Production and Operations Management

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Preface

The branch of management which deals with the organizing, directing and planning of the production process is called production management. Its primary focus is the efficient management of the resources which are vital for the production of goods and services. It is also involved in the making of decisions which deal with the quality, price, quantity and design in order to ensure that the products meet the required specifications. Operations management refers to the domain of management which focuses on the controlling and designing of the process of production. It is responsible for the smooth and effective running of operations within an organization. This book provides comprehensive insights into the field of production and operations management. It consists of contributions made by international experts. This textbook is appropriate for students seeking detailed information in this area as well as for experts.

A foreword of all Chapters of the book is provided below:

Chapter 1 - The application of business concepts for the creation of goods and services is referred to as production and operations management. Some of the aspects which are dealt with under this field are strategic management and enterprise resource planning. This is an introductory chapter which will introduce briefly all these significant aspects of production and operations management.; **Chapter 2** - The process of making predictions of the future by analyzing trends as well as on the past and present data is known as forecasting. Capacity refers to the highest level of output which a company can maintain to provide a service or make a product. The topics elaborated in this chapter will help in gaining a better perspective about forecasting, capacity and aggregate planning.; **Chapter 3** - The capability of firms to plan total material requirements is known as materials management. Inventory management refers to the supervision of inventory. The diverse aspects of materials and inventory management such as materials requirement planning and purchase management have been thoroughly discussed in this chapter.; **Chapter 4** - Production planning refers to the planning of manufacturing and production modules in an industry or company. The process of controlling, arranging and optimizing workloads and work in a manufacturing or production process is known as scheduling. This chapter has been carefully written to provide an easy understanding of the varied facets of production planning, control and scheduling.; **Chapter 5** - The examination of the cost, quality, availability and features of a product is known as product analysis. Some of the aspects which are dealt with under this field are product development and product design. The topics elaborated in this chapter will help in gaining a better perspective about these aspects of product analysis.; **Chapter 6** - The action of overseeing all activities and tasks which are needed to maintain a desired degree of excellence is known as quality management. The process through which the quality of the different factors which are a part of production are reviewed is known as quality control. This chapter closely examines the key concepts of quality management and control to provide an extensive understanding of the subject.;

I would like to thank the entire editorial team who made sincere efforts for this book and my family who supported me in my efforts of working on this book. I take this opportunity to thank all those who have been a guiding force throughout my life.

Jonathan Molaro

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Introduction to Production and Operations Management

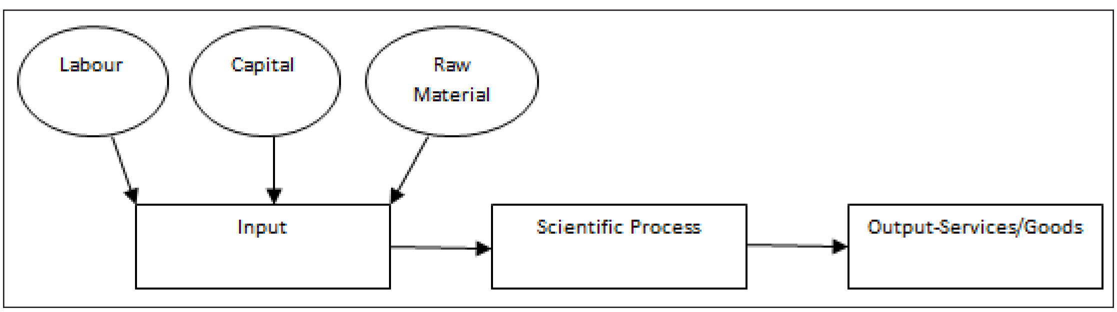
The application of business concepts for the creation of goods and services is referred to as production and operations management. Some of the aspects which are dealt with under this field are strategic management and enterprise resource planning. This is an introductory chapter which will introduce briefly all these significant aspects of production and operations management.

The very essence of any business is to cater needs of customer by providing services and goods, and in process create value for customers and solve their problems. Production and operations management talks about applying business organization and management concepts in creation of goods and services.

Production

Production is a scientific process which involves transformation of raw material (input) into desired product or service (output) by adding economic value. Production can broadly categorize into following based on technique:

1. Production through separation: It involves desired output is achieved through separation or extraction from raw materials. A classic example of separation or extraction is Oil into various fuel products.
2. Production by modification or improvement: It involves change in chemical and mechanical parameters of the raw material without altering physical attributes of the raw material. Annealing process (heating at high temperatures and then cooling), is example of production by modification or improvement.
3. Production by assembly: Car production and computer are example of production by assembly.



Importance of Production Function and Production Management

Successful organizations have well defined and efficient line function and support function. Production comes under the category of line function which directly affects customer experience and there by future of organization itself.

Aim of production function is to add value to product or service which will create a strong and long lasting customer relationship or association. And this can be achieved by healthy and productive association between Marketing and Production people. Marketing function people are frontline representative of the company and provide insights to real product needs of customers.

An effective planning and control on production parameters to achieve or create value for customers is called production management.

Operations Management

As to deliver value for customers in products and services, it is essential for the company to do the following:

1. Identify the customer needs and convert that into a specific product or service (numbers of products required for specific period of time).
2. Based on product requirement do back-ward working to identify raw material requirements.
3. Engage internal and external vendors to create supply chain for raw material and finished goods between vendor → production facility → customers.

Operations management captures above identified 3 points.

Production Management vs. Operations Management

A high level comparison which distinct production and operations management can be done on following characteristics:

- Output: Production management deals with manufacturing of products like (computer, car, etc.) while operations management cover both products and services.
- Usage of Output: Products like computer/car are utilized over a period of time whereas services need to be consumed immediately.
- Classification of work: To produce products like computer/car more of capital equipment and less labour are required while services require more labour and lesser capital equipment.
- Customer Contact: There is no participation of customer during production whereas for services a constant contact with customer is required.

Production management and operations management both are very essential in meeting objective of an organization.

Strategy and Strategic Management

Strategy is an action that managers take to attain one or more of the organization's goals. Strategy can also be defined as "A general direction set for the company and its various components to achieve a desired state in the future. Strategy results from the detailed strategic planning process".

A strategy is all about integrating organizational activities and utilizing and allocating the scarce resources within the organizational environment so as to meet the present objectives. While planning a strategy it is essential to consider that decisions are not taken in a vaccum and that any act taken by a firm is likely to be met by a reaction from those affected, competitors, customers, employees or suppliers.

Strategy can also be defined as knowledge of the goals, the uncertainty of events and the need to take into consideration the likely or actual behavior of others. Strategy is the blueprint of decisions in an organization that shows its objectives and goals, reduces the key policies, and plans for achieving these goals, and defines the business the company is to carry on, the type of economic and human organization it wants to be, and the contribution it plans to make to its shareholders, customers and society at large.

Features of Strategy

1. Strategy is Significant because it is not possible to foresee the future. Without a perfect foresight, the firms must be ready to deal with the uncertain events which constitute the business environment.
2. Strategy deals with long term developments rather than routine operations, i.e. it deals with probability of innovations or new products, new methods of productions, or new markets to be developed in future.
3. Strategy is created to take into account the probable behavior of customers and competitors. Strategies dealing with employees will predict the employee behavior.

Strategy is a well-defined roadmap of an organization. It defines the overall mission, vision and direction of an organization. The objective of a strategy is to maximize an organization's strengths and to minimize the strengths of the competitors.

Strategic Management

Strategic Management is all about identification and description of the strategies that managers can carry so as to achieve better performance and a competitive advantage for their organization. An organization is said to have competitive advantage if its profitability is higher than the average profitability for all companies in its industry.

Strategic management can also be defined as a bundle of decisions and acts which a manager undertakes and which decides the result of the firm's performance. The manager must have a thorough knowledge and analysis of the general and competitive organizational environment so as to take right decisions. They should conduct a SWOT Analysis (Strengths, Weaknesses, Opportunities, and Threats), i.e., they should make best possible utilization of strengths, minimize the organizational weaknesses, make use of arising opportunities from the business environment and shouldn't ignore the threats.

Strategic management is nothing but planning for both predictable as well as unfeasible contingencies. It is applicable to both small as well as large organizations as even the smallest organization face competition and, by formulating and implementing appropriate strategies, they can attain sustainable competitive advantage.

It is a way in which strategists set the objectives and proceed about attaining them. It deals with making and implementing decisions about future direction of an organization. It helps us to identify the direction in which an organization is moving.

Strategic management is a continuous process that evaluates and controls the business and the industries in which an organization is involved; evaluates its competitors and sets goals and strategies to meet all existing and potential competitors; and then reevaluates strategies on a regular basis to determine how it has been implemented and whether it was successful or does it needs replacement.

Strategic Management gives a broader perspective to the employees of an organization and they can better understand how their job fits into the entire organizational plan and how it is co-related to other organizational members. It is nothing but the art of managing employees in a manner which maximizes the ability of achieving business objectives. The employees become more trustworthy, more committed and more satisfied as they can co-relate themselves very well with each organizational task. They can understand the reaction of environmental changes on the organization and the probable response of the organization with the help of strategic management. Thus the employees can judge the impact of such changes on their own job and can effectively face the changes. The managers and employees must do appropriate things in appropriate manner. They need to be both effective as well as efficient.

One of the major role of strategic management is to incorporate various functional areas of the organization completely, as well as, to ensure these functional areas harmonize and get together well. Another role of strategic management is to keep a continuous eye on the goals and objectives of the organization.

Operation Strategy

An operational strategy is a map that helps companies to reach their targets and objectives. Enterprises develop operational strategies to identify their business flaws, evaluate the quality and strength of their resources, assess their workflow, create effective plans, and implement them in their business ventures. Operations Strategy also enables entrepreneurs to connect long-term goals with the short-term ones and execute the plans efficiently.

Operational Strategies in Corporate World

Corporate Strategies are made up keeping in mind the company as a system, which has been created by several parts, which are interconnected parts, just like the parts of the body. It is considered that all the parts of the company are important and must function healthily together to keep the lifeline of the company running.

Customer-Oriented Strategies are concerned with the needs and requirements of the target customer belt, stay abreast of all the changes and challenges evolving in the market, making changes in the strategy accordingly, while simultaneously improvise upon the core competencies and look out for new skill sets and strengths and incorporate them in fresh strategies.

Developing core competencies involve assessing the resources and enhancing them on an ongoing basis. This may include the reshuffling of the teams, improving the marketing strategies, or even reframing the infrastructure. These approaches pave a smooth way toward customer satisfaction.

Companies should keep in mind the competitive scenario of the market. Assessing the rival companies thoroughly and developing strategies accordingly make the base of competing priorities.

Enterprise Resource Planning

ERP is a package software solution that addresses the enterprise needs of an organization by tightly integrating the various functions of an organization using a process view of the organization.

- ERP software is ready-made generic software; it is not custom-made for a specific firm. ERP software understands the needs of any organization within a specific industry segment. Many of the processes implemented in an ERP software are core processes such as order processing, order fulfillment, shipping, invoicing, production planning, BOM (Bill of Material), purchase order, general ledger, etc., that are common to all industry segments.
- ERP does not merely address the needs of a single function such as finance, marketing, production or HR; rather it addresses the entire needs of an enterprise that cuts across these functions to meaningfully execute any of the core processes.
- ERP integrates the functional modules tightly. It is not merely the import and export of data across the functional modules. The integration ensures that the logic of a process that cuts across the function is captured genuinely. This in turn implies that data once entered in any of the functional modules (whichever of the module owns the data) is made available to every other module that needs this data. This leads to significant improvements by way of improved consistency and integrity of data.
- ERP uses the process view of the organization in the place of function view, which dominated the enterprise software before the advent of ERP.

Importance of ERP

In spite of heavy investments involved in ERP implementation, many organizations around the world have gone in for ERP solutions. A properly implemented ERP solution would pay for the heavy investments handsomely and often reasonably fast. Since ERP solutions address the entire organizational needs, and not selected islands of the organization, ERP introduction brings a new culture, cohesion and vigor to the organization. After ERP introduction the line managers would no longer have to chase information, check compliance to rules or conformance to budget. What is striking is that a well-implemented ERP can guarantee these benefits even if the organization is a multi- plant, multi- location global operation spanning the continents.

In a sense ERP systems can be compared to the “fly-by-wire” operation of an aircraft. ERP systems similarly would relieve operating managers of routine decisions and leave them with lots of time to think, plan and execute vital long-term decisions of an organization. Just as “fly-by-wire” operation brings in amazing fuel efficiency to the aircraft operation by continuous monitoring of the airplane operation, ERP systems lead to significant cost savings by continuously monitoring the organizational health. The seemingly high initial investments become insignificant in the face of hefty long-term returns.

At another level, organizations today face the twin challenges of globalization and shortened product life cycle. Globalization has led to unprecedented levels of competition. To face such a competition successful corporations should follow the best business practices in the industry. Shortened life cycles call for continuous design improvement, manufacturing flexibility and super efficient logistics control; in short a better management of the entire supply chain. This in turn presupposes faster access to accurate information both inside the organization and from the entire supply chain outside. The organizational units such as Finance, Marketing, Production and HRD need to operate with a very high level of integration without losing flexibility. ERP systems with an organizational wide view of business processes, business needs of information and flexibility meet these demands admirably.

Need for Enterprise Resource Planning

Organizations today face twin challenges of globalization and shortened product life cycle. Globalization has led to unprecedented levels of competition. To face such competitions, successful corporations should follow the best business practices in the industry. Shortened life cycles call for continuous design improvements, manufacturing flexibility, super-efficient logistics control and better management of the entire supply chain. All these need faster access to accurate information, both inside the organization and the entire supply chain outside. The organizational units such as finance, marketing, production, human resource development etc. need to operate with a very high level of integration without losing flexibility. ERP system with an organization-wide view of business processes, business need of information and flexibility meet these demands admirably. One of the developments in computing and communication channels is providing tighter integration among them.

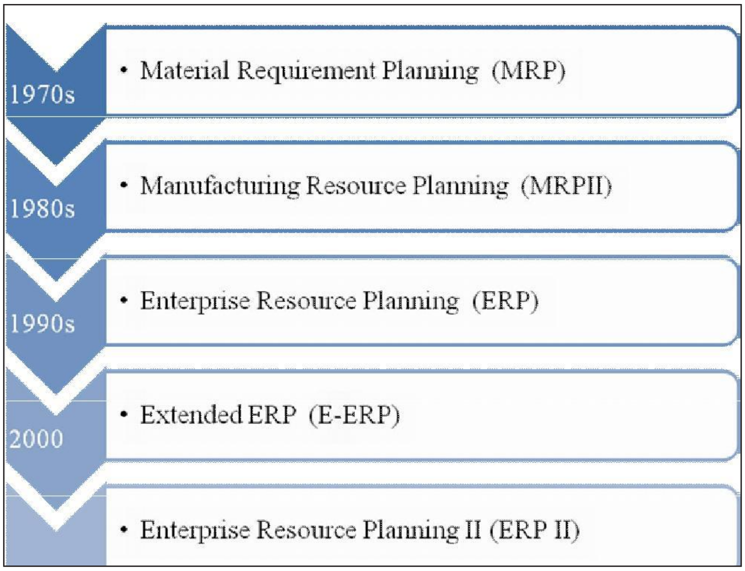
Evolution of Enterprise Resource Planning

Enterprise resource planning (ERP) has evolved as a strategic tool, an outcome of over four decades. This is because of continuous improvements done to the then available techniques to manage business more efficiently and also with developments and inventions in information technology field.

Pre-material Requirement Planning (MRP) Stage

Prior to 1960s businesses generally relied on traditional ways of managing inventories to ensure smooth functioning of the organizations. These theories are popularly known as '*Classical Inventory Management or Scientific Inventory Control Methods*'. Most popularly used among them were Economic Order Quantity (EOQ); Bill of Material (BOM) etc. However these systems had very limited scope.

ERP system has evolved from the Material Planning System of 1980's. There are various phases through which this evolution process has gone through. The various phases of development of resource planning system in relation to time and evolution of concept of ERP.



Stages of ERP Evolution

Material Requirement Planning (MRP)

MRP was the fundamental concept of production management and control in the mid-1970s and considered as the first stage in evolution of ERP. Assembly operations involving thousands of parts such as automobile manufacture led to large inventories. The need to bring down the large inventory levels associated with these industries led to the early MRP systems that planned the order releases. Such planned order releases ensured proper time phrasing and accurate planning of the sub-assembly items, taking into account complex sub-assembly to assembly relationships characterized by the Bill of Materials.

Example:

A typical example is a bicycle manufacture. To manufacture 100 units of bicycles, one needs 200 wheels, 100 foot-pedals, and several thousands of spokes. On a given day, a plant may have 40 units of complete bicycles in stock, 57 units of wheels, 43 units of foot-pedals and 879 units of spokes. If the plant is to assemble 20 units of bicycles for the next 4 days of production, wheels and spokes-is a non-trivial problem. If the independent demand of the spare parts is also to be taken into account, one can visualize the complexity of it.

A typical automobile plant with hundreds, if not thousands of parts, has to face problems that are in order of magnitude even more difficult. MRP systems address this need. Using the processing power of computers, databases to store lead-times and order quantities and algorithms to implement Bill-of-Material (BOM) explosion, MRP systems brought considerable order into the chaotic process of material planning in a discrete manufacturing operation.

Essentially MRP addresses a single task in manufacturing alone. Material requirement planning (MRP) system was adopted by firms for creation and maintenance of master data and bill of material across all products and part within an organization. MRP on the other hand was an outgrowth of bill of material (BOM) processing, which is purchase order management that utilizes parts list management and parts development.

Manufacturing Resources Planning II (MRP- II)

A natural evolution from the first generation MRP systems was the manufacturing planning systems MRP II that addressed the entire manufacturing function and not just a single task within the manufacturing function. MRP II went beyond computations of the materials requirement to include loading and scheduling. MRP II systems could determine whether a given schedule of production was feasible, not merely from material availability but also from other resource point of view.

Typically, the resources considered from MRP II systems would include production facilities, machine capacities and precedence sequences. The increased functionality enabled MRP II systems provided a way to run the system in a loop. First it was used to check the feasibility of a production schedule taking into account the constraints; second to adjust the loading of the resources, if possible, to meet the production schedules; third to plan the materials using the traditional MRP II systems. Both MRP system and MRP II systems were fairly successful in industry. Due to the power of information systems- databases, algorithms and their integration, organizations did find real support for efficiently managing the manufacturing function in the eighties

Enterprise Resource Planning (ERP)

The nineties saw unprecedented global competition, customer focus and shortened product life cycles. To respond to these demands corporations had to move towards agile (quick moving) manufacturing of products, continuous improvements of process and business process reengineering. This called for integration of manufacturing with other functional areas including accounting, marketing, finance and human resource development.

Activity-based costing would not be possible without the integration of manufacturing and accounting. Mass customization of manufacturing needed integration of marketing and manufacturing. Flexible manufacturing with people empowerment necessitated integration of manufacturing with the HRD function. In a sense the 1990s truly called integration of all the functions of management. ERP systems are such integrated information systems build to meet the information and decision needs of an enterprise spanning all the functions of management.

Extended ERP (E-ERP)

Further developments in the enterprise resource planning system concept have led to evolution of extended ERP (E- ERP) or web - enabled ERP. With globalization on one hand and massive development in the internet technology on the other, need for web based IT solution was felt. Thus E- ERP is development in the field of ERP which involves the technology of Internet and World Wide Web to facilitate the functions of an organization around the web.

Enterprise Resource Planning II (ERP- II)

ERP II is the advanced step of E-ERP. It is the software package which has strengthened the original ERP package by included capabilities like customer relationship management, knowledge management, workflow management and human resource management. It is a web friendly application and thus addresses the issue of multiple office locations.

ERP – A Manufacturing Perspective

ERP systems evolved out of MRP and MRP II systems. MRP systems addressed the single task of materials requirements planning. MRP II extended the scope to the entire manufacturing function. The manufacturing industry traditionally had a better climate to use computers. First of all the manufacturing community being dominated by engineers had no computer phobia. Second the extensive use of Computer Aided Drafting (CAD), Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) had prepared the manufacturing function to use computers well, in fact exceptionally well. In fact manufacturing engineers contributed significantly to the theoretical computer science by way of contributions in the areas of graphics, computational geometry, significant visualization, feature recognition etc.

Large corporations like General Motors (GM), Ford, Hewlett Packard (HP), and Digital primarily viewed themselves as manufacturing companies until the 1980s. Naturally complex MRP systems were considered the ultimate in enterprise information systems. The investments in hardware and software to manage such complex manufacturing solutions gave these systems a visibility unparalleled in the industry. Compared to these systems accounting systems, financial systems or personnel information systems were relatively inconsequential to the organization.

