factors of production change, any or combination of the factors of labor, land, technology), productivity growth is almost everything if not everything.
2. Do not create artificial non operational management strategies means to balance capacity to demand (It can cause competitive advantage to shift towards your competitor and your organization losing the competition.
3. How much does it really cost to manufacture a product or develop a service (refer to the concept of total costs, which we learnt in our discussions on inventory management, alternative capacity, quality, maintenance and waiting lines)
4. Competitive advantage in operational and organization strategy creates a win win situation for the organization.
5. Operations Manager should learn to think at the margin (an addition in cost by 1 Rupee(unit cost) would increase or decrease the revenue by 1 Rupee(unit revenue/benefit)).
6. How we as Operations Manager can play a part in minimization of costs of most important of services in Pakistan i.e. education and medical. Trade off between Effectiveness and quality.
7. How and why Project Management concepts are equally important to Production Operations Management and vice versa.
8. The importance of coordinating, planning, controlling, budgeting operations and project activities in achieving our firms short and long term objectives.
9. The concepts of strategy, competitiveness and productivity, design of product and services, design of work systems and facilities, concept of quality and system improvement as applicable in organizations be applied to Pakistan.
10. How as Operations Manager we can communicate to masses the importance of Pakistani domestic markets and how they help in capital formation. If we say no to foreign goods consumption, foreign good would not come to our place and we can generate a well deserved saving. That saving can be channelized to provide clean and drinkable water, better health care, education or even used for infrastructural issues. e.g. if 1 % of Pakistani population saves Rs. 10 per week for 1 year alone we would have almost 780 million rupees or 12 to 13 Million US dollars by which we can set biogas plants or waste incinerator boiler based power generation or clean drinking waters or even institutions of higher learning.

————THE END————

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