With the globalization of operations and the proliferation of computer networks, it was important that the manufacturing organizations extend their information system across the supply chain. The supplier's information system spread across continents with complex combinations of hardware and software need to be integrated. Similarly the dealer-distributor network had to be integrated with the manufacturing information systems. The reduction in product life cycle necessitated a quick response manufacturing system that had its ears tuned to the market.

This forced manufacturing information systems to have a tighter integration with marketing information systems. The manufacturing flexibility had translated into mass customization calling for further integration of information systems. The opening up of several world economies including that of the Asian giants like China and India, the emergence of trade blocks and consolidated markets such as European Union paved the need for accounting and finance functions to be tightly integrated with manufacturing functions. It was not sufficient anymore just to manufacture and sell but organizations had to arrange for finance, comply with complex trade restrictions, barriers, and quotas.

The balance sheets needed to account for multiple currencies, multiple export import rules and regulations, multiple accounting codes, practices, accounting periods. This necessitated further integration of accounting and financial information systems with manufacturing systems. In fact with large capacities built around the world particularly in Asian countries, outsourcing and contract manufacturing became viable alternative even in the high-tech industries like semiconductor manufacturing

Suddenly the need was for an Enterprise Information System that looks beyond the manufacturing function to address inbound logistics, outbound logistics, manufacturing, materials managements, project management, quality management, accounting, finance, sales and personnel management. It was nearly impossible to integrate individual modules of information systems. What was necessary was a system that addressed the enterprise needs from the design stage. ERP systems were the natural choice in this changed scenario.

Benefits of ERP

- Business integration: The first and the most important advantage lie in the promotion of integration. The reason ERP packages are called integrated is the automatic data up gradation between related business components, since conventional company information systems were aimed at the optimization of independent business functions in business units, almost all were weak in terms of the communication and integration of information that transcended the different business functions in the case of large companies in particular, the timing of system structure and directives differs from each product and department / functions and sometimes they are disconnected.

  For this reason, it has become an obstacle in the shift to new product and business classification. In the case of ERP packages the data of related business functions is also automatically updated at the time a transaction occurs. For this reason, one is able to grasp business details in real time, and carry out various types of management decisions in a timely manner based o that information.

- Flexibility: The second advantage of ERP packages is their flexibility. Diverse multi-functional environments such as language, currency, accounting standards and so on are covered in one system and functions that comprehensively managed multiple locations that span a company are packaged and can be implemented automatically. To cope with company globalization and system unification, this flexibility is essential, and one could say that it has major advantages, not simply for development and maintenance, but also in terms of management.

- Better analysis and planning capabilities: Yet another advantage is the boosting of planning type functions. By enabling the comprehensive and unified management of related business and its data, it becomes possible to fully utilize many types of decision support systems and stimulation systems. Furthermore, since it becomes possible to carry out flexibility and in real time the feeling and analysis of data from a variety of dimensions, one is able to give decision makers the information they want, thus enabling them to make better and informed decisions.

- Use of latest technology: The fourth advantage is the utilization of latest developments in information technology (IT). The ERP vendors were very quick to realize that in order to grow and to sustain that growth: they have to embrace the latest developments in the field of information technology. So they quickly adopted their systems to take advantages of the latest technologies like open systems, client server technology, internet/ intranet, computer aided acquisition and logistics support, electronic commerce etc. It is this quick adaptation to the latest changes in information technology that makes the flexible adaptation to changes to future business environments possible. It is this flexibility that makes the incorporation of the latest technology possible during the system customization, maintenance and expansion phases.

- Reduced inventory and inventory carrying cost: The manufacturing nature of many ERP users makes the issue of process and material costs savings paramount. The main factor behind these savings is that implementation of the ERP system allows customers to obtain information on cost, revenues and margins, which allow it to better, manage its overall material cost structure. This ability to manage costs is best seen in savings that organizations can obtain in their inventory systems. Customers can perform a more complete inventory planning and status checking with the ERP system.

- These checks and plans reveal existing surpluses or shortages in supplies. Improved planning and scheduling practices typically lead to inventory reductions to the order of 20 per cent or better. This provides not only a one time reduction in assets (cost of the material stocked), but also provides ongoing savings of the inventory carrying costs. The cost of carrying inventory includes not only interest but also the costs of warehousing, handling, obsolescence, insurance, taxes, damage and shrinkage.
- Reduced manpower cost: Improved manufacturing practices lead to fever shortages and interruptions and to less rework and overtime. Typical labor savings from a successful ERP system are a 10 per cent reduction in direct and indirect labor costs. By minimizing rush jobs and parts shortages, less time is needed for expediting, material handling, extra set-ups, disruptions and tracking splits lots odd jobs that have been set aside. Production supervisors have better visibility of required work and can adjust capacity or loads to meet schedules. Supervisors have more time for managing, directing and training people. Production personnel have more time to develop better methods and improve quality.
- Reduced material costs: Improves procurement practices lead to better vendor negotiations for prices, typically resulting in cost reductions of 5 per cent or better. Valid schedules permit purchasing people to focus on vendor negotiations and quality improvements rather than spending their time on shortages and getting material at premium prices. ERP systems provide negotiation information, such as projected material requirements by commodity group and vendor performance statistics. Giving suppliers better visibility of future requirements help them achieve efficiencies that can be passed on as lower material costs.
- Improves sales and customer service: Improved coordination of sales and production leads to better customer service and increased sales. Improvements in managing customer contacts, making and meeting delivery promises, and shorter order to ship lead times, lead to higher customer satisfaction, goodwill and repeat orders. Sales people can focus on selling instead of verifying or apologizing for late deliveries. In custom product environment, configurations can be quickly identified and prices, often by sales personnel or even the customer rather than the technical staff.
- Taken together, these improvements in customer service can lead to fewer lost sales and actual increase in sales, typically 10 per cent or more. ERP systems also provide the ability to react to changes in demand and to diagnose delivery problems. Corrective actions can be taken early such as determining shipment priorities, notifying customers of changes to promise delivery dates, or altering production schedules to satisfy demand.
- Efficient financial management: Improves collection procedures can reduce the number of days of outstanding receivables, thereby providing additional available cash. Underlying these improvements is fast, accurate invoice creation directly from shipment transactions, timely customer statements and follows through on delinquent accounts. Credit checking during order entry and improved handling of customer inquiries further reduces the number of problem accounts. Improved credit management and receivable practices typically reduce

the days of outstanding receivables by 18 per cent or better. Trade credit can also be maximized by taking advantage by supplier discounts and cash planning, and paying only those invoices with matching recipients. This can lead to lower requirements for cash-on- hand.

The benefits from ERP come in three different forms i.e. in the short-term, medium-term and long-term. When initially implemented, in a year of the organization going live with ERP, it helps in streamlining the operational areas such as purchase, production, inventory control, finance and accounts, maintenance, quality control, sales and distribution, etc. This benefit is in form of 'automating' the transactions which promises accuracy, reliability, availability and consistency of data.

Risk Implementation

Even in a single site, implementing ERP means "Early Retirement Probably." An ERP package is so complex and vast that it takes several years and millions of dollars to roll it out. It also requires many far-flung outposts of a company to follow exactly the same business processes. In fact, implementing any integrated ERP solution is not as much a technological exercise but an "organizational revolution." Extensive preparation before implementation is the key to success. Implementations carried out without patience and careful planning will turn out to be corporate root canals, not competitive advantage. Several issues must be addressed when dealing with a vast ERP system.

Top Management Commitment

Implementing an ERP system is not a matter of changing software systems, rather it is a matter of repositioning the company and transforming the business practices. Due to enormous impact on the competitive advantage of the company, top management must consider the strategic implications of implementing an ERP solution.

Management must ask several questions before embarking on the project. Does the ERP system strengthen the company's competitive position? How might it erode the company's competitive position? How does ERP affect the organizational structure and the culture? What is the scope of the ERP implementation - only a few functional units or the entire organization? Are there any alternatives that meet the company's needs better than an ERP system? If it is a multinational corporation, the management should be concerned about whether it would be better to roll the system out globally or restrict it to certain regional units?

Management must be involved in every step of the ERP implementation. Some companies make the grave mistake of handing over the responsibility of ERP implementation to the technology department. This would risk the entire company's survival because of the ERP system's profound business implications.

It is often said that ERP implementation is about people, not processes or technology. An organization goes through a major transformation, and the *management* of this change must be carefully planned (from a strategic viewpoint) and meticulously implemented. Many parts of the business that used to work in silos now have to be tightly integrated for ERP to work effectively. Cutting corners in planning and implementation is detrimental to a company.

The top *management* must not only fund the project but also take an active role in leading the change. A review of successful ERP implementations has shown that the key to a smooth rollout is the effective change *management* from top. Intervention from *management* is often necessary to resolve conflicts and bring everybody to the same thinking, and to build cooperation among the diverse groups in the organization, often times across the national borders

Top *management* needs to constantly monitor the progress of the project and provide direction to the implementation teams.

The success of a major project like an ERP implementation completely hinges on the strong, sustained commitment of top *management*. This commitment when percolated down through the organizational levels results in an overall organizational commitment. An overall organizational commitment that is very visible, well defined, and felt is a sure way to ensure a successful implementation.

Reengineering

Implementing an ERP system involves reengineering the existing business processes to the best business process standard. ERP *systems* are built on best practices that are followed in the industry. One major benefit of ERP comes from reengineering the company's existing way of doing business. All the processes in a company must conform to the ERP model. The cost and benefits of aligning with an ERP model could be very high. This is especially true if the company plans to roll out the system worldwide. It is not very easy to get everyone to agree to the same process. Sometimes business processes are so unique that they need to be preserved, and appropriate steps need to be taken to customize those business processes.

An organization has to change its processes to conform to the ERP package, customize the software to suit its needs, or not be concerned about meeting the balance 30 percent. If the package cannot adapt to the organization, then organization has to adapt to the package and change its procedures. When an organization customizes the software to suit its needs, the total cost of implementation rises. The more the customization, the greater the implementation costs. Companies should keep their *systems* "as is" as much as possible to reduce the costs of customization and future maintenance and upgrade expenses.

Integration

There is a strong trend toward a single ERP solution for an entire company. Most companies feel that having a single vendor means a "common view" necessary to serve their customers efficiently and the ease of maintaining the system in future. Unfortunately, no single application can do everything a company needs.

Companies may have to use other specialized software products that best meet their unique needs. These products have to be integrated along with all the homegrown *systems* with the ERP suite. In this case, ERP serves as a backbone, and all the different software are bolted on to the

ERP software: There is third party software, called middleware, which can be used to integrate software applications from several vendors to the ERP backbone.

Unfortunately, middleware is not available for all the different software products that are available in the market. Middleware vendors concentrate only on the most popular packaged applications and tend to focus on the technical aspects of application interoperability rather than linking business processes.

Many times, organizations have to develop their own interfaces for commercial software applications and the homegrown applications. Integration software also poses other kinds of problems when it comes to maintenance. It is a nightmare for IS personnel to manage this software whenever there are changes and upgrades to either ERP software or other software that is integrated with the ERP system. For every change, the IT department will be concerned about which link is going to fail this time.

Integration problems would be severe if the middleware links the ERP package of a company to its vendor companies in the supply chain. Maintaining the integration patchwork requires an inordinate and ongoing expenditure of resources. Organizations spend up to 50 percent of their IT budgets on application integration? It is also estimated that the integration market (products and services) equals the size of the entire ERP market.When companies choose bolt-on *systems*, it is advisable to contact the ERP vendor for a list of certified third-party vendors. Each year, all the major ERP vendors publish a list of certified third-party vendors. There are several advantages to choosing this option, including continuous maintenance and upgrade support.

One of the major benefits of ERP solutions is the integration they bring into an organization. Organizations need to understand the nature of integration and how it affects the entire business. Before integration, the functional departments used work in silos and were slow to experience the consequences of the mistakes other departments committed. The *information* flow was rather slow, and the departments that made the mistakes had ample time to correct them before the errors started affecting the other departments. However, with tight integration the ripple effect of mistakes made in one part of the business unit passes onto the other departments in real time. Also, the original mistakes get magnified as they flow through the value chain of the company.

For example, the errors that the production department of a company made in its bill of materials could affect not only the operations in the production department but also the inventory department, accounting department, and others. The impact of these errors could be detrimental to a company. For example, price errors on purchase orders could mislead financial analysts by giving a distorted view of how much the company is spending on materials.

Companies must be aware of the potential risks of the errors and take proper steps, such as monitoring the transactions and taking immediate steps to rectify the problems should they occur. They must also have a formal plan of action describing the steps to be taken if an error is detected. A proper means to communicate to all the parties who are victims of the errors as soon as the errors are detected is extremely important. Consider the recent example of a manufacturing company that implemented an ERP package. It suddenly started experiencing a shortage of manufacturing materials. Production workers noticed that it was due to incorrect bills of materials, and they made necessary adjustments because they knew the correct number of parts needed to manufacturer.

However, the company did not have any procedures to notify others in case any errors were found in the data. The domino effect of the errors started affecting other areas of business. Inventory managers thought the company had more material than what was on the shelves, and material shortages occurred. Now the company has mandatory training classes to educate employees about how transactions flow through the system and how errors affect the activities in a value chain. It took almost eight weeks to clean up the incorrect bills of materials in the database.

Companies implementing electronic supply chains face different kinds of problems with integration of *information* across the supply chain companies. The major challenge is the impact automation has on the business process. Automation changes the way companies deal with one another, from planning to purchase to paying. Sharing and control of *information* seem to be major concerns. Companies are concerned about how much *information* they need to share with their customers and suppliers and how to control the *information*. Suppliers do not want their competitors to see their prices or order volumes.

The general fear is that sharing too much *information* hurts their business. Regarding controlling *information*, companies are aware that it is difficult to control what they own let alone control what they do not own. Companies need to trust their partners and must coordinate with each other in the chain. The whole chain suffers if one link is slow to provide *information* or access. The *management* also must be concerned about the stress an automated supply chain brings within each organization. For instance, a sales department may be unhappy that electronic ordering has cut it out of the loop, while manufacturing may have to adjust to getting one week's notice to order changes and accommodate those changes into its production orders.

ERP Consultants

Because the ERP market has grown so big so fast, there has been a shortage of competent consultants. The skill shortage is so deep that it cannot be filled immediately. Finding the right people and keeping them through the implementation is a major challenge. ERP implementation demands multiple skills - functional, technical, and interpersonal skills. Again, consultants with specific industry knowledge are fewer in number. There are not many consultants with all the required skills.

One might find a consultant with a stellar reputation in some areas, but he may lack expertise in the specific area a company is looking for. Hiring a consultant is just the tip of the iceberg. Managing a consulting firm and its employees is even more challenging. The success or failure of the project depends on how well you meet this challenge.

Implementation Time

ERP *systems* come in modular fashion and do not have to be implemented entirely at once. Several companies follow a phase-in approach in which one module is implemented at a time.

For example, SAP R/3 is composed of several "complete" modules that could be chosen and implemented, depending on an organization's needs. Some of the most commonly installed modules are sales and distribution (SD), materials *management* (MM), production and planning, (PP), and finance and controlling (FI) modules.

The average length of time for a "typical" implementation is about 14 months and can take as much as 150 consultants. Corning, Inc. plans to roll out ERP in ten of its diversified manufacturing divisions, and it expects the rollout to last five to eight years. The length of implementation is affected to a great extent by the number of modules being implemented, the scope of the implementation (different functional units or across multiple units spread out globally), the extent of customization, and the number of interfaces with other applications.

The more the number of units, the longer implementation. Also, as the scope of implementation grows from a single business unit to multiple units spread out globally, the duration of implementation increases. A global implementation team has to be formed to prepare common requirements that do not violate the individual unit's specific requirements. This involves extensive travel and increases the length of implementation.

Fundamental Technology of ERP

When it comes time for your organization to evaluate ERP systems, whether you are replacing a small business accounting package or an aging ERP, It is important to clarify the components. Each piece (often called module) of the ERP system delivers different value for your organization. To get the most from the full system, make sure your evaluation team understands the fundamentals.

Financial Management

At the core of ERP are the financial modules, including general ledger, accounts receivable, accounts payable, billing and fixed asset management. If your organization is considering the move to an ERP system to support expansion into global markets, make sure that multiple currencies and languages are supported.

Other functionality in the financial management modules will include budgets, cash-flow, expense and tax reporting. The evaluation team should focus on areas that are most important to support the strategic plans for your organization.

Business Intelligence

Business Intelligence (BI) has become a standard component of most ERP packages. In general, BI tools allow users to share and analyze the data collected across the enterprise and centralized in the ERP database. BI can come in the form of dashboards, automated reporting and analysis tools used to monitor the organization business performance. BI supports informed decision making by everyone, from executives to line managers and accountants.

Supply Chain Management

Supply Chain Management (SCM), sometimes referred to as logistics, improves the flow of materials through an organization by managing planning, scheduling, procurement, and fulfillment, to maximize customer satisfaction and profitability. Sub modules in SCM often include production scheduling, demand management, distribution management, inventory management, warehouse management, and procurement and order management.

Any company dealing with products, from manufacturers to distributors, needs to clearly define their SCM requirements to properly evaluate an ERP solution.

Human Resource Management

Human resource management ERP modules should enhance the employee experience – from initial recruitment to time tracking. Â Sub modules can include payroll, performance management, time tracking, benefits, compensation and workforce planning. Self-service tools that allow managers and employees to enter time and attendance, choose benefits and manage PTO are available in many ERP solutions.

Manufacturing Operations

Manufacturing modules make manufacturing operations more efficient through product configuration, job costing and bill of materials management. ERP manufacturing modules often include Capacity Requirements Planning, Materials Requirements Planning, forecasting, Master Production Scheduling, work-order management and shop-floor control.

Integration

Key to the value of an ERP package is the integration between modules, so that all of the core business functions are connected. Information should flow across the organization so that BI reports on organization-wide results.

Issues to be consider in planning design and implementation of cross functional integrated ERP systems:

The problem with ERP packages is that they are very general and need to be configured to a specific type of business. This customization takes a long time, depending on the specific requirements of the business. The extent of customization determines the length of the implementation. The more customization needed, the longer it will take to roll the software out and the more it will cost to keep it up-to-date.

For small companies, SAP recently launched Ready-to-Run, a scaled-down suite of R/3 programs preloaded on a computer server. ERP vendors are now offering industry-specific applications to cut the implementation time down. SAP has recently outlined a comprehensive plan to offer 17 industry-specific solutions, including chemical, aerospace and defense, insurance, retail, media, and utilities industries. Even though these specific solutions would able to substantially reduce the time to implement an application, organizations still have to customize the product for their specific requirements.

Implementation Costs

Even though the price of prewritten software is cheap compared with in-house development, the total cost of implementation could be three to five times the purchase price of the software. The implementation costs would increase as the degree of customization increases. The cost of hiring consultants and all that goes with it can consume up to 30 percent of the overall budget for the implementation.

Once the selected employees are trained after investing a huge sum of money, it is a challenge to retain them, especially in a market that is hungry for skilled SAP consultants. Employees could double or triple their salaries by accepting other positions. Retention strategies such as bonus programs, company perks, salary increases, continual training and education, and appeals to company loyalty could work. Other intangible strategies such as flexible work hours, telecommuting options, and opportunities to work with leading-edge technologies are also being used. Many companies simply strive to complete the projects quickly for fear of poaching by head-hunting agencies and other companies.

Selecting the Right Employees

Companies intending to implement an ERP system must be willing to dedicate some of their best employees to the project for a successful implementation. Often companies do not realize the impact of choosing the internal employees with the right skill set. The importance of this aspect cannot be overemphasized. Internal resources of a company should not only be experts in the company's processes but also be aware of the best business practices in the industry. Internal resources on the project should exhibit the ability to understand the overall needs of the company and should play an important role in guiding the project efforts in the right direction.

Most of the consulting organizations do provide comprehensive guidelines for selecting internal resources for the project. Companies should take this exercise seriously and make the right choices. Lack of proper understanding of the project needs and the inability to provide leadership and guidance to the project by the company's internal resources is a major reason for the failure of ERP projects. Because of the complexities involved in the day-to-day running of an organization, it is not uncommon to find functional departments unwilling to sacrifice their best resources toward ERP project needs. However, considering that ERP system implementation can be a critical step in forging an organization's future, companies are better off dedicating their best internal resources to the project.

Training Employees

Training and updating employees on ERP is a major challenge. People are one of the hidden costs of ERP implementation. Without proper training, about 30 percent to 40 percent of front- line workers will not be able to handle the demands of the new system. The people at the keyboard are now making important decisions about buying and selling -- important commitments of the company. They need to understand how their data affects the rest of company. Some of the decisions front-line people make with an ERP system were the responsibility of a manager earlier. It is important for managers to understand this change in their job and encourage the front-line people to be able to make those decisions themselves.

Training employees on ERP is not as simple as Excel training in which you give them a few weeks of training, put them on the job, and they blunder their way through. ERP *systems* are extremely complex and demand rigorous training. It is difficult for trainers or consultants to pass on the knowledge to the employees in a short period of time. This "knowledge transfer" gets hard if the employees lack computer literacy or have computer phobia. In addition to being taught ERP technology, the employees now have to be taught their new responsibilities. With ERP *systems* you are continuously being trained. Companies should provide opportunities to enhance the skills of the employees by providing training opportunities on a continuous basis to meet the changing needs of the business and employees.

Employee Morale

Employees working on an ERP implementation project put in long hours (as much as 20 hours per day) including seven-day weeks and even holidays. Even though the experience is valuable for their career growth, the stress of implementation coupled with regular job duties (many times employees still spend 25 to 50 percent of their time on regular job duties) could decrease their morale rapidly. Leadership from upper *management* and support and caring acts of project leaders would certainly boost the morale of the team members. Other strategies, such as taking the employees on field trips, could help reduce the stress and improve the morale.

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Forecasting, Capacity and Aggregate Planning

The process of making predictions of the future by analyzing trends as well as on the past and present data is known as forecasting. Capacity refers to the highest level of output which a company can maintain to provide a service or make a product. The topics elaborated in this chapter will help in gaining a better perspective about forecasting, capacity and aggregate planning.

Forecasting

Forecasting is the art and science of predicting what will happen in the future. Sometimes that is determined by a mathematical method; sometimes it is based on the intuition of the operations manager. Most forecasts and end decisions are a combination of both.

Forecasting is conducted by what are referred to as time horizons:

1. Short range forecast: While it can be up to one year, this forecast is usually used for three months or less. It is used for planning purchases, hiring, job assignments, production levels, and the like.
2. Medium range forecast: This is generally three months to three years. Medium range forecasts are used for sales and production planning, budgeting, and analysis of different operating plans.
3. Long range forecast: Generally three years or more in time span, it is used for new products, capital expenditures, facility expansion, relocation, and research and development.

Medium and long range forecasts differ from short range forecasts by other characteristics as well:

1. Medium and long range forecasts are more comprehensive in nature. They support and guide management decisions in planning products, processes, and plants. A new plant can take seven or eight years from the time it is thought of, until it is ready to move into and become functional.
2. Short term forecasts use different methodologies than the others. Most short term forecasts are quantitative in nature and use existing data in mathematical formulas to anticipate immediate future needs and impacts.
3. Short term forecasts are more accurate than medium or long range forecasts. A lot can change in three months, a year, three years, and longer. Factors that could influence those

forecasts change every day. Short term forecasts need to be updated regularly to maintain their effectiveness.

There are three major types of forecasting, regardless of time horizon, that are used by organizations.

1. Economic forecasts address the business cycle. They predict housing starts, inflation rates, money supplies, and other indicators.

2. Technological forecasts monitor rates of technological progress. This keeps organizations abreast of trends and can result in exciting new products. New products may require new facilities and equipment, which must be planned for in the appropriate time frame.

3. Demand forecasts deal with the company's products and estimate consumer demand. These are also referred to as sales forecasts, which have multiple purposes. In addition to driving scheduling, production, and capacity, they are also inputs to financial, personnel, and marketing future plans.

Strategic Importance of Forecasts

Operations managers have two tools at their disposal by which to make decisions: actual data and forecasts. The importance of forecasting cannot be underestimated. Take a product forecast and the functions of human resources, capacity, and supply chain management.

The workforce is based on demand. This includes hiring, training, and lay-off of workers. If a large demand is suddenly thrust upon the organization, training declines and the quality of the product could suffer.

When the capacity cannot keep up to the demand, the result is undependable delivery, loss of customers, and maybe loss of market share. Yet, excess capacity can skyrocket costs.

Last minute shipping means high cost. Asking for parts last minute can raise the cost. Most profit margins are slim, which means either of those scenarios can wipe out a profit margin and have an organization operating at cost - or at a loss.

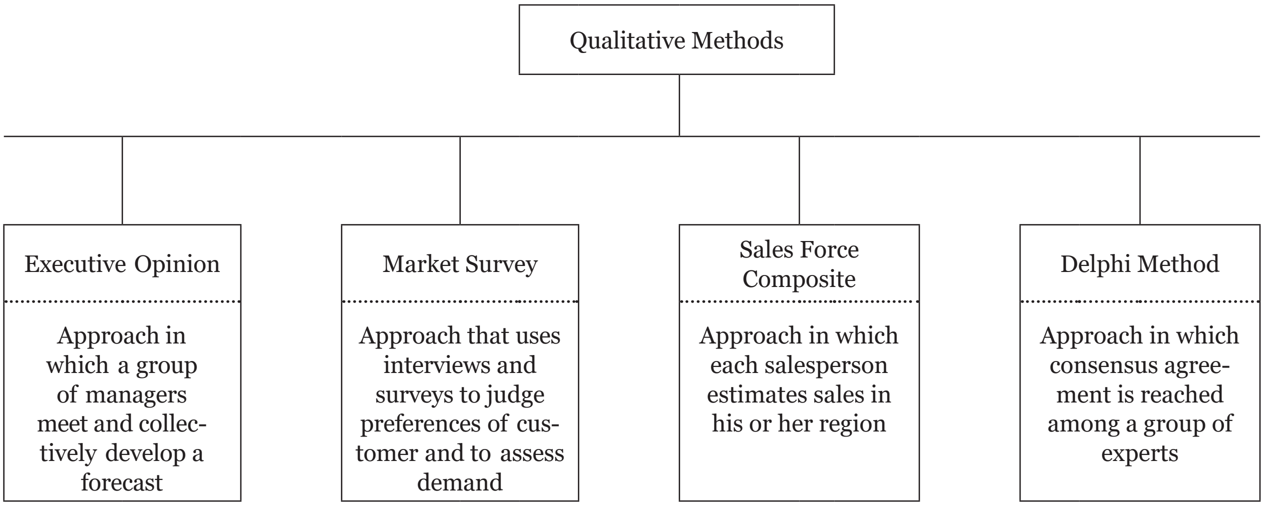
These scenarios are why forecasting is important to an organization. Good operations managers learn how to forecast, to trust the numbers, and to trust their instincts to make the right decisions for their firm.

Types of Forecasting Methods

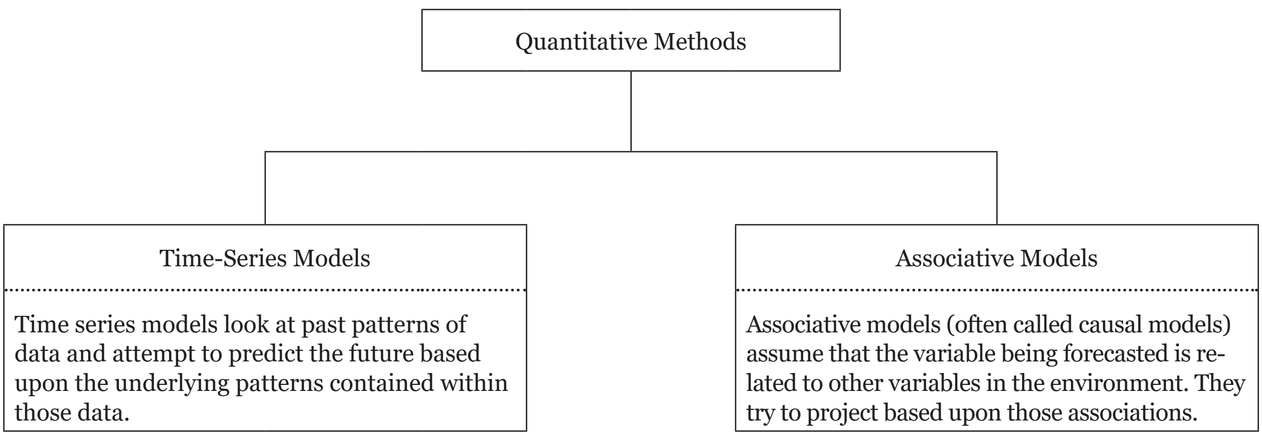
1. Qualitative methods: These types of forecasting methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations.

2. Quantitative methods: These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations.

Qualitative Forecasting Methods



Quantitative Forecasting Methods



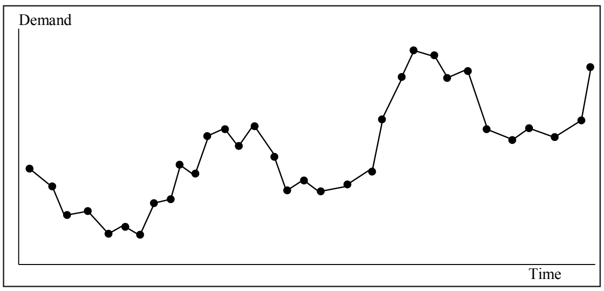
Time Series Models

Model	Description
Naïve	Uses last period's actual value as a forecast.
Simple Mean (Average)	Uses an average of all past data as a forecast.
Simple Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight).
Weighted Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving a different emphasis (weight).
Exponential Smoothing	A weighted average procedure with weights declining exponentially as data become older.
Trend Projection	Technique that uses the least squares method to fit a straight line to the data.
Seasonal Indexes	A mechanism for adjusting the forecast to accommodate any seasonal patterns inherent in the data.

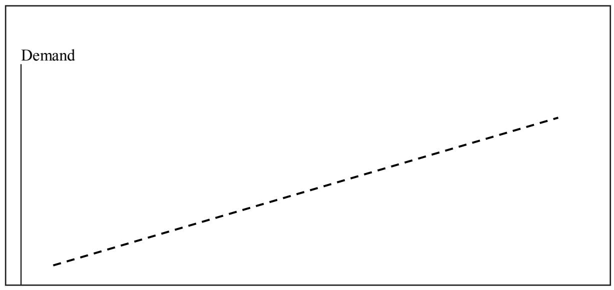
Decomposition of a Time Series

Patterns that may be present in a time series:

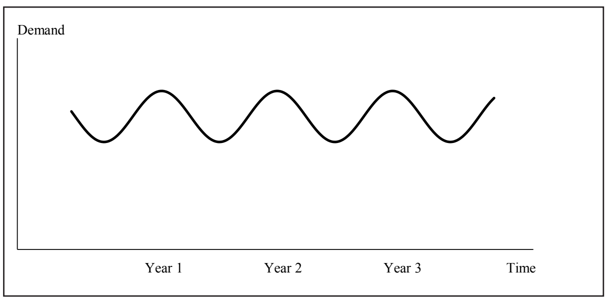
- Trend: Data exhibit a steady growth or decline over time.
- Seasonality: Data exhibit upward and downward swings in a short to intermediate time frame (most notably during a year).
- Cycles: Data exhibit upward and downward swings in over a very long time frame.
- Random variations: Erratic and unpredictable variation in the data over time with no discernable pattern.



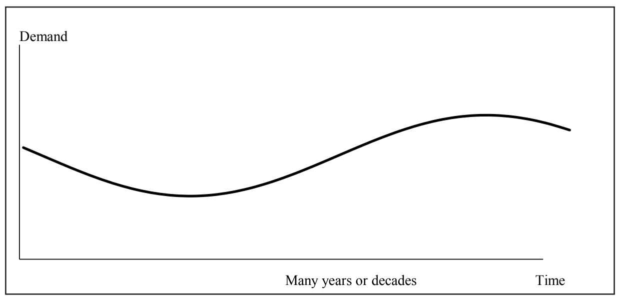
Hypothetical Pattern of Historical Demand



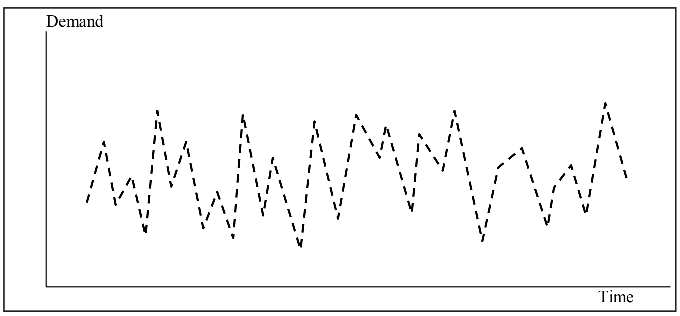
Trend Component in Historical Demand



Seasonal Component In Historical Demand



Cycle Component in Historical Demand



Random Component in Historical Demand

Data Set to Demonstrate Forecasting Methods

The following data set represents a set of hypothetical demands that have occurred over several consecutive years. The data have been collected on a quarterly basis, and these quarterly values have been amalgamated into yearly totals.

For various illustrations that follow, we may make slightly different assumptions about starting points to get the process started for different models. In most cases we will assume that each year a forecast has been made for the subsequent year. Then, after a year has transpired we will have observed what the actual demand turned out to be (and we will surely see differences between what we had forecasted and what actually occurred, for, after all, the forecasts are merely educated guesses).

Finally, to keep the numbers at a manageable size, several zeros have been dropped off the numbers (i.e., these numbers represent demands in thousands of units).

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total Annual Demand
1	62	94	113	41	310
2	73	110	130	52	365
3	79	118	140	58	395
4	83	124	146	62	415
5	89	135	161	65	450
6	94	139	162	70	465

Examples of the Naïve Method

Naïve method: The forecast for next period (period t+1) will be equal to this period's actual demand (At).

In this example we assume that each year (beginning with year 2) we made a forecast, then waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

Year	Actual Demand (At)	Forecast (Ft)
1	310	--
2	365	310
3	395	365
4	415	395
5	450	415
6	465	450
7		465

Mean (Simple Average) Method

Mean (simple average) method: The forecast for next period (period t+1) will be equal to the average of all past historical demands.

In this illustrations we assume that a simple average method is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). At the end of year 1 we could start using this forecasting method. In this illustrations we assume that each year (beginning with year 2) we made a forecast, then waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

Year	Actual Demand (At)	Forecast (Ft)
1	310	300
2	365	310.000
3	395	337.500
4	415	356.667
5	450	371.250
6	465	387.000
7		400.000

Simple Moving Average Method

Simple moving average method: The forecast for next period (period t+1) will be equal to the average of a specified number of the most recent observations, with each observation receiving the same emphasis (weight).

In this illustrations we assume that a 2-year simple moving average is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, after year 1 elapsed, we made a forecast for year 2 using a naïve method (310). Beyond that point we had sufficient data to let our 2-year simple moving average forecasts unfold throughout the years.

Year	Actual Demand (At)	Forecast (Ft)
1	310	300
2	365	310
3	395	337.500
4	415	380.000
5	450	405.000
6	465	432.500
7		457.500

Another Simple Moving Average Method

In this illustrations we assume that a 3-year simple moving average is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, after year 1 elapsed, we used a naïve method to make a forecast for year 2 (310) and year 3 (365). Beyond that point we had sufficient data to let our 3-year simple moving average forecasts unfold throughout the years.

Year	Actual Demand (At)	Forecast (Ft)
1	310	300
2	365	310
3	395	365
4	415	356.667
5	450	391.667
6	465	420.000
7		433.333

Weighted Moving Average Method

Weighted moving average method: The forecast for next period (period t+1) will be equal to a weighted average of a specified number of the most recent observations.

In this illustrations we assume that a 3-year weighted moving average is being used. We will also assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300).

Then, after year 1 elapsed, we used a naïve method to make a forecast for year 2 (310) and year 3 (365). Beyond that point we had sufficient data to let our 3-year weighted moving average forecasts unfold throughout the years. The weights that were to be used are as follows: Most recent year,. 5; year prior to that,. 3; year prior to that.

Year	Actual Demand (At)	Forecast (Ft)
1	310	300
2	365	310
3	395	365
4	415	369.000
5	450	399.000
6	465	428.500
7		450.500

Exponential Smoothing Method

Exponential smoothing method: The new forecast for next period (period t) will be calculated as follows:

New forecast = Last period's forecast + α(Last period's actual demand – Last period's forecast)

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

$$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1} \text{ (alternate equation 1 – a bit more user friendly)}$$

Where α is a smoothing coefficient whose value is between 0 and 1.

The exponential smoothing method only requires that you dig up two pieces of data to apply it (the most recent actual demand and the most recent forecast).

An attractive feature of this method is that forecasts made with this model will include a portion of every piece of historical demand. Furthermore, there will be different weights placed on these historical demand values, with older data receiving lower weights. At first glance this may not be obvious; however, this property is illustrated on the following page.

Exponential Smoothing Method

In this illustrations we assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, for each subsequent year (beginning with year 2) we made a forecast using the exponential smoothing model. After the forecast was made, we waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

This set of forecasts was made using an avalue of. 1.

Year	Actual Demand (A)	Forecast (F)
1	310	300
2	365	301
3	395	307.4
4	415	316.16
5	450	326.044
6	465	338.4396
7		351.09564

A Second Exponential Smoothing Method

In this illustrations we assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, for each subsequent year (beginning with year 2) we made a forecast using the exponential smoothing model. After the forecast was made, we waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

This set of forecasts was made using an avalue of 2.

Year	Actual Demand (A)	Forecast (F)
1	310	300
2	365	302
3	395	314.6
4	415	330.68
5	450	347.544
6	465	368.0352
7		387.42816

A Third Exponential Smoothing Method

In this illustrations we assume that, in the absence of data at startup, we made a guess for the year 1 forecast (300). Then, for each subsequent year (beginning with year 2) we made a forecast using the exponential smoothing model. After the forecast was made, we waited to see what demand unfolded during the year. We then made a forecast for the subsequent year, and so on right through to the forecast for year 7.

This set of forecasts was made using an α value of 4.

Year	Actual Demand (A)	Forecast (F)
1	310	300
2	365	304
3	395	328.4
4	415	355.04
5	450	379.024
6	465	407.4144
7		430.44864

Trend Projection

Trend projection method: This method is a version of the linear regression technique. It attempts to draw a straight line through the historical data points in a fashion that comes as close to the points as possible. (Technically, the approach attempts to reduce the vertical deviations of the points from the trend line, and does this by minimizing the squared values of the deviations of the points from the line). Ultimately, the statistical formulas compute a slope for the trend line (b) and the point where the line crosses the y-axis (a). This results in the straight line equation,

$$Y = a + bX$$

Where X represents the values on the horizontal axis (time), and Y represents the values on the vertical axis (demand).

For the demonstration data, computations for b and a reveal the following:

$$b = 30$$

$$a = 295$$

$$Y = 295 + 30X$$

This equation can be used to forecast for any year into the future. For examples:

Year 7: Forecast = 295 + 30(7) = 505

Year 8: Forecast = 295 + 30(8) = 535

Year 9: Forecast = 295 + 30(9) = 565

Year 10: Forecast = 295 + 30(10) = 595

Stability vs. Responsiveness in Forecasting

All demand forecasting methods vary in the degree to which they emphasize recent demand changes when making a forecast. Forecasting methods that react very strongly (or quickly) to demand changes are said to be *responsive*. Forecasting methods that do not react quickly to demand changes are said to be *stable*. One of the critical issues in selecting the appropriate forecasting method hinges on the question of *stability* versus *responsiveness*. How much stability or how much responsiveness one should employ is a function of how the historical demand has been fluctuating. If demand has been showing a steady pattern of increase (or decrease), then more responsiveness is desirable, for we would like to react quickly to those demand increases (or decreases) when we make our next forecast. On the other hand, if demand has been fluctuating upward and downward, then more stability is desirable, for we do not want to “over react” to those up and down fluctuations in demand.

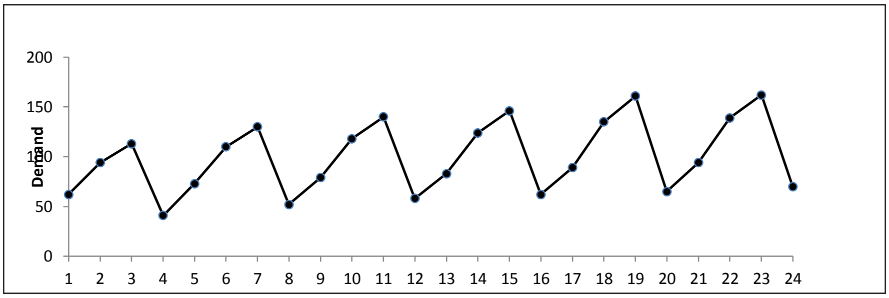
For some of the simple forecasting methods we have examined, the following can be noted:

- Moving Average Approach: Using more periods in your moving average forecasts will result in more stability in the forecasts. Using fewer periods in your moving average forecasts will result in more responsiveness in the forecasts.
- Weighted Moving Average Approach: Using more periods in your weighted moving average forecasts will result in more stability in the forecasts. Using fewer periods in your weighted moving average forecasts will result in more responsiveness in the forecasts. Furthermore, placing lower weights on the more recent demand will result in more stability in the forecasts. Placing higher weights on the more recent demand will result in more responsiveness in the forecasts.
- Simple Exponential Smoothing Approach: Using a lower alpha (α) value will result in more stability in the forecasts. Using a higher alpha (α) value will result in more responsiveness in the forecasts.

Seasonality Issues in Forecasting

Up to this point we have seen several ways to make a forecast for an upcoming year. In many instances managers may want more detail that just a yearly forecast. They may like to have a projection for individual time periods within that year (e.g., weeks, months, or quarters). Let's assume that our forecasted demand for an upcoming year is 480, but management would like a forecast for each of the quarters of the year. A simple approach might be to simply divide the total annual forecast of 480 by 4, yielding 120. We could then project that the demand for each quarter of the year will be 120. But of course, such forecasts could be expected to be quite inaccurate, for an examination of our original table of historical data reveals that demand is not uniform across each quarter of the year. There seem to be distinct peaks and valleys (i.e., quarters of higher demand and quarters of lower demand). The graph below of the historical quarterly demand clearly shows those peaks and valleys during the course of each year.

Quarterly Demands over Six-year History



Sequential Quarters Over Six Years

Calculating Seasonal Index Values

This is the way you will find seasonal index values calculated in the textbook. Begin by calculating the average demand in each of the four quarters of the year.

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6
Year	Q1	Q2	Q3	Q4	Annual Demand
1	62	94	113	41	310
2	73	110	130	52	365
3	79	118	140	58	395
4	83	124	146	62	415
5	89	135	161	65	450
6	94	139	162	70	465
Avg. Demand Per Qtr.	(62+73+79+83+89+94) ÷ 6 = 80	(94+110+118+124+135+139) ÷ 6 = 120	(113+130+140+146+161+162) ÷ 6 = 142	(41+52+58+62+65+70) ÷ 6 = 58	

Next, note that the total demand over these six years of history was 2400 (i.e., 310 + 365 + 395 + 415 + 450 + 465), and if this total demand of 2400 had been evenly spread over each of the 24 quarters in this six year period, the average quarterly demand would have been 100 units.

Another way to look at this is the average of the quarterly averages is 100 units, i.e. (80 + 120 + 142 + 58)/4 = 100 units.

But, the numbers above indicate that the demand wasn't evenly distributed over each quarter. In Quarter 1 the average demand was considerably below 100 (it averaged 80 in Quarter 1). In Quarters 2 and 3 the average demand was considerably above 100 (with averages of 120 and 142, respectively). Finally, in Quarter 4 the average demand was below 100 (it averaged 58 in Quarter 4). We can calculate a seasonal index for each quarter by dividing the average quarterly demand by the 100 that would have occurred if all the demand had been evenly distributed across the quarters.

This would result in the following alternate seasonal index values:

Year	Q1	Q2	Q3	Q4
Seasonal Index	80/100 = .80	120/100 = 1.20	142/100 = 1.42	58/100 = .58

A quick check of these alternate seasonal index values reveals that they average out to 1.0 (as they should). (.80 + 1.20 + 1.42 +. 58)/4 = 1.000

Using Seasonal Index Values

The following forecasts were made for the next 4 years using the trend projection line approach (the trend projection formula developed was Y = 295 + 30X, where Y is the forecast and X is the year number).

Year	Forecast
7	505
8	535
9	565
10	595

If these annual forecasts were evenly distributed over each year, the quarterly forecasts would look like the following:

Year	Q1	Q2	Q3	Q4	Annual Forecast	Annual/4
7	126.25	126.25	126.25	126.25	505	126.25
8	133.75	133.75	133.75	133.75	535	133.75
9	141.25	141.25	141.25	141.25	565	141.25
10	148.75	148.75	148.75	148.75	595	148.75

However, seasonality in the past demand suggests that these forecasts should not be evenly distributed over each quarter. We must take these even splits and multiply them by the seasonal index

(S.I.) values to get a more reasonable set of quarterly forecasts. The results of these calculations are shown below.

S.I.	.80	1.20	1.42	.58

Year	Q1	Q2	Q3	Q4	Annual Forecast
7	101.000	151.500	179.275	73.225	505
8	107.000	160.500	189.925	77.575	535
9	113.000	169.500	200.575	81.925	565
10	119.000	178.500	211.225	86.275	595

If you check these final splits, you will see that the sum of the quarterly forecasts for a particular year will equal the total annual forecast for that year (sometimes there might be a slight rounding discrepancy).

Other Methods for Making Seasonal Forecasts

Let's go back and reexamine the historical data we have for this problem. I have put a little separation between the columns of each quarter to let you better visualize the fact that we could look at any one of those vertical strips of data and treat it as a time series. For examples, the Q1 column displays the progression of quarter 1 demands over the past six years. One could simply peel off that strip of data and use it along with any of the forecasting methods we have examined to forecast the Q1 demand in year 7. We could do the same thing for each of the other three quarterly data strips.

Year	Q1	Q2	Q3	Q4
1	62	94	113	41
2	73	110	130	52
3	79	118	140	58
4	83	124	146	62
5	89	135	161	65
6	94	139	162	70

To illustrate, I have used the linear trend line method on the quarter 1 strip of data, which would result in the following trend line:

$$Y = 58.8 + 6.0571X$$

For year 7, X = 7, so the resulting Q1 forecast for year 7 would be 101.200

We could do the same thing with the Q2, Q3, and Q4 strips of data. For each strip we would compute the trend line equation and use it to project that quarter's year 7 demands. Those results are summarized here:

Q2 trend line: $Y = 89.4 + 8.7429X$; Year 7 Q2 forecast would be 150.600

Q3 trend line: $Y = 107.6 + 9.8286X$; Year 7 Q3 forecast would be 176.400

Q4 trend line: Y = 39.2 + 5.3714X; Year 7 Q4 forecast would be 76.800

Total forecast for year 7 = 101.200 + 150.600 + 176.400 + 76.800 = 505.000

These quarterly forecasts are in the same ballpark as those made with the seasonal index values earlier. They differ a bit, but we cannot say one is correct and one is incorrect. They are just slightly different predictions of what is going to happen in the future. They do provide a total annual forecast that is equal to the trend projection forecast made for year 7. (Don't expect this to occur on every occasion, but since it corroborates results obtained with a different method, it does give us confidence in the forecasts we have made).

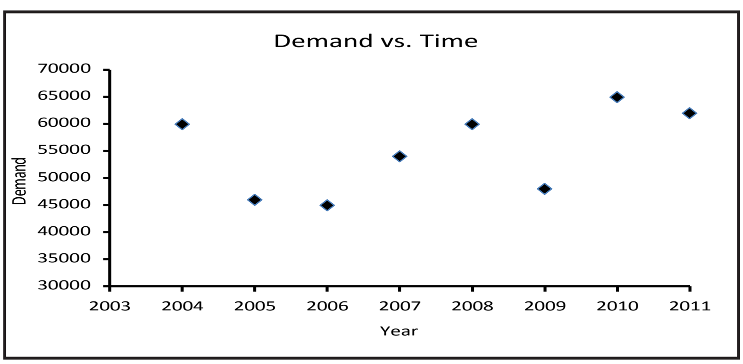
Associative Forecasting Method

Associative forecasting models (causal models) assume that the variable being forecasted (the dependent variable) is related to other variables (independent variables) in the environment. This approach tries to project demand based upon those associations. In its simplest form, linear regression is used to fit a line to the data. That line is then used to forecast the dependent variable for some selected value of the independent variable.

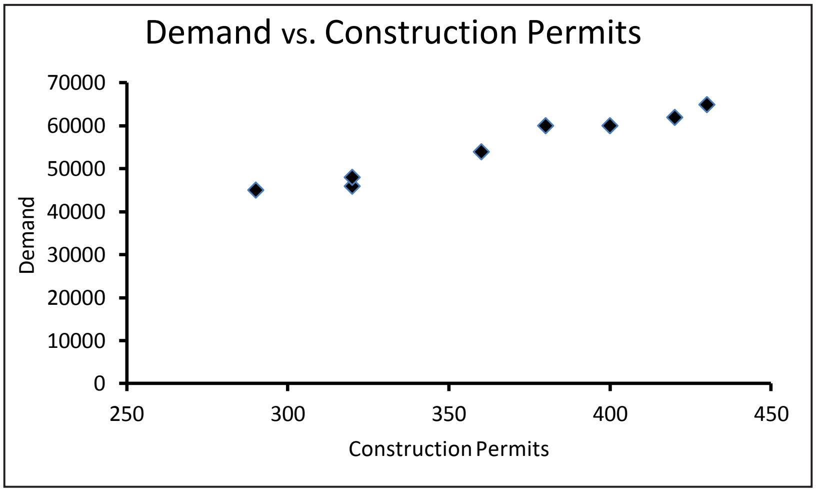
In this illustrations a distributor of drywall in a local community has historical demand data for the past eight years as well as data on the number of permits that have been issued for new home construction. These data are displayed in the following table:

Year	# of new home construction permits	Demand for 4'x8' sheets of drywall
2004	400	60,000
2005	320	46,000
2006	290	45,000
2007	360	54,000
2008	380	60,000
2009	320	48,000
2010	430	65,000
2011	420	62,000

If we attempted to perform a time series analysis on demand, the results would not make much sense, for a quick plot of demand vs. time suggests that there is no apparent pattern relationship here, as seen below.



If you plot the relationship between demand and the number of construction permits, a pattern emerges that makes more sense. It seems to indicate that demand for this product is lower when fewer construction permits are issued and higher when more permits are issued. Therefore, regression will be used to establish a relationship between the dependent variable (demand) and the independent variable (construction permits).



The independent variable (X) is the number of construction permits. The dependent variable (Y) is the demand for drywall.

Application of regression formulas yields the following forecasting model:

$$Y = 250 + 150X$$

If the company plans finds from public records that 350 construction permits have been issued for the year 2012, then a reasonable estimate of drywall demand for 2012 would be:

$$Y = 250 + 150(350) = 250 + 52{,}500 = 52{,}750$$

(which means next year's forecasted demand is 52,750 sheets of drywall).

Measuring Forecast Accuracy

Mean Forecast Error (MFE): Forecast error is a measure of how accurate our forecast was in a given time period. It is calculated as the actual demand minus the forecast, or

$$E_t = A_t - F_t$$

Forecast error in one time period does not convey much information, so we need to look at the accumulation of errors over time. We can calculate the average value of these forecast errors over time (i.e., a Mean Forecast Error, or MFE).Unfortunately, the accumulation of the Et values is not always very revealing, for some of them will be positive errors and some will be negative. These positive and negative errors cancel one another, and looking at them alone (or looking at the MFE over time) might give a false sense of security. To illustrate, consider our original data, and the accompanying pair of hypothetical forecasts made with two different forecasting methods.

Year	Actual Demand At	Hypothetical Forecasts Made With Method 1Ft	Forecast Error With Method 1 At - Ft	Hypothetical Forecasts Made With Method 2Ft	Forecast Error With Method 2 At - Ft
1	310	315	-5	370	-60
2	365	375	-10	455	-90
3	395	390	5	305	90
4	415	405	10	535	-120
5	450	435	15	390	60
6	465	480	-15	345	120
Accumulated Forecast Errors 0 0 Mean Forecast Error, MFE0/6 = 0			0		0
			0/6 = 0		

Based on the accumulated forecast errors over time, the two methods look equally good. But, most observers would judge that Method 1 is generating better forecasts than Method 2 (i.e., smaller misses).

Mean Absolute Deviation (MAD): To eliminate the problem of positive errors canceling negative errors, a simple measure is one that looks at the absolute value of the error (size of the deviation, regardless of sign). When we disregard the sign and only consider the size of the error, we refer to this deviation as the absolute deviation. If we accumulate these absolute deviations over time and find the average value of these absolute deviations, we refer to this measure as the mean absolute deviation (MAD). For our hypothetical two forecasting methods, the absolute deviations can be calculated for each year and an average can be obtained for these yearly absolute deviations, as follows:

Year	Actual Demand At	Hypothetical Forecasting Method 1			Hypothetical Forecasting Method 2		
		Forecast Ft	Forecast Error At - Ft	Absolute Deviation|At - Ft|	Forecast Ft	Forecast Error At - Ft	Absolute Deviation|At - Ft|
1	310	315	-5	5	370	-60	60
2	365	375	-10	10	455	-90	90
3	395	390	5	5	305	90	90
4	415	405	10	10	535	-120	120
5	450	435	15	15	390	60	60
6	465	480	-15	15	345	120	120
	Total Absolute Deviation			60			540
	Mean Absolute Deviation			60/6=10			540/6=90

The smaller misses of Method 1 has been formalized with the calculation of the MAD. Method 1 seems to have provided more accurate forecasts over this six year horizon, as evidenced by its considerably smaller MAD.

Mean Squared Error (MSE): Another way to eliminate the problem of positive errors canceling negative errors is to square the forecast error. Regardless of whether the forecast error has a positive or negative sign, the squared error will always have a positive sign. If we accumulate these squared errors over time and find the average value of these squared errors, we refer to this measure as the mean squared error (MSE). For our hypothetical two forecasting methods, the squared errors can be calculated for each year and an average can be obtained for these yearly squared errors, as follows:

Year	Actual Demand A_t	Hypothetical Forecasting Method 1			Hypothetical Forecasting Method 2		
		Forecast Ft	Forecast Error At - Ft	Squared Error $(At - Ft)^2$	Forecast Ft	Forecast Error At - Ft	Squared Error $(At - Ft)^2$
1	310	315	-5	25	370	-60	3600
2	365	375	-10	100	455	-90	8100
3	395	390	5	25	305	90	8100
4	415	405	10	100	535	-120	14400
5	450	435	15	225	390	60	3600
6	465	480	-15	225	345	120	14400
	Total Squared Error			700			52200
	Mean Squared Error			700/6 =116.67			52200/6 =8700

Method 1 seems to have provided more accurate forecasts over this six year horizon, as evidenced by its considerably smaller MSE.

The Question often arises as to why one would use the more cumbersome MSE when the MAD calculations are a bit simpler (you don't have to square the deviations). MAD does have the advantage of simpler calculations. However, there is a benefit to the MSE method. Since this method squares the error term, large errors tend to be magnified. Consequently, MSE places a higher penalty on large errors. This can be useful in situations where small forecast errors don't cause much of a problem, but large errors can be devastating.

Mean Absolute Percent Error (MAPE): A problem with both the MAD and MSE is that their values depend on the magnitude of the item being forecast. If the forecast item is measured in thousands or millions, the MAD and MSE values can be very large. To avoid this problem, we can use the MAPE. MAPE is computed as the average of the absolute difference between the forecasted and actual values, expressed as a percentage of the actual values. In essence, we look at how large the miss was relative to the size of the actual value. For our hypothetical two forecasting methods, the absolute percentage error can be calculated for each year and an average can be obtained for these yearly values, yielding the MAPE, as follows:

Year	Actual Demand A_t	Hypothetical Forecasting Method 1			Hypothetical Forecasting Method 2		
		Forecast F_t	Forecast Error At - F_t	Absolute% Error$_{100\|At - Ft\|/At}$	Forecast F_t	Forecast Error A_t - F_t	Absolute% Error$_{100\|At - Ft\|/At}$
1	310	315	-5	1.16%	370	-60	19.35%
2	365	375	-10	2.74%	455	-90	24.66%
3	395	390	5	1.27%	305	90	22.78%
4	415	405	10	2.41%	535	-120	28.92%
5	450	435	15	3.33%	390	60	13.33%
6	465	480	-15	3.23%	345	120	17.14%
	Total Absolute % Error			14.59%			134.85%
	Mean Absolute % Error			14.59/6= 2.43%			134.85/6= 22.48%

Method 1seems to have provided more accurate forecasts over this six year horizon, as evidenced by the fact that the percentages by which the forecasts miss the actual demand are smaller with Method 1 (i.e., smaller MAPE).

Illustrations of the four Forecast Accuracy Measures

Here is a further illustrations of the four measures of forecast accuracy, this time using hypothetical forecasts that were generated using some different methods than the previous illustrations (called forecasting methods A and B; actually, these forecasts were made up for purposes of illustrations). These calculations illustrate why we cannot rely on just one measure of forecast accuracy.

		Hypothetical Forecasting Method A					Hypothetical Forecasting Method B				
Year	Actual Demand A_t	Forecast F_t	Forecast Error A_t - F_t	Absolute Deviation $\|A_t$ - $F_t\|$	Squared Deviation (A_t - F_t)2	Abs. % Error $\|A_t$-$F_t\|/A_t$	Forecast F_t	Forecast Error A_t - F_t	Absolute Deviation $\|A_t$ - $F_t\|$	Squared Deviation (A_t - F_t)2	Abs. % Error $\|A_t$-$F_t\|/A_t$
1	310	330	-20	20	400	6.45%	310	0	0	0	0%
2	365	345	20	20	400	5.48%	365	0	0	0	0%
3	395	415	-20	20	400	5.06%	395	0	0	0	0%
4	415	395	20	20	400	4.82%	415	0	0	0	0%
5	450	430	20	20	400	4.44%	390	60	60	3600	13.33%
6	465	485	-20	20	400	4.30%	525	-60	60	3600	12.90%
Totals			0	120	2400	30.55%	Totals	0	120	7200	26.23%
			MFE = 0/6= 0	MAD = 120/6 = 020	MSE = 2400/6 = 400	MAPE= 30.55/6 5.09%		MFE = 0/6 = 0	MAD = 120/6 = 20	MSE = 7200/6 = 1200	MAPE= 26.23/6 4.37%

You can observe that for each of these forecasting methods, the same MFE resulted and the same MAD resulted. With these two measures, we would have no basis for claiming that one of these forecasting methods was more accurate than the other. With several measures of accuracy to consider, we can look at all the data in an attempt to determine the better forecasting method to use.

Interpretation of these results will be impacted by the biases of the decision maker and the parameters of the decision situation. For examples, one observer could look at the forecasts with method A and note that they were pretty consistent in that they were always missing by a modest amount (in this case, missing by 20 units each year). However, forecasting method B was very good in some years, and extremely bad in some years (missing by 60 units in years 5 and 6).

That observation might cause this individual to prefer the accuracy and consistency of forecasting method A. This causal observation is formalized in the calculation of the MSE. Forecasting method A has a considerably lower MSE than forecasting method B. The squaring magnified those big misses that were observed with forecasting method B. However, another individual might view these results and have a preference for method B, for the sizes of the misses relative to the sizes of the actual demand are smaller than for method A, as indicated by the MAPE calculations.

Advantages and Limitations

Advantages of Forecasting:

Assists in Planning

One of the biggest advantages of forecasting is that it enables the manager to plan for the future of the organization. Planning and forecasting actually go hand in hand. Without an idea of what the future hols for the company, we cannot plan for it. Thus, forecasting plays a very important role in planning.

Environmental Changes

When done correctly, forecasts should be able to point out the upcoming changes in the environment. This means that it can allow the company to benefit from such environmental changes. When the changes are favorable to the company it can expand and grow its business. And in conditions that are adverse, it can plan and prepare to protect itself.

Identifying Weak Spots

Another advantage of forecasting is that it will help the manager identify any weak spots, or ignored areas that the organization may have. Once attention has been drawn to these areas, the manager can put into effect effective controls and planning techniques to rectify them.

Improves Co-ordination and Control

Forecasting requires information and data from a lot of external and internal sources. This information is collected by the various managers and staff from various internal sources. So almost all units and verticals of the organization are involved in the process of forecasting. This allows for better communication and coordination amongst them.

Limitations of Forecasting

Along with the benefits, there are also some limitations of forecasting. Let us take a look at a few of them.

Just Estimates

The future will always be uncertain. Even if use the best of forecasting techniques and account for every aspect imaginable, a forecast is still just an estimate. One can never predict future events with 100% success. So even the best-laid plans may amount to nothing. This will always remain one of the biggest limitations of forecasting.

Based on Assumptions

The basis of any forecasting method is assumptions, approximations, normal conditions, etc. This makes these forecasts unreliable. So one must always keep in mind the inherent limitations of forecasting and be cautious in being over-reliant on them.

Time and Cost Factors

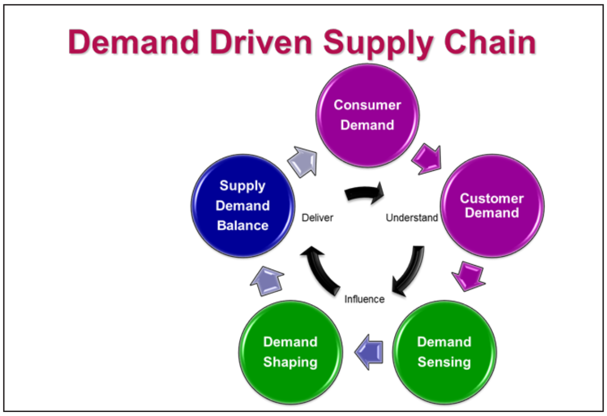
The data and information required to make formal forecasts are generally a lot. And the collection and tabulation of such data involve a lot of time and money. The conversion of qualitative data into quantitative data is also another factor. One must be careful that the time, money and effort spent forecasting must not outweigh the actual benefits from such forecasts.

Demand Management and Forecasting

A forecast should be made up of a number of different elements, and it needs a formal process to support this. The two key elements to a good forecast are:

- Demand Sensing – Using whatever tools are available to understand what is happening in the market place, and recording trends to determine what is going on.
- Demand Shaping – Using the tools or levers at the company's disposal to ensure that the business gets the optimum profit from its sales and marketing efforts – which includes optimisation of the capacity that the company has got. The levers are pricing, promotion, new product development and distribution.

The following diagram shows the overall process that the business should continually follow in sensing and shaping the demand. It is a circle as the process should be happening all the time in response to the market place:



Ultimately, there is a consumer for your products. You may be very removed from your market place. However, you need to understand the demand coming from your direct customer by getting alongside your customer through effective customer relationships. This is what we call Demand Sensing. Many companies supply retail organizations, who in turn supply customers through supermarket retail outlets are investing in systems which forecast consumer sales based on Electronic Point of Sales (EPOS) data. That is another way of getting to understand better the data. Some companies invest in forecasting systems, which can be a sensible investment - as long as it is supplemented by 'Market Intelligence'.

Demand Shaping is about comparing the statistical forecast and current trends, gained from the Demand Sensing activity, with the capability of the organisation to supply, and then shaping the demand to fit. Thus don't accept a promotion on a plant where there is no capacity, or increase prices, if you don't have the capacity to cope with the effect of the demand being pulled forward If you have spare capacity sell it at incremental prices in markets where you will not have an effect on long-term strategy.

A good forecast, then, is a 'Consensus' forecast agreed by all parties in the organisation. An effective process should be supported by a proper agreement on RACI – who is Responsible, Accountable, Consulted, and Informed. The following is an examples:

Responsible	Sales and Marketing Director
Accountable	Sales and Marketing Managers
Consulted	Customer
Informed	Supply Chain and Operations

What Level of Detail Should One use?

For a Make to Stock company, a forecast should be prepared at Stock Keeping Unit (SKU) or part number level, and sometimes go down to the customer level. It should be aggregated up to sub-families (brands and/or manufacturing processes) so you can see the wood from the trees.

Some companies, particularly those that are "Assemble to Order" should forecast at the family level, and then get to the "Part Number" level through using Family Planning Bills of Materials.

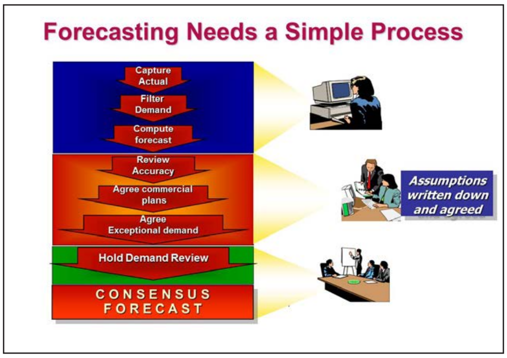
If you are a Make to Order Company, then you may only need to forecast the amount of capacity you need in hours.

The company must decide whether it is Make to Stock, Make to Order, or Assemble to Order by comparing the lead time it offers to the customer with the lead time of materials and capacity before it can effectively answer the level at which to forecast.

It is vital that it is provided in volume and value - with the value being reported at the level of gross margin/trading profit i.e. the level at which Sales and Marketing are accountable.

What Should the Process be for Forecasting?

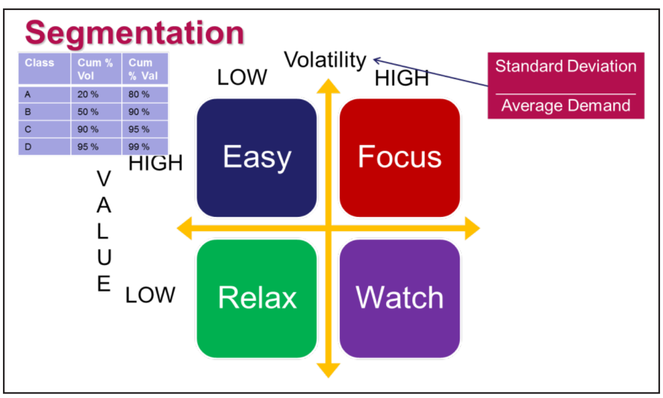
Each month or week as part of a formal monthly Integrated Enterprise Leadership process, the business should review its forecast. The key steps are illustrated in the following. The first step is to capture the actual data - which should be what the customer ordered by required date for delivery. The actual demand should be adjusted to take out spikes, and then the statistical forecast should be run. The next step should be to review the accuracy and bias of the forecasts to understand and correct the basis of the forecasts. Commercial plans should then be used to adjust the forecast. This should be done in the light of new product plans, pricing changes, new customers, promotional and advertising plans and responses to competitive threats, and external economic factors. A positive decision on whether to include or exclude unusual spikes in demand (which for examples can be caused by extreme epidemics or seasonal factors) needs to be made which will then handle 'exceptional items'. On the principle that what gets forecast gets made, it is important to decide what gets into the forecast.



Critical to this whole process is the creation of a visible set of assumptions which supports the forecast and any changes to the forecast. These should be included as notes to any product where the statistical forecast is replaced by 'Market Intelligence'.

Forecast Segmentation

To avoid sales people spending too much time on forecasting, it is really useful to segment forecasts along the lines of high and low value items, and high and low variability of demand. High and low value can be measured in terms of revenue and gross margin. High and low variability can be measured by the ratio of the error of the monthly forecast to average monthly demand. If it is below 50% it is low; if it is above 50% it is high. You can then follow the matrix as on the next page, and direct people's effort accordingly.



'Easy' means those products which are relatively easy to forecast, and should largely be capable of being managed by a statistical forecast – unless there is commercial activity associated with any of these products. Being high value they need the attention of sales and marketing people. Low value, low volatile products should definitely not be chased too much, we can 'Relax'.

The products which need careful attention, 'Focus' are those that are highly volatile and high value. These should be carefully reviewed to avoid too much or too little stock. And lastly, we need just keep an eye on, 'Watch', those products with low value but high volatility.

Ways to Know if the Forecast is Good

Many companies use the MAPE measurement of forecasting – Mean Absolute Percentage Error. The advantage of this is that it shows the size of the deviations across all products. The following table illustrates the calculation for a couple of product groups:

Forecast Accuracy Report - MAPE

Group	Product	Forecast	Actual	Abs Error	% Error
Product Group A	Product 123	100	120	20	20
	Product 456	200	150	50	25
	Product 789	300	330	30	10
Total		600	600	100	17 %
Product Group B	Product 345	200	300	100	50
	Product 567	500	300	200	40
	Product 890	600	700	100	17
	Product 678	200	400	200	100
Total		1500	1700	600	40 %

The 'Abs Error' is the absolute error - the difference between forecast and actual, ignoring whether it is plus or minus. In the case of the first group, if you add up all of the errors you get 100. If you divide this by the total forecast you get 17% - that is the 'average' error of the forecasts for that product group.

You can do the same calculation and group it by customer, account manager, region or whatever. Some people then calculate accuracy as 1 – the error (thus 83% for product Group A. This is fine until the error works out at > 100%. So it is better to stick with error).

Experience suggests that if you can get your forecast error to be less than 20% you are doing really well.

Demand Management

If one looks over the horizon, there comes a point where you need to manage demand, rather than plan it. This point is the 'cumulative lead time' for a product. The cumulative lead time is the sum of the longest lead time from acquisition of raw material through to the delivery of the product.

When a company is inside this 'time fence' capacity and materials are fixed. Hence the company typically has to choose between one product or another, or, one customer or another. Additional supply can only be sourced beyond the cumulative lead time.

Suppose the cumulative lead time for a product is 12 weeks. All demand inside this lead time (whether actual orders or forecast) is reserved for orders and those people who have forecast their demand.

Any unforecast demand should be promised in week 13 and beyond (depending on availability of capacity and raw materials). This principle would be easy to apply if it were not for the fact that some very big companies want the product and they want it now.

So an effective demand management process requires a way of identifying abnormal or unforecast demand, and a policy of how to treat customers. If you are travelling on a plane, and you find that they are overbooked, you will soon find out why there are gold, silver and ordinary grade customers.

Capacity

Capacity is the maximum level of output that a company can sustain to make a product or provide a service. Planning for capacity requires management to accept limitations on the production process. No system can operate at full capacity for a prolonged period; inefficiencies and delays make it impossible to reach a theoretical level of output over the long run.

Capacity ties into the fact that all production operates within a relevant range. No piece of machinery or equipment can operate above the relevant range for very long. Assume, for example, ABC Manufacturing makes jeans, and that a commercial sewing machine can operate effectively when used between 1,500 and 2,000 hours a month. If the firm sees a spike in production, the machine can operate at more than 2,000 hours for a month, but the risk of a breakdown increases. Management has to plan production so that the machine can operate within a relevant range.

Capacity Level Differences

Capacity assumes a constant level of maximum output. This production level assumes no machine or equipment breakdowns and no stoppages due to employee vacations or absences. Since this level of capacity is not possible, companies should instead use practical capacity, which accounts for repair and maintenance on machines and employee scheduling.

Capacity Planning and Management

Capacity management affects all areas of an operation. Capacity *measures* the rate that the operation can transform inputs into outputs. Capacity is about the *quantity* of a product or service that can be made within a *given time period*. This, for example, could be:

- The number of passengers per flight on an aeroplane,
- The number of patients that can be seen in a surgery session at a doctors,
- The number of mobile phones that can be produced a week by a factory.

It is defined as the number of units (goods and/or services) an operation can produce over a given time period, under normal working conditions, where no additional resources are deployed.

Capacity is usually measured in convenient units such as litres per hour or passengers per taxi. For instance, a domestic tap may be able to deliver 20 litres per minute of water; a bus may have a capacity of 53 passengers, a football stadium may be able to seat 50,000 spectators or a McDonalds may be able to serve 600 customers per hour.

In many instances capacity may be simple to calculate, however more difficult questions might be:

- How many fire engines should an airport have on standby?
- How many operations should a surgeon schedule?
- What service level should be offered to broadband customers?

When planning capacity there are always two sides to consider: - firstly there is the demand – the amount of the product or service that might be wanted; and secondly there is the provision of the good or service. In providing products or services the operation must evaluate the costs involved and the tradeoff between satisfying customers and the costs of production. Having too little capacity to respond to customer demand may mean missed opportunities and annoyed customers, however under-utilised capacity is a waste of resources resulting in higher costs.

Adjusting Capacity

Discrepancies between the capacity of an organisation and the demands of its customers result in inefficiency, either in underutilised resources or dissatisfied customers. The former may be a serious cost but the latter may result in lost sales, lost customers and potentially loss of reputation. The ability of the operation to adjust the key resources will minimise these discrepancies.

Some capacity changes can happen almost instantly, others may take longer time to put in place. The capacity of an operation is a complicated mix of resources. These resources are inputs to the process that allow capacity to be expanded or contracted, by changing the inputs into the process. How flexible the resource is depends on how quickly it can be altered.

Capacity can be increased using a number of methods which involve adjusting the resources and inputs into an organisation such as:

- Introducing new approaches and materials,
- Increasing the number of service providers or machines,
- Increasing the number of operational hours,
- Acquiring additional facilities.

Decreasing capacity can be more difficult or expensive; it tends to rely on the operations ability to sell or reduce resources as cost effectively as possible. There are usually costs involved in reducing resources, for example if the resource is staff there may be redundancy costs, or closing facilities may incur significant costs.

Therefore the decision to alter capacity has to be taken carefully in line with future predictions of demand.

Capacity Constraints

A constraint on capacity is a resource that is less capable, of increasing its throughput over the given time period, than other parts of the operation. A number of machines may be in sequence on a manufacturing line yet one may not be able to process as many units per hour as the other machines. The capacity will be constrained by this under producing machine and this may create a 'bottle neck' in the process. By increasing the capacity of this machine the capacity of the overall facility will also increase.

Capacity is always constrained by the lowest producing part of the process. In layman's terms an operation will *'always go at the pace of the slowest walker'*. Identifying a restrictive part of the process and adding resources that can increase its capacity will improve the overall capacity of the operation.

The resource mix that can be potentially constraining to an operation could include;

- Staff/Skill levels: Staff can be trained over time to be more flexible in their contribution to the process. The operation can benefit from the learning curve, where a new employee can become more efficient at a given process and therefore be quicker at their job, which can increase the capacity of the operation.
- IT facilities/Technology: This can be a small or very significant improvement to a process. The investment in ICT can reduce process time or even completely change the nature of the process itself. Online banking has been a significant improvement in the finance sector by reducing the number of staff required to process a transaction and therefore massively increasing the capacity of the bank to deal with its customers.
- Materials availability: A change in the supply of raw materials can increase the capacity potential of an operation. If there is a restriction in availability of materials or a timing problem and this is released, the capacity could be improved.
- Product or service mix: Adjustments in the other products or services made by the facility can restrict the capacity of the operation. This is because different products and services may use different quantities of resources per unit; therefore a change in the product mix may result in a change in capacity.
- Storage: This can affect the capacity of an operation if there is a resource constraint that is affected by timing in the process. If the operation has the ability to store work in progress or finished goods it can improve the capacity of the process in the short term. The swings and fluctuations in demand can be mitigated by the ability to store products and allow the full capacity of the operation to flow.
- Working schedules and access to facilities: This can also dictate the full availability of capacity. A lecture theatre that can accommodate 100 students at a time could operate beyond a standard working day; however both staff and students may have an issue regarding 6am lectures.

These factors should be considered in a short-term, medium-term and long-term time frame to establish their ability to be changed over time. A short term strategy for expanding capacity in a café would be to put a few extra tables outside or extend the staff working hours to cope with the extra demand, in the medium term the cafe owner would have more options available to increase the capacity, such as hiring more staff of having additional cooking facilities in the kitchen to cope with extra demand. In the long-term the possibilities can be much greater, the premises could be expanded, better equipment, more staff and so on. The options available to an operation are greater the more time it has to plan them.

Theory of Constraint (TOC)

The theory of constraints was first proposed in 1986 by Goldratt. The theory is the practical results of Goldratt's work on 'how to think'. TOC is a philosophy that suggests that any system must have *at least one constraint* otherwise it would generate an infinite amount of output and that constraints generally determine the pace of an organisation's ability to achieve its goal which is profit.

Goldratt emphasises that constraints pose a significant threat to the wellbeing of an organisation and must be identified. He suggests that constraints may be labour availability, staff skills, machine availability, and capital or time available. They may however be more difficult to identify such as; organisational policies, guiding principles or rate of innovation.

He identifies that there is rarely an equal flow of work within each work centre in a process. The constraint should therefore be the control of the pace of the process. This theory reduces the emphasis on maximising all resources within the process and prioritises the management of the bottleneck. The theory he advocates is called 'drum, buffer, rope' where the bottleneck is the 'drum' which marks the time through the process – due to insufficient capacity this should be working the most. The 'buffer' principle is required to make sure that the bottleneck is never short of work and therefore the front end of the process should stockpile inventory to maximise output. The 'rope' element is the communication device to make sure the front part of the process does not overproduce.

Goldratt's Five Focusing Steps

The theory identified a process to follow in order to free the system from the bottleneck that slowed it down. By following the steps the operation identifies and clears the blockage, this will then in turn reveal a new bottleneck and the 5 steps can start again.

1. Identify the systems constraints
2. Exploit the systems constraints
3. Subordinate everything else to the above decision
4. Elevate the systems constraints (identify the next constraint)
5. If in a previous step, a constraint has been removed, go back to step 1 but do not allow inertia to become the systems constraints.

Goldratt advises that any constraint having been identified is only transitional. As this constraint is exploited, another will appear in its place. Without identifying the real constraints, Goldratt suggests that management may not be able to find the real causes that restrict capacity so will take actions to work around the problem rather than solve the real cause.

Constraint analysis is a subject that is larger than the subject of Capacity Management. However it does offer an important perspective on the question; *'is all capacity equally important?'*

Measuring Capacity

When measuring capacity the unit of measure can be either an input or an output to the process. The key is to take the most logical unit that reflects the ability of the operation to create its product or service. However, where the input is more complicated to measure, such as machine hours on a process layout, then output is a more suitable measure. The unit of time could be a minute, an hour, a day or a week, or whatever time scale fits the operation, but the unit of output and time scale needs to be consistent.

Input Measures of Capacity

When using input measures of capacity, the measure selected is defined by the key input into the process. Where the provision of capacity is fixed, it is often easier to measure capacity by inputs, for example; rooms available in a hotel or seats at a conference venue. Input measures are most appropriate for small processes or where capacity is relatively fixed, or for highly customised or variable outputs such as complicated services.

Output Measures of Capacity

The output measures count the finished units from the process such as mobile phones produced in a day or cars manufactured per week. This measure is best used where there is low variety in the product mix or limited customisation.

Table: An example of possible input or output measures.

Process	Input capacity measure	Output capacity measure
Music festival	Square metres of land	Number of festival attendees
Hotel	Rooms available	Number of guests per week
Car Manufacturing plant	Machine capacity	Cars produced per month
Milk Bottling Plant	Machine hours available	Bottles filled per day
Lecture theatre	Number of seats available	Students on courses
Wedding planning service	Consultants available	Weddings per season

Capacity can be measured from looking at the operation as a whole and then calculated on the resources and facilities available and process time.

For example, the measure of output capacity could be cars per shift or tonnes per hour or customers per day. However, the capacity of a surgeon or a University Professor may not be measured in this manner. In these cases, capacity could be shown in the form of working hours per week.

A simple formula for capacity can be:

$$\text{Capacity} = \frac{\text{Time available}}{\text{Time of task}}$$

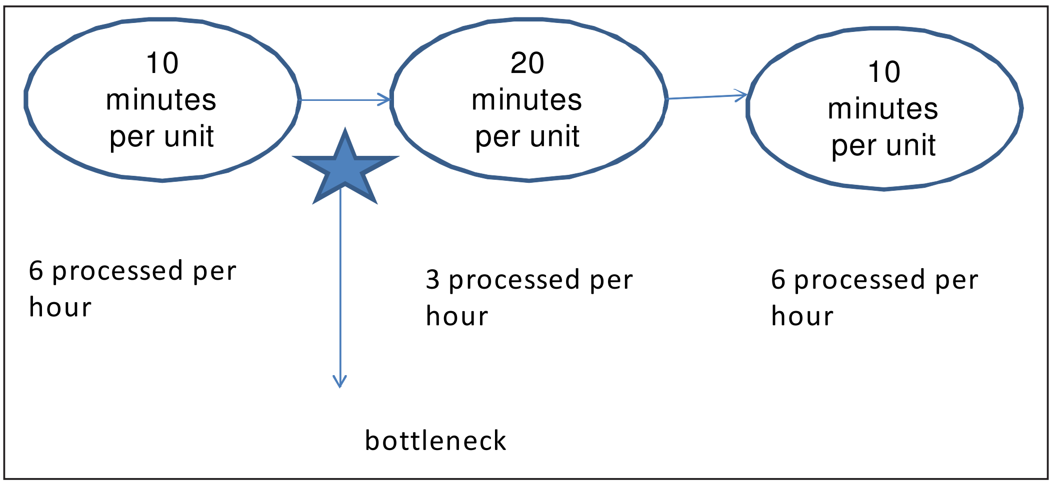
For example, a service provider works an eight hour day, takes two fifteen minute coffee breaks and has a half hour lunch break. The time available for work is seven hours per worker per day.

If this particular worker was fitness instructor and he spends 70 minutes with each customer (10 minutes for the consultation and booking and 1 hour for the gym session), how many clients could the instructor process during a five day week?

$$\frac{(7 \text{ hour per day} \times 60 \text{ minutes per hour}) \times 5}{7 \text{ minutes per client}} = 30 \text{ clients per week}$$

This is a simplified measure as it presumes that the fitness instructor doesn't have time off sick or do any other activities such as maintain the gym equipment or diversify into other areas such as taking classes. Most processes will not have just one activity; many will have interlinking processes with different capacity constraints on each.

Here the operation will have to consider the capacity of the whole process and not individual constituent processes. Also the individual process durations may differ. If the first part of the process takes 10 minutes but stage 2 takes 20 minutes and stage three takes 10 minutes then a backlog will appear at stage 2.



The bottleneck point in a simple process

The diagram shows that the output of a process will be constrained by the slowest point. This is referred to as a 'bottleneck' in the process.

However it is not always possible to accurately predict how long each stage is actually going to take. A hair dresser, for example, may allocate thirty minutes to each haircut, forty minutes to each hair colorant and ten minutes to styling, but individual customers may take more time and others less. In such circumstances it may not be possible to accurately locate the bottleneck in variable processes.

This shows an important feature of capacity planning, assumptions must be made as to what the process is capable of in order to understand the output of the operation. However, although assumptions are needed to plan the process, often in reality these assumptions can be found to be inaccurate.

Efficiency and Utilisation Calculations

For the efficient use of the resources available, efficiency is output shown as a percentage of available capacity.

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

For an operation that has been well designed, there will be minimal planned losses. This allows the resources to be used to the best of their ability. Capacity utilisation is the measure of how much of the available capacity is used. Utilisation is output shown as a percentage of the facilities or designed capacity.

$$\text{Utilisation} = \frac{\text{Actual output}}{\text{Design capacity}}$$

For example if the fitness trainer in the previous example only had 24 clients who arrive at their appointments on time, the calculation would be:

$$\text{Utilisation} = \frac{24}{30} \times 100 = 80\%$$

Therefore the utilisation rate is 80%.

These measures of capacity can tell an operation how well they are utilising their resources and how efficient the manufacturing process is.

Example Calculating Capacity Measurements

You are managing a group of 10 Electricians. These individuals undertake in-home servicing of electrical systems and are called by telephone for either emergency or pre-arranged visits. They charge a minimum call out fee that covers the first 15 minutes of their visit plus travelling time. Beyond the first fifteen minutes they charge in minimum blocks of 15 minutes plus any materials that might be necessary to carry out the job. The average call out takes 1 hour.

The workers usually are available for eight hours a day but with 2 coffee breaks of 15 minutes each and a half hour lunch break, they actually work a 7 hour day. Taking time off and illness into account reduces the electricians' available time by 20%. This means the 7 hours per day is reduced to a 5 hour and 36 minute day (5.6 hours).

If actual work is only 200 hours billed in the week then (a) What is the capacity utilisation of the team? (b) What is their efficiency?

Approach: First, you need to calculate (a)the design capacity and (b) the effective capacity. Then use the actual output given above to calculate the capacity utilisation and efficiency.

Solution:

$$\text{Design capacity} = \frac{10 \text{ workers} \times 7 \text{ hours per day}}{1 \text{ hour per customer call out}} \times 5 \text{ day of a working week}$$

$$= 350 \textit{ customers per week}$$

$$\text{Efficiency capacity} = \frac{10\,\text{workers} \times 5{,}6\,\text{hour day}}{1\,\text{hour per customer call out}} \times 5\,\text{day of a working week}$$
$$= 280\ \textit{customers per week}$$

$$\text{Efficiency} = \frac{A\text{ctual output } 200}{\text{Effective capacity } 280}$$

Then the efficiency of the process is 71%.

$$\text{Utilisation} = \frac{\text{actual output } 200}{\text{design capacity } 350}$$

The Utilisation of the process is 57%.

Takt or Cycle Time

In the above example, we suggested that the time to service each customer was 1 hour. This is often referred to as the Takt time.

Takt or cycle time can be defined as the maximum time per unit allowed making a product or providing a service in order to meet the demand. It is derived from the German word Taktzeit which translates to *cycle time*.

Takt time usually determines the output rate for manufacturing lines. For instance in automobile manufacturing cars are assembled on an assembly line, and are moved from station to station after a certain time – this is the takt time. In a fast food restaurant the service time for each order would also be called the takt time.

Takt (or cycle) Time can be first determined with the formula:

$$T = \frac{T_a}{T_d}$$

Where:

T = Takt time, e.g. [minutes of work / unit produced],

T_a = Time available to work, e.g. [minutes of work / day],

T_d = Time demand (customer demand), e.g. [units required / day].

Available time is the amount of time available for work to be done. This excludes break times and any expected stoppage time (for example scheduled maintenance, team briefings, etc.)

Example of Calculating Takt time

An assembly line has a total of 8 hours available time in a shift. The employees working the shifts have a half hour lunch break and two fifteen minute tea breaks each shift. The machines also require ten minutes per shift in basic maintenance. At the start of each working day, the supervisor spends ten minutes talking to the staff and setting goals for the shift ahead.

Calculate the available time to work for the line and Takt time for 100 units per day.

Approach: You will need to calculate the minutes available in the working shift and then subtract the non-working time

Solution: 8 hours shift is 480 minutes. Take away 30 minutes for lunch, 30 minutes for breaks (2x15 minutes) 10 minutes for a team briefing and 10 minutes for basic maintenance work;

The available time to work = 480 – 30 – 30 – 10 – 10 = 400 minutes

If output demand was for 100 units a day and you were running one shift, then the line would be allowed to spend a maximum of four minutes to make a product in order to be able to keep up with demand of 100 units per shift.

The *takt or cycle time* would be 4 minutes.

Capacity Planning

When capacity needs to be increased or decreased, the operation must consider how this is going to be achieved. This is a key decision as the organisation will have to make investment decisions based upon what level of capacity is to be selected and when it is to be provided. The operation has several ways in which it can respond to the changes in demand with its provision of capacity. The decision to provide capacity depends upon the selected strategy and the ability to store the product or timeliness of service production. The timing decisions of how and when to provide capacity need to be determined in line with demand.

Capacity Planning Methods

The organisation has 3 main choices;

1. It can provide capacity ahead of the forecast so that it is ready to respond immediately which is known as a *capacity leads demand* strategy.
2. It can provide capacity as demand changes so that it expands and contracts its capacity to follow demand, which is a *capacity matches demand* strategy.
3. It can wait to see what demand is and then respond after it is confirmed, a *capacity lags demand* strategy.

Capacity Leads Demand

It is possible to have capacity ready to react to an increase in demand as ready and available capacity. This is where a buffer is provided in order to allow the operation to react quickly to increases in demand. This strategy adds capacity in anticipation of extra demand and is therefore an opportunistic strategy with the purpose of attracting customers away from competitors. This capacity strategy has an advantage in that the operation is ready to satisfy customer demand and meet short term opportunities.

However there is a risk of demand not rising and the operation is then left with the wasted costs of unused capacity.

It is a more expensive way of providing capacity as it requires investment to be made ahead of demand, but it is a useful strategy if the organisation is trying to build market share and the benefit of establishing a customer relationship outweighs the cost of providing excess capacity.

An example of a capacity leads demand approach would be an extension to a lecture theatre being built before student numbers were confirmed.

Capacity Matches Demand

For the provision of capacity in line with demand then this strategy is adopted. This is done by adding capacity in measured amounts in response to changing demand in the market. This is usually accomplished by flexible addition of capacity either from flexible labour or flexible facilities that are able to meet the demand upon requirement. Either good planning is in place or there is a risk of underutilised resources.

This strategy relies heavily on forecasting and accurate information as investment decisions are made in line with the forecast. Incorrect forecasting will cause missed opportunities or wasted resources.

This often happens in services where staffs are the flexible resource and can be brought in to cover peak demand yet sent home in quieter times, such as a toy store catering to Christmas demand or a restaurant expanding and contracting capacity in line with anticipates peaks and troughs in customer demand.

Capacity Lags Demand

Here increments of capacity are only added after the demand has increased by providing capacity after the demand rises. This allows the organisation to provide capacity with certainty and reduces the risk of incorrect investment into capacity increases. However this method does rely on the ability to provide products and services on short lead-time and assumes that the customer is prepared to wait.

This is less risky than providing investment ahead of demand; however, it has the disadvantage that customers may not be prepared to wait for the product or service and opportunities can therefore be lost.

Producing products on a lead time can be frustrating for customers, it can be almost impossible to buy a sofa from a store and have it delivered on the day, most have a four week lead time to allow the manufacturers to plan their capacity ahead of time. This is becoming an increasingly unusual strategy for consumer goods as consumers are often less tolerant of waiting.

Anticipating Changes in Demand

Demand can be volatile and is something that tends to happen ‘to’ an operation. It exists outside the organisation and is therefore difficult to control. Demand may change due to a number of factors or circumstances. As it is in the future and yet to happen and is subject to many influences;

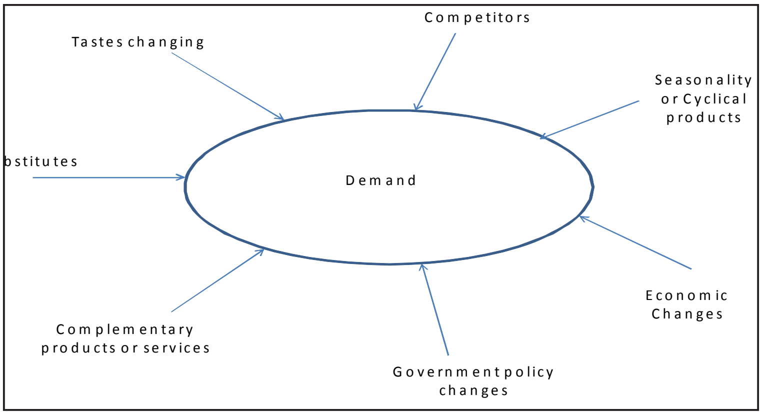


Diagram shows the external factors affecting demand.

- Tastes changing - these can be hard to plan for. Fashions change and new ideas occur. This can happen slowly overtime and be a natural trend towards an idea, for example the trend towards a more environmentally-friendly life style has been a slow but steady evolution and products and services have been able to follow this trend. Alternatively, they can be sudden swings or changes that are virtually unpredictable, for example an influential celebrity may 'adopt' a product or service and create a sudden increase in demand.

- Competition – the demand for an organisation's product or service will be highly dependent on the actions and reactions of its competitors. The product the organisation provides may have a steady demand but should a competitor bring out a new, improved or even cheaper version of the product then this will affect the demand horizon. It is important for the organisation to be aware of their competitors and the impact they may have upon future demand.

- Substitutes - this can be similar to the effect of competitors, mentioned above, as there may be an alternative product that will become available and divert the market demand for the product.

- Seasonality - many products are naturally seasonal. Ice cream, fireworks and fluffy Valentines-day teddy bears have a time period where demand will peak. This relates to the product or service use; how specific it is depends on how much it will be demanded at a given time. For example, sun screen sales in the UK peak in June and July, yet there will be a lower demand during the rest of the year for travel aboard, whereas Christmas cards only have the short window of demand in the months up to Christmas (generally August to December these days) and then demand virtually evaporates outside of this window. With a seasonal event, the previous year's demand can be used when predicting future demand patterns.

- Cyclical events are similar to seasonal demand peaks in the fact that they may be known events, but may not occur in line with a defined calendar time frame.

- Special events- there are one off unique events that have very little or no demand pattern or history. These are the most complicated to plan or predict demand for.

- The external environment may also affect demand patterns, tax and mortgage rates, government policy may also affect the demand for a product or service.

- Economic changes will have a significant impact on demand for goods and services and will affect buying habits and behaviours.

It is most important to try to understand what the demand pattern is likely to be and how reliable it is. The operation should then be aware of the potential impacts to their demand.

Capacity Strategies

When an operation is planning how much capacity it needs, it must also think about how it plans to react to the demand it faces. The operation must be aware of the options available to satisfy demand. There are three general strategies that can be used in the medium term: They are:

- Level production
- Chase demand
- Demand management

These strategies are not mutually exclusive and most organisations use a mix of these three, however it is likely that one method will dominate the strategy. These strategies are not reactionary to small daily swings in demand but look at demand over a longer time frame. Such decisions require planning and investment.

Level Production

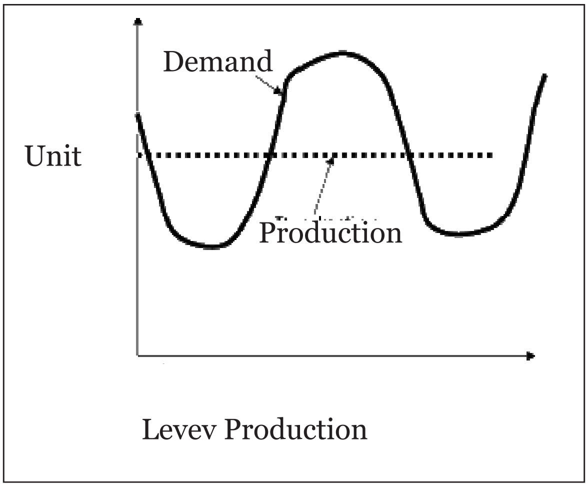
Level production largely ignores demand fluctuations and works on producing units efficiently and then either storing the finished goods or satisfying demand from stock. Basically this allows an operation to manufacture efficiently and optimise capacity irrespective of the demand. There are two key conditions for this to work;

- The product must be suitable for storage, i.e. not highly customised and nonperishable or with a reasonable shelf life.
- Demand must be relatively reliable – to avoid risk of large stock outs or excessive stock levels.

This level production strategy doesn’t work for services.

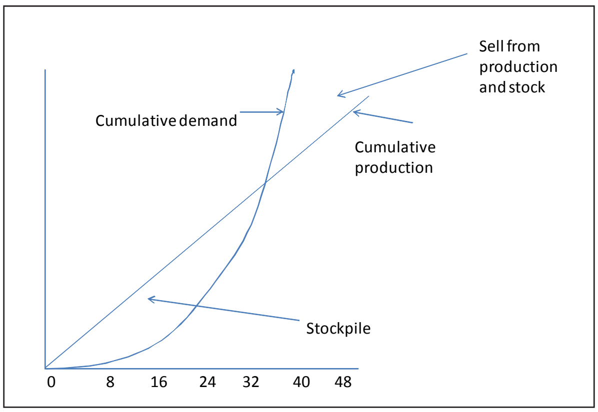
This strategy forms part of a cumulative plan, where demand is satisfied over a period of time to suit the operation and stock holding and selling from stock allows production to be effectively managed by stock control allowing the operation to have the benefits of working to a less volatile plan.

Certain industries and products lend themselves to this strategy. For example, the demand for cigarettes is fairly consistent; there is a drop off in sales in January and February as a number of smokers make New Year resolutions to give up, yet demand returns, for those who fail to achieve this, to fairly consistent levels after this time and then peaks at around Christmas time for the party season. The product is straightforward to store and has a reasonable shelf life. As demand is fairly consistent the operation can feel confident about following such as strategy.



The level production strategy produces units to a consistent rate

Aggregate planning is where forecasts are set to be as capacity-efficient as possible yet still aims to match the demand. This style of planning rises above the detail of the product or service mix and looks at capacity overall in line with the demand. It is a schedule that works in the medium term and makes decisions based upon staffing and stock holding levels or leasing decisions. This works as part of a level production strategy so that manufacturing is carried out to cover the demand so that stockpiling occurs ahead of selling from stock and not the other way round – it is hard to sell product from an empty warehouse.

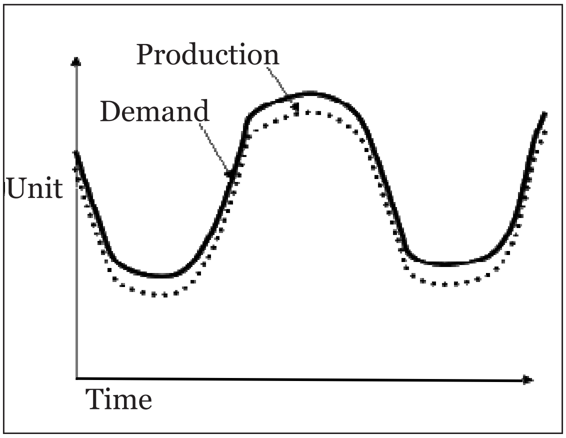


The level production strategy considers cumulative production ahead of cumulative demand

Chase Demand

This is where the operation attempts to follow demand by expanding and contracting capacity. There is always going to be an element of fixed capacity that can only be adjusted over the long term, such as a building or invested facilities, however other elements are flexible. By expanding and contracting these flexible resources the operation can minimise the costs involved with having excess capacity yet still increase capacity to meet increases in demand.

To follow such a strategy requires considerable planning in process design and staff training. The operation needs to consider the question *'if demand goes up and then falls, how are we going to expand and then contract our capacity without wasting money?'* In order to expand and contract capacity efficiently the process needs to be adaptable. This can be achieved by designing a very simple process so staff can be hired and fired or even multi skilled. Of course staff are not the only adjustable resource in the process – flexible machinery or the ability to make other products in times of low demand may help with this too – if a demand peak for one product could be combined with a demand slump in another then reallocating resources can allow the demand to be followed Both the level capacity and chase demand strategies follow a supply management approach where the provision of additional increments of capacity is adjusted. However the alternative approach is to manage or control demand.



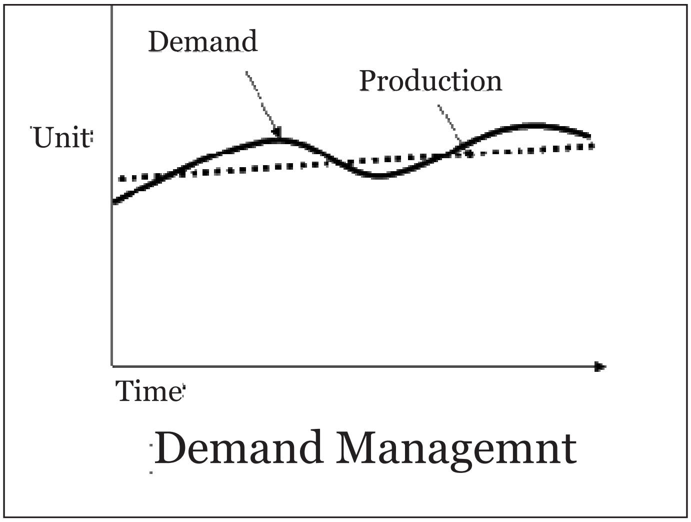
A chase demand strategy has production following demand

Demand Management

The attempt to manipulate or control demand may be unfamiliar to an operations manager, however it is possible by use of marketing tools to smooth demand in line with the required forecast for some products or services. Many of the tools suggested may be short term measures; however it is important that the adjustments made do not damage the potential long term demand. Some methods of demand adjustment may include;

- Varying the price. A discounted price for an elastic demand curve product can be a strong incentive for a consumer to buy more products. This happens regularly in supermarkets with price discounting, it works well if combined with additional advertising, mentioned below.
- Providing an incentive for off peak services or products. This works well with services to help smooth demand throughout a given time period. Good examples of this is an off-peak rate in the gym, or the 'happy hour' in bars, which are both used to flatten the peaks in demand and increase utilisation of wasted capacity at quieter times.
- Additional marketing can create awareness of a product that wasn't there before – this is most effective when combined with other methods such as price discounting.
- Alternative products or services could be provided using the same capacity and skills level but smoothing demand.

Demand management practices work in combination with the supply approaches mentioned above, it may not be possible to control demand to a level state, but it may help to smooth out the fluctuations of a chase demand strategy.



Demand management attempts to smooth demand fluctuations to allow a level production rate to be used.

Contemporary Thinking: Yield Management

Yield management is widely regarded as an increasingly useful business tool and is generally used in operations where the medium term capacity is relatively fixed and there is no straightforward way to expand and contract the capacity provided. This is often the case in services with high investment facilities, variable costs are low, closed entry and exit points and fixed capacity prevail, such as hotels with fixed numbers of rooms or airlines with the fixed number of seats.

Yield or more commonly 'Revenue Management' was first introduced as the option to choose to maximise returns from business assets. Revenue management is founded in pure economics where the demand versus supply curves rule. This rule has been studied in business using computer software that looks at historical trends, fixed capacities and revenues generated and then 'forecasts the future', giving the business a 'set of rules' to apply to its assets in order to maximise their financial potential.

This strategy involves a set of strategies that an operation can employ to maximise revenue by either charging individual customers as much as they are prepared to pay or by extracting as much revenue from a process as possible. This asks the question; if a customer is prepared to pay more for a good or service, is it possible to charge them a higher price than another customer.

Certain conditions enable companies to use yield management. These include:

- Fixed capacity in the short and medium term.
- The ability to sell the service at different times to the different customers and in advance of the service being delivered.
- A market that has different and diverse customer requirements.
- A service that has some unique characteristics to avoid a homogenous market. This may be the destination or timing of a flight or the facilities or location of a hotel.

The 3 key strategies for maximising revenue through yield management are as follows:

1. Overbooking – this is where the operation books more customers than it can accommodate and presumes that there will be some 'no shows'. It has the rather obvious disadvantage of what will happen if all the customers do turn up! A policy of overbooking can only be effective if the take up rate for the service is predictable, and if the costs of compensating a customer if they are unable to have their booked service are not too high. The advantages for the operation include maximum revenue and full capacity. This has been a popular policy of many airlines, where flights are overbooked. Airlines have a large volume of data from previous flights to predict rates of no shows on various routes, customers who miss flights because of this policy are then compensated with alternative flights and possible upgrades. However recent legislation that requires airlines to financially compensate passengers as well as finding alternative flights and this extra cost has led to many of the budget airlines discontinuing this policy.

2. Price discounting – this is similar to a demand management policy to try to optimise the capacity at non-peak times. In the case of price discounting the top price that can be charged is set for the time of highest demand and then reduced for less attractive time periods. A high peak time price may also be used to deter those booking at peak times to control demand. It helps smooth demand over a time period and maximises revenue. A good example of this is the holiday market – with a finite number of holidays available in Europe, peak time such as school holidays may incur heavy premiums yet there are many bargains to be had 'off peak'.

3. Varying the service type - this allows an operation to grade what service they are selling and charge different prices accordingly. This allows them to charge those who are prepared to pay more, the extra with some justification. Seats in a theatre will be grouped in order of quality and price, such as the dress circle seats being the best and most expensive and the stalls being the cheapest. Upgrading a service can differentiate it from the standard service and therefore higher prices can be charged. The advantage of this policy is that it is flexible in the short term; if an airline has over demand for economy seats for a flight but does not sell all its business class seats, then a business class seat on a flight can be 'converted' to an economy seat to maximise revenue.

Capacity Measurement

Measurement of Capacity Planning

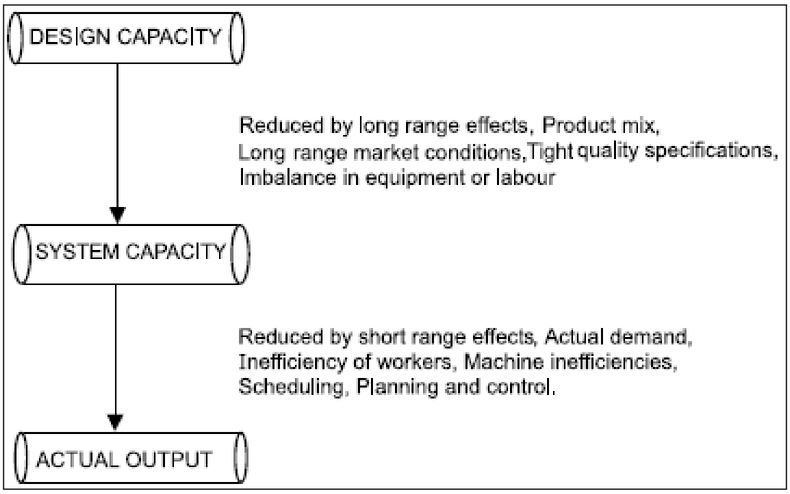
The capacity of the manufacturing unit can be expressed in number of units of output per period. In some situations measuring capacity is more complicated when they manufacture multiple products. In such situations, the capacity is expressed as man-hours or machine hours. The relationship between capacity and output.

1. Design capacity: Designed capacity of a facility is the planned or engineered rate of output of goods or services under normal or full scale operating conditions. For example, the designed capacity of the cement plant is 100 TPD (Tonnes per day). Capacity of the sugar factory is 150 tonnes of sugarcane crushing per day.

2. System capacity: System capacity is the maximum output of the specific product or product mix the system of workers and machines is capable of producing as an integrated whole.

System capacity is less than design capacity or at the most equal, because of the limitation of product mix, quality specification, breakdowns. The actual is even less because of many factors affecting the output such as actual demand, downtime due to machine/equipment failure, unauthorized absenteeism.

Capacity and Output Relationship



The system capacity is less than design capacity because of long range uncontrollable factors. The actual output is still reduced because of short-term effects such as, breakdown of equipment, inefficiency of labor. The system efficiency is expressed as ratio of actual measured output to the system capacity.

System Efficiency (SE) = Actual output /System capacity

1. Licensed capacity: Capacity licensed by the various regulatory agencies or government authorities. This is the limitation on the output exercised by the government.
2. Installed capacity: The capacity provided at the time of installation of the plant is called installed capacity.
3. Rated capacity: Capacity based on the highest production rate established by actual trials is referred to as rated capacity.

Aggregate Planning

Aggregate planning is the process of developing, analyzing, and maintaining a preliminary, approximate schedule of the overall operations of an organization. The aggregate plan generally contains targeted sales forecasts, production levels, inventory levels, and customer backlogs. This schedule is intended to satisfy the demand forecast at a minimum cost. Properly done, aggregate planning should minimize the effects of shortsighted, day-to-day scheduling, in which small amounts of material may be ordered one week, with an accompanying layoff of workers, followed by ordering larger amounts and rehiring workers the next week. This longer-term perspective on resource use can help minimize short-term requirements changes with a resulting cost savings.

In simple terms, aggregate planning is an attempt to balance capacity and demand in such a way that costs are minimized. The term "aggregate" is used because planning at this level includes all resources "in the aggregate;" for example, as a product line or family. Aggregate resources could be total number of workers, hours of machine time, or tons of raw materials. Aggregate units of output could include gallons, feet, pounds of output, as well as aggregate units appearing in service industries such as hours of service delivered, number of patients seen, etc.

Aggregate planning does not distinguish among sizes, colors, features, and so forth. For example, with automobile manufacturing, aggregate planning would consider the total number of cars planned for not the individual models, colors, or options. When units of aggregation are difficult to determine (for example, when the variation in output is extreme) equivalent units are usually determined. These equivalent units could be based on value, cost, worker hours, or some similar measure.

Aggregate planning is considered to be intermediate-term (as opposed to long- or short-term) in nature. Hence, most aggregate plans cover a period of three to 18 months. Aggregate plans serve as a foundation for future short-range type planning, such as production scheduling, sequencing, and loading. The master production schedule (MPS) used in material requirements planning (MRP) has been described as the aggregate plan "disaggregated."

Steps taken to produce an aggregate plan begin with the determination of demand and the determination of current capacity. Capacity is expressed as total number of units per time period that can be produced (this requires that an average number of units be computed since the total may include a product mix utilizing distinctly different production times). Demand is expressed as total number of units needed. If the two are not in balance (equal), the firm must decide whether to increase or decrease capacity to meet demand or increase or decrease demand to meet capacity. In order to accomplish this, a number of options are available.

Options for situations in which demand needs to be increased in order to match capacity include:

1. Pricing: Varying pricing to increase demand in periods when demand is less than peak. For example, matinee prices for movie theaters, off-season rates for hotels, weekend rates for telephone service, and pricing for items that experience seasonal demand.

2. Promotion: Advertising, direct marketing, and other forms of promotion are used to shift demand.

3. Back ordering: By postponing delivery on current orders demand is shifted to period when capacity is not fully utilized. This is really just a form of smoothing demand. Service industries are able to smooth demand by taking reservations or by making appointments in an attempt to avoid walk-in customers. Some refer to this as "partitioning" demand.

4. New demand creation: A new, but complementary demand is created for a product or service. When restaurant customers have to wait, they are frequently diverted into a complementary (but not complimentary) service, the bar. Other examples include the addition of video arcades within movie theaters, and the expansion of services at convenience stores.

Options which can be used to increase or decrease capacity to match current demand include:

1. Hire/lay off: By hiring additional workers as needed or by lying off workers not currently required to meet demand, firms can maintain a balance between capacity and demand.
2. Overtime: By asking or requiring workers to work extra hours a day or an extra day per week, firms can create a temporary increase in capacity without the added expense of hiring additional workers.
3. Part-time or casual labor: By utilizing temporary workers or casual labor (workers who are considered permanent but only work when needed, on an on-call basis, and typically without the benefits given to full-time workers).
4. Inventory: Finished-goods inventory can be built up in periods of slack demand and then used to fill demand during periods of high demand. In this way no new workers have to be hired, no temporary or casual labor is needed, and no overtime is incurred.
5. Subcontracting: Frequently firms choose to allow another manufacturer or service provider to provide the product or service to the subcontracting firm's customers. By subcontracting work to an alternative source, additional capacity is temporarily obtained.
6. Cross-training: Cross-trained employees may be able to perform tasks in several operations, creating some flexibility when scheduling capacity.
7. Other methods: While varying workforce size and utilization, inventory buildup/backlogging, and subcontracting are well-known alternatives, there are other, more novel ways that find use in industry. Among these options are sharing employees with counter-cyclical companies and attempting to find interesting and meaningful projects for employees to do during slack times.

Aggregate Planning Strategies

There are two pure planning strategies available to the aggregate planner: a level strategy and a chase strategy. Firms may choose to utilize one of the pure strategies in isolation, or they may opt for a strategy that combines the two.

Level Strategy

A level strategy seeks to produce an aggregate plan that maintains a steady production rate and/or a steady employment level. In order to satisfy changes in customer demand, the firm must raise or lower inventory levels in anticipation of increased or decreased levels of forecast demand. The firm maintains a level workforce and a steady rate of output when demand is somewhat low. This allows the firm to establish higher inventory levels than are currently needed. As demand increases, the firm is able to continue a steady production rate/steady employment level, while allowing the inventory surplus to absorb the increased demand.

A second alternative would be to use a backlog or backorder. A backorder is simply a promise to deliver the product at a later date when it is more readily available, usually when capacity begins to catch up with diminishing demand. In essence, the backorder is a device for moving demand from one period to another, preferably one in which demand is lower, thereby smoothing demand requirements over time.

A level strategy allows a firm to maintain a constant level of output and still meet demand. This is desirable from an employee relations standpoint. Negative results of the level strategy would include the cost of excess inventory, subcontracting or overtime costs, and backorder costs, which typically are the cost of expediting orders and the loss of customer goodwill.

Chase Strategy

A chase strategy implies matching demand and capacity period by period. This could result in a considerable amount of hiring, firing or laying off of employees; insecure and unhappy employees; increased inventory carrying costs; problems with labor unions; and erratic utilization of plant and equipment. It also implies a great deal of flexibility on the firm's part. The major advantage of a chase strategy is that it allows inventory to be held to the lowest level possible, and for some firms this is a considerable savings. Most firms embracing the just-in-time production concept utilize a chase strategy approach to aggregate planning.

Most firms find it advantageous to utilize a combination of the level and chase strategy. A combination strategy (sometimes called a hybrid or mixed strategy) can be found to better meet organizational goals and policies and achieve lower costs than either of the pure strategies used independently.

Techniques for Aggregate Planning

Techniques for aggregate planning range from informal trial-and-error approaches, which usually utilize simple tables or graphs, to more formalized and advanced mathematical techniques. William Stevenson's textbook *Production/Operations Management* contains an informal but useful trial-and-error process for aggregate planning presented in outline form. This general procedure consists of the following steps:

1. Determine demand for each period.
2. Determine capacity for each period. This capacity should match demand, which means it may require the inclusion of overtime or subcontracting.
3. Identify company, departmental, or union policies that are pertinent. For example, maintaining a certain safety stock level, maintaining a reasonably stable workforce, backorder policies, overtime policies, inventory level policies, and other less explicit rules such as the nature of employment with the individual industry, the possibility of a bad image, and the loss of goodwill.
4. Determine unit costs for units produced. These costs typically include the basic production costs (fixed and variable costs as well as direct and indirect labor costs). Also included are the costs associated with making changes in capacity. Inventory holding costs must also be considered, as should storage, insurance, taxes, spoilage, and obsolescence costs. Finally, backorder costs must be computed. While difficult to measure, this generally includes expediting costs, loss of customer goodwill, and revenue loss from cancelled orders.

5. Develop alternative plans and compute the cost for each.
6. If satisfactory plans emerge, select the one that best satisfies objectives. Frequently, this is the plan with the least cost. Otherwise, return to step 5.

This plan is an example of a plan determined utilizing a level strategy. Notice that employment levels and output levels remain constant while inventory is allowed to build up in earlier periods only to be drawn back down in later periods as demand increases. Also, note that backorders are utilized in order to avoid overtime or subcontracting. The computed costs for the individual variables of the plan are as follows:

Output costs:

- Regular time = \$5 per unit
- Overtime = \$8 per unit
- Subcontracted = \$12 per unit

Other costs:

- Inventory carrying cost = \$3 per unit per period applied to average inventory
- Backorders = \$10 per unit per period

Cost of aggregate plan utilizing a level strategy:

Output costs:

- Regular time = \$5 × 1,500 = \$7,500
- Overtime = \$8 × 0 = 0
- Subcontracted = \$10 × 0 = 0

Other costs:

- Inventory carrying cost = \$3 × 850 = \$2,400
- Backorders = \$10 × 100 = \$1,000

Total cost = \$10,900

Period		1	2	3	4	5	6
Forecast		100	150	300	300	500	150
Output							
	Regular	250	250	250	250	250	250
	Overtime						
	Subcontract						
Output-forecast		150	100	-50	-50	-250	100
Inventory							
	Beginning	0	150	250	200	150	0

	Ending	150	250	200	150	0	100
	Average	75	200	225	175	75	50
Backlog	0	0	0	0	0	0	0

Cost of a aggregate plan utilizing a level strategy :

Output :

Regular time = \$5 X 1500 = \$7500

Overtime = \$8 X 0 = 0

Subcontact = \$10 X 0 = 0

Inventory carrying cost = \$3 X 850 = 2550

Backorder = \$10 X 100 = 1000

Total Costs \$11050

A second example, shown in figure, presents the same scenario as in figure but demonstrates the use of a combination strategy (i.e., a combination of level and chase) to meet demand and seek to minimize costs. For this example, let's assume that company policy prevents us from utilizing backorders and limits our plan to no more than 50 units of overtime per period. Notice that the regular output level is constant, implying a level workforce, while overtime and subcontracting are used to meet demand on a period by period basis (chase strategy). One will notice that the cost of the combination plan is slightly lower than the cost of the level plan.

Output costs:

- Regular time = \$5 × 1,200 = \$6,000
- Overtime = \$8 × 100 = 800
- Subcontracted = \$12 × 250 = 2,500

Other costs:

- Inventory carrying cost = \$3 × 325 = 975
- Backorders = \$10 × 0 = 0

Total cost = \$10,275

Period		1	2	3	4	5	6
Forecast		100	150	300	300	500	150
Output							
	Regular	250	250	250	250	250	250
	Overtime						
	Subcontract						
Output-forecast		100	50	-100	-50	0	50
Inventory							
	Beginning	0	100	150	50	0	0

	Ending	100	150	50	0	0	50
	Average	50	125	100	25	0	25
Backlog	0	0	0	0	0	0	0

Output :

Regular time	= $5 X 1200	=	$6000
Overtime	= $8 X 100	=	800
Subcontact	= $12 X 250	=	3000
Inventory carrying cost	= $3 X 325	=	975
Backorder	= $10 X 0	=	0
Total Costs			$10775

Mathematical Approaches to Aggregate Planning

The following are some of the better known mathematical techniques that can be used in more complex aggregate planning applications.

Linear Programming

Linear programming is an optimization technique that allows the user to find a maximum profit or revenue or a minimum cost based on the availability of limited resources and certain limitations known as constraints. A special type of linear programming known as the Transportation Model can be used to obtain aggregate plans that would allow balanced capacity and demand and the minimization of costs. However, few real-world aggregate planning decisions are compatible with the linear assumptions of linear programming. *Supply Chain Management: Strategy, Planning and Operation,* by Sunil Chopra and Peter Meindl, provide an excellent example of the use of linear programming in aggregate planning.

Mixed-integer Programming

For aggregate plans that are prepared on a product family basis, where the plan is essentially the summation of the plans for individual product lines, mixed-integer programming may prove to be useful. Mixed-integer programming can provide a method for determining the number of units to be produced in each product family.

Linear Decision Rule

Linear decision rule is another optimizing technique. It seeks to minimize total production costs (labor, overtime, hiring/lay off, inventory carrying cost) using a set of cost-approximating functions (three of which are quadratic) to obtain a single quadratic equation. Then, by using calculus, two linear equations can be derived from the quadratic equation, one to be used to plan the output for each period and the other for planning the workforce for each period.

Management Coefficients Model

The management coefficients model, formulated by E.H. Bowman, is based on the suggestion that the production rate for any period would be set by this general decision rule:

$$P_t = aW_{t-1} - bI_{t-1} + cF_{t+1} + K,$$

Where,

P_t = the production rate set for period t,

W_{t-1} = the workforce in the previous period,

I_{t-1} = the ending inventory for the previous period,

F_{t+1} = the forecast of demand for the next period,

$a, b, c,$ and K are constants.

It then uses regression analysis to estimate the values of $a, b, c,$ and K. The end result is a decision rule based on past managerial behavior without any explicit cost functions, the assumption being that managers know what is important, even if they cannot readily state explicit costs. Essentially, this method supplements the application of experienced judgment.

Search Decision Rule

The search decision rule methodology overcomes some of the limitations of the linear cost assumptions of linear programming. The search decision rule allows the user to state cost data inputs in very general terms. It requires that a computer program be constructed that will unambiguously evaluate any production plan's cost. It then searches among alternative plans for the one with the minimum cost. However, unlike linear programming, there is no assurance of optimality.

Simulation

A number of simulation models can be used for aggregate planning. By developing an aggregate plan within the environment of a simulation model, it can be tested under a variety of conditions to find acceptable plans for consideration. These models can also be incorporated into a decision support system, which can aid in planning and evaluating alternative control policies. These models can integrate the multiple conflicting objectives inherent in manufacturing strategy by using different quantitative measures of productivity, customer service, and flexibility.

Functional Objective Search Approach

The functional objective search (FOS) system is a computerized aggregate planning system that incorporates a broad range of actual planning conditions. It is capable of realistic, low-cost operating schedules that provide options for attaining different planning goals. The system works by comparing the planning load with available capacity. After management has chosen its desired actions and associated planning objectives for specific load conditions, the system weights each planning goal to reflect the functional emphasis behind its achievement at a certain load condition. The computer then uses a computer search to output a plan that minimizes costs and meets delivery deadlines.

Aggregate Planning in Services

For manufacturing firms the luxury of building up inventories during periods of slack demand allows coverage of an anticipated time when demand will exceed capacity. Services cannot be stockpiled or inventoried so they do not have this option. Also, since services are considered "perishable," any capacity that goes unused is essentially wasted. An empty hotel room or an empty seat on a flight cannot be held and sold later, as can a manufactured item held in inventory.

Service capacity can also be very difficult to measure. When capacity is dictated somewhat by machine capability, reasonably accurate measures of capacity are not extremely difficult to develop. However, services generally have variable processing requirements that make it difficult to establish a suitable measure of capacity.

Historically, services are much more labor intensive than manufacturing, where labor averages 10 percent (or less) of total cost. This labor intensity can actually be an advantage because of the variety of service requirements an individual can handle. This can provide quite a degree of flexibility that can make aggregate planning easier for services than manufacturing.

Linear Programming

Operations management often presents complex problems that can be modeled by linear functions. The mathematical technique of linear programming is instrumental in solving a wide range of operations management problems.

Linear Program Structure

Linear programming models consist of an objective function and the constraints on that function. A linear programming model takes the following form:

- Objective function:

$$Z = a_1X_1 + a_2X_2 + a_3X_3 + \ldots + a_nX_n$$

- Constraints:

$$b_{11}X_1 + b_{12}X_2 + b_{13}X_3 + \ldots + b_{1n}X_n < c_1$$
$$b_{21}X_1 + b_{22}X_2 + b_{23}X_3 + \ldots + b_{2n}X_n < c_2$$
$$.$$
$$.$$
$$.$$
$$b_{m1}X_1 + b_{m2}X_2 + b_{m3}X_3 + \ldots + b_{mn}X_n < c_m$$

In this system of linear equations, Z is the objective function value that is being optimized, X_i are the decision variables whose optimal values are to be found, and a_i, b_{ij}, and c_i are constants derived from the specifics of the problem.

Linear Programming Assumptions

Linear programming requires linearity in the equations as shown in the above structure. In a linear equation, each decision variable is multiplied by a constant coefficient with no multiplying between decision variables and no nonlinear functions such as logarithms. Linearity requires the following assumptions:

- Proportionality - a change in a variable results in a proportionate change in that variable's contribution to the value of the function.
- Additivity - the function value is the sum of the contributions of each term.
- Divisibility - the decision variables can be divided into non-integer values, taking on fractional values. Integer programming techniques can be used if the divisibility assumption does not hold.

In addition to these linearity assumptions, linear programming assumes certainty; that is, that the coefficients are known and constant.

Problem Formulation

With computers able to solve linear programming problems with ease, the challenge is in problem formulation - translating the problem statement into a system of linear equations to be solved by computer. The information required to write the objective function is derived from the problem statement. The problem is formulated from the problem statement as follows:

1. Identify the objective of the problem; that is, which quantity is to be optimized. For example, one may seek to maximize profit.
2. Identify the decision variables and the constraints on them. For example, production quantities and production limits may serve as decision variables and constraints.
3. Write the objective function and constraints in terms of the decision variables, using information from the problem statement to determine the proper coefficient for each term. Discard any unnecessary information.
4. Add any implicit constraints, such as non-negative restrictions.
5. Arrange the system of equations in a consistent form suitable for solving by computer. For example, place all variables on the left side of their equations and list them in the order of their subscripts.

The following guidelines help to reduce the risk of errors in problem formulation:

- Be sure to consider any initial conditions.
- Make sure that each variable in the objective function appears at least once in the constraints.
- Consider constraints that might not be specified explicitly. For example, if there are physical quantities that must be non-negative, then these constraints must be included in the formulation.

The Effect of Constraints

Constraints exist because certain limitations restrict the range of a variable's possible values. A constraint is considered to be binding if changing it also changes the optimal solution. Less severe constraints that do not affect the optimal solution are nonbinding.

Tightening a binding constraint can only worsen the objective function value, and loosening a binding constraint can only improve the objective function value. As such, once an optimal solution is found, managers can seek to improve that solution by finding ways to relax binding constraints.

Shadow Price

The shadow price for a constraint is the amount that the objective function value changes per unit change in the constraint. Since constraints often are determined by resources, a comparison of the shadow prices of each constraint provides valuable insight into the most effective place to apply additional resources in order to achieve the best improvement in the objective function value.

The reported shadow price is valid up to the allowable increase or allowable decrease in the constraint.

Applications of Linear Programming

Linear programming is used to solve problems in many aspects of business administration including:

- Product mix planning.
- Distribution networks.
- Truck routing.
- Staff scheduling.
- Financial portfolios .
- Corporate restructuring.

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3

Materials and Inventory Management

The capability of firms to plan total material requirements is known as materials management. Inventory management refers to the supervision of inventory. The diverse aspects of materials and inventory management such as materials requirement planning and purchase management have been thoroughly discussed in this chapter.

Materials Management

'Materials Management' is a term used to connote "controlling the kind, amount, location, movement and timing of various commodities used in production by industrial enterprises". Materials Management is the planning, directing, controlling and coordinating those activities which are concerned with materials and inventory requirements, from the point of their inception to their introduction into the manufacturing process.

It begins with the determination of materials quality and quantity and ends with its issuance to production to meet customer's demand as per schedule and at the lowest cost. Materials Management is a basic function of the business that adds value directly to the product itself.

Materials Management embraces all activities concerned with materials except those directly concerned with designing or manufacturing the product. Materials Management deals with controlling and regulating the flow of material in relation to changes in variables like demand, prices, availability, quality, delivery schedules etc.

Thus, material management is an important function of an organisation covering various aspects of input process, i.e., it deals with raw materials, procurement of machines and other equipment's necessary for the production process and spare parts for the maintenance of the plant. Thus in a production process materials management can be considered as a preliminary to transformation process.

It involves planning and programming for the procurement of material and capital goods of desired quality and specification at reasonable price and at the required time.

It is also concerned with market exploration for the items to be purchased to have up to date information, stores and stock control, inspection of the material received in the enterprise, transportation and material handling operations related to materials and many other functions. In the words of Bethel, "Its responsibility end when the correct finished product in proper condition and quantity passes to the consumer."

General Electric Company (G.E.C.) of U.S.A. who is pioneers in the field of Materials Management listed the functions of materials management under following heads:

- Planning and programming for materials purchase.

- Stores and Stock control.
- Receiving and issue of the material.
- Transportation and material handling of the material.
- Value engineering and value analysis.
- Disposal of scrap and surplus materials.

Objectives of Materials Management

Materials management contributes to survival and profits of an enterprise by providing adequate supply of materials at the lowest possible costs.

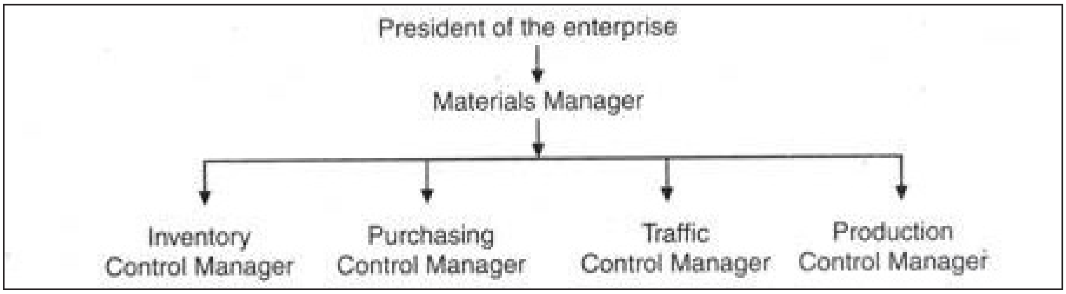
The fundamental objectives of materials management activities can be:

- Material Selection: Correct specification of material and components is determined. Also the material requirements in agreement with sales programme are assessed. This can be done by analysing the requisition order of the buying department. With this standardisation one may have lower cost and the task of procurement, replacement etc. may be easier.
- Low operating costs: It should endeavor to keep the operating costs low and increase the profits without making any concessions in quality.
- Receiving and controlling material safely and in good condition.
- Issue material upon receipt of appropriate authority.
- Identification of surplus stocks and taking appropriate measures to produce it.

The outcome of all these objectives can be listed as given below:

- Regular uninterrupted supply of raw-materials to ensure continuity of production.
- By providing economy in purchasing and minimising waste it leads to higher productivity.
- To minimise storage and stock control costs.
- By minimising cost of production to increase profits.
- To purchase items of best quality at the most competitive price.

Organization of Materials Management Department



To facilitate planning, direction, control and co-ordination of various activities related to material in an enterprise there should be a separate department of materials management. The organisational structure of the department can be.

There can be more sub-sections of the department but in general, materials manager controls the four major sections and is responsible for reporting to the president of the organisation.

Materials Planning and Control

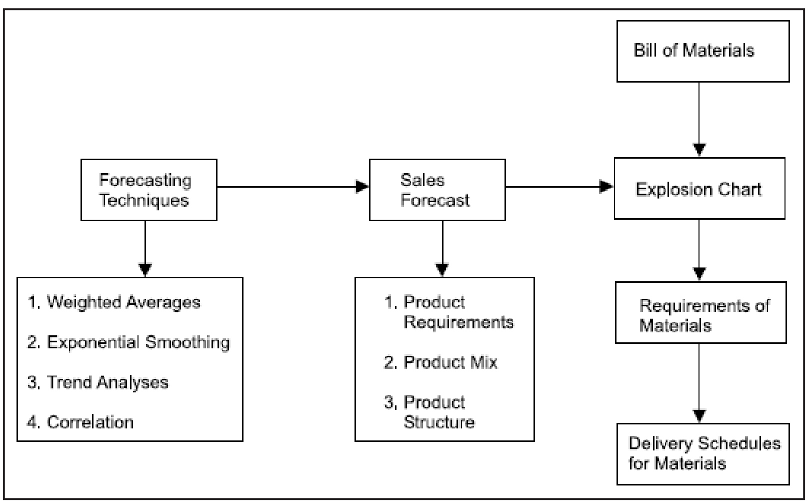
Material planning is a scientific technique of determining in advance the requirements of raw materials, ancillary parts and components, spares etc. as directed by the production program. It is a sub-system in the overall planning activity. There are many factors, which influence the activity of material planning. These factors can be classified as macro and micro systems.

1. Macro factors: Some of the micro factors which affect material planning, are price trends, business cycles Govt. import policy etc.
2. Micro factors: Some of the micro factors that affect material planning are plant capacity utilization, rejection rates, lead times, inventory levels, working capital, delegation of powers and communication.

Techniques of Material Planning

One of the techniques of material planning is bill of material explosion. Material planning through bill of material explosion.

Material Planning



The basis for material planning is the forecast demand for the end products. Forecasting techniques such as weighted average method, exponential smoothening and time series models are used for the same. Once the demand forecast is made, it is possible go through the excurse of material planning. Bill of materials is a document which shows list of materials required, unit consumption location code for a given product. An explosive chart is a series of bill of material grouped in a matrix form so that combined requirements for different components can be done requirements of various materials are arrives at from the demand forecast, using bill of materials, through explosion charts. Thus material requirement plan will lead to be the development of delivery schedule of the materials and purchasing of those material requirements

Materials Requirement Planning

Material Requirements Planning (MRP) is a computer-based production planning and inventory control system. MRP is concerned with both production scheduling and inventory control. It is a material control system that attempts to keep adequate inventory levels to assure that required materials are available when needed. MRP is applicable in situations of multiple items with complex bills of materials. MRP is not useful for job shops or for continuous processes that are tightly linked. The major objectives of an MRP system are too simultaneously:

1. Ensure the availability of materials, components, and products for planned production and for customer delivery,
2. Maintain the lowest possible level of inventory,
3. Plan manufacturing activities, delivery schedules, and purchasing activities.

MRP is especially suited to manufacturing settings where the demand of many of the components and subassemblies depend on the demands of items that face external demands. Demand for end items are independent. In contrast, demand for components used to manufacture end items depend on the demands for the end items. The distinctions between independent and dependent demands are important in classifying inventory items and in developing systems to manage items within each demand classification. MRP systems were developed to cope better with dependent demand items.

The three major inputs of an MRP system are the master production schedule, the product structure records, and the inventory status records. Without these basic inputs the MRP system cannot function.

The demand for end items is scheduled over a number of time periods and recorded on a master production schedule (MPS). The master production schedule expresses how much of each item is wanted and when it is wanted. The MPS is developed from forecasts and firm customer orders for end items, safety stock requirements, and internal orders. MRP takes the master schedule for end items and translates it into individual time-phased component requirements.

The product structure records, also known as bill of material records (BOM), contain information on every item or assembly required to produce end items. Information on each item, such as part number, description, quantity per assembly, next higher assembly, lead times, and quantity per end item, must be available.

The inventory status records contain the status of all items in inventory, including on hand inventory and scheduled receipts. These records must be kept up to date, with each receipt, disbursement, or withdrawal documented to maintain record integrity.

MRP will determine from the master production schedule and the product structure records the gross component requirements; the gross component requirements will be reduced by the available inventory as indicated in the inventory status records.

MRP Computations

We will illustrate MRP computations through examples.

Example: Suppose you need to produce 100 units of product A eight week from now, where product A requires one unit of product B and two units of product C, while product C requires one unit of product D and two units of product E. How many units of each type do you need? In this example it is easy to compute the requirements of each item to produce 100 units of product A:

Req(B) = 100, Req(C) = 200, Req(D) = 200, Req(E) = 400.

Suppose further that the lead-times for the products are as follows: Product A, four weeks, product B three weeks, product C two weeks, products D and E one week each. Since the production lead-time for product A is four weeks, we must have products B and C available at the end of week four. Since product B has a lead time of three weeks, we need to release the production of product B by the end of the first week. Similarly, product C need to be released for production at the end of week two, while products D and E must be released for production at the end of week one.

A material requirements plan has been developed for product A based on the product structure of A and the lead-time needed to obtain each component. Planned order releases of a parent item are used to determine gross requirements for its component items. Planned order release dates are simply obtained by offsetting the lead times.

The computations and steps required in the MRP process are not complicated. They involve only simple arithmetic. However, the bill-of-materials explosion must be done with care. What may get complicated is the product structure, particularly when a given component is used in different stages of the production of a finished item.

The Level of an Item

To form a useful bill of material matrix it is convenient to order the items by levels. The level of an item is the maximum number of stages of assembly required to get the item into an end product.

Example: Consider a system with two end items, item 1 and item 2.

- Item 1 requires two units of item A and one unit of item C.
- Item 2 requires one unit of item B, one unit of item D and three units of item E.
- Item A requires one unit of item B and two units of item F.
- Item B requires two units of item C and one unit of item E.
- Item C requires one unit of item F and three units of item G.
- Item D requires two units of item B and one unit of item C.

The levels of the items are:

- Level 0: Items 1 and 2.
- Level 1: Items A and D.

- Level 2: Item B.
- Level 3: Items C and E.
- Level 4: Items F and G.

An Outline of the MRP Process

Starting with end items the MRP process goes through the following steps:

1. Establish gross requirements.
2. Determine net requirements by subtracting scheduled receipts and on hand inventory from the gross requirements.
3. Time phase the net requirements.
4. Determined the planned order releases.

Table: MRP Table

Week	1	2	3	4	5	6	7
Gross requirements							
Scheduled receipts							
Net requirements							
Time-phased net req							
Planned order releases							

The planned order releases aggregated over all the end items will result in the gross requirements for level one items, the gross requirements for this items are then netted and time phased to determined their own order releases. The process is continued until all the items have been exploded. Table shows a typical MRP table.

Example: MRP computations are shown in table where the lead-time is two weeks. Here the planned releases were obtained by solving a Wagner-Whitin problem with time-varying demand. More often, however, MRP will plan releases in a lot-by-lot fashion.

Table: Standard MRP Table

Week	1	2	3	4	5	6	7
Gross requirements	10	15	25	30	45	20	30
Schedule receipts	10	25					
Net requirements			15	30	45	20	30
Time-phased net req	15	30	45	20	30		
Planned order releases	45	0	45	50			

Computing Direct and Indirect Requirements

Let B_{ij} denote the numbers of units of item j required making directly one unit of item i, and let R_{ij} denote the total number of units of item j, direct or indirect, required to produce one unit of item i. Clearly $R_{ii} = 1$, while for $j \neq i$ we have,

$$R_{ij} = \sum_k B_{ik} R_{kj}$$

In matrix notation, we have:

$$R = I + BR$$

So,

$$(I - B)R = I$$

And

$$R = (I - B)^{-1}$$

Let d be a row vector of item requirements, then dB and dR represent respectively, the direct and total derived demand.

Example: We illustrate these concepts using the data from previous example.

$$B = \begin{array}{c} \\ 1 \\ 2 \\ A \\ D \\ B \\ C \\ E \\ F \\ G \end{array} \begin{array}{c} \begin{array}{ccccccccc} 1 & 2 & A & D & B & C & E & F & G \end{array} \\ \begin{pmatrix} 0 & 0 & 2 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 0 & 2 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array},$$

While,

$$R = \begin{array}{c} \\ 1 \\ 2 \\ A \\ D \\ B \\ C \\ E \\ F \\ G \end{array} \begin{array}{c} \begin{array}{ccccccccc} 1 & 2 & A & D & B & C & E & F & G \end{array} \\ \begin{pmatrix} 1 & 0 & 2 & 0 & 2 & 5 & 2 & 9 & 15 \\ 0 & 1 & 0 & 1 & 3 & 7 & 6 & 7 & 21 \\ 0 & 0 & 1 & 0 & 1 & 2 & 1 & 4 & 6 \\ 0 & 0 & 0 & 1 & 2 & 5 & 2 & 5 & 15 \\ 0 & 0 & 0 & 0 & 1 & 2 & 1 & 2 & 6 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 3 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \end{array}$$

Thus, we need a total of 21 units of item G to manufacture one unit of item 2. Suppose that you require 120 units of product 1 and 100 units of product 2. What is the direct and total demand for the subassemblies? We can form a row vector,

d = (120 100 0 0 0 0 0 0 0),

then,

dB = (0 0 240 100 100 120 300 0 0),

and,

dR = (120 100 240 100 540 1300 840 1780 3900).

These formulas are very useful. To convince yourself try finding the total derived demand for G.

Expediting and Deferring Scheduled Receipts

The process of determining net requirements, as outlined above, is to subtract scheduled receipts and on hand inventory from the gross requirements. Occasionally, because of anticipated changes in the MPS, we will find that the scheduled receipts are not enough to cover the gross requirements within a lead time. Consider, for example, table, and assume that the lead time is three weeks.

Notice that the schedule has a net requirement of 15 units in period 2. An order placed for 15 units in period 1 will arrive in period 4, so it would need to be expedited to be ready by period 2. An easier alternative, is to issue an expedite notice to the schedule receipt of period 3, stating that we need 15 units by period 2. Suppose that it is only possible to have 10 units ready by period 2. Then we will have a shortfall of five units. When a shortage occurs, it is important to backtrack and identify the source of demand. It may be that 10 of the 15 units required in period 2 are for actual orders, while the other five are in anticipation of future demand. In this case, we will allocate the 10 units to the actual order and avoid a stock out. On the other hand, there may be changes in the MPS that make scheduled receipts unnecessary. In that case the schedule receipts can be deferred to a later period.

Table: Expediting in MRP

Week	1	2	3	4	5	6	7
Gross requirements	10	15	25	30	45	20	30
Schedule receipts	10		25				
Net requirements		15		30	45	20	30

Lot Sizing Rules

The problem of lot sizing is one of satisfying the requirements while trying to minimize holding and setup costs. A variety of lots sizing rules have been proposed. The lot-for-lot (LFL) is the simplest approach, and it calls for producing in period t the net requirements for period t. The LFL approach minimizes the holding cost by producing just-in-time. This approach is optimal if setup costs and setup times have been reduced to negligible levels, but it may be expensive if setup costs are significant. A variety of lots sizing algorithms have been developed to deal with the case where setup costs are significant. The Wagner-Whitin (WW) algorithm can be used to optimally select the lot sizes at one level. However, applying the Wagner-Whitin algorithm, or any other single level approach, to different levels does not guarantee that the overall policy is optimal. An alternative to the Wagner-Whitin policy is the Silver-Meal (SM) heuristic. Starting from the first period with positive requirements, the SM heuristic attempts to cover more and more periods with one setup while the average cost of doing this is decreasing. Once it is determined that adding the requirements of the next period increases the average cost, a new setup is incurred and the method is repeated until all the requirements are covered. Another approach, which is popular in practice, is the part period balancing (PPB) heuristic which attempts to select the number of periods covered by a setup by making the holding cost over the covered horizon as close as possible to the setup cost. The fixed order quantity (FOQ) heuristic is to order a predetermined quantity whenever an order is placed. Finally, the fixed order period (FOP) heuristics calls for covering the demand of a fixed number of periods with one setup. Vollman et. al. recommends the use of different lot-sizing rules for different levels in the BOM, with FOQ for end items, either FOQ or LFL for intermediate levels, and FOP for the lowest levels. The idea is to avoid the propagation of the bullwhip effect to the lowest items.

Dealing with Uncertainty in MRP

There are several sources of uncertainty that we have ignored so far. These include uncertainty in the quantity demanded (forecast errors) and the quantity supplied (yield losses), and uncertainty in the timing of demand and the timing of supply (random lead times). Many MRP systems cope with uncertainty by inflating lead times (inducing safety time), by expediting orders, and by shifting priorities of shop and vendor orders. Another way of protecting against uncertainty is to carry safety stock for end items with random demand, and to carry safety stock of items produced at bottleneck operations.

Shortcomings of MRP

Capacity

MRP expects the lead time to be constant regardless of how much work has been released into the production system, so it is implicitly assuming infinite capacity. This can create problems when production levels are at or near capacity. One way to address this problem is to make sure that the MPS is capacity feasible. Rough-cut capacity planning (RCCP) attempts to do this by checking the capacity of a few critical resources. RCCP makes use of the bill of resources (BOR) for each item on the MPS. The BOR specifies the number of hours required at each critical resource to build a particular end item and its components, and then aggregates the number of hours required at each critical resource over the end items in the MPS. RCCP then checks whether the available resources are enough to cover the MPS on each time bucket. Notice that RCCP does not perform time offsets, so the calculation of the number of hours required has to be done with time buckets that are large enough so that parts and their components can all be completed within a single time bucket. This usually makes RCCP an optimistic estimation of what can be done. Advanced MRP systems provide more detailed capacity analysis proposing alternative production schedules when the current plan is not feasible.

Long Lead Times

There are many pressures to increase planned lead times in an MRP system. MRP uses constant lead times when, in fact, actual lead times vary considerably. To compensate, planners typically choose pessimistic estimates. Long lead times lead to large work-in-process (WIP) inventories.

Nervousness

MRP is typically applied in a rolling horizon basis. As customer orders firm up, and forecasts become better, a new MPS is fed to MRP which produces updated planned order releases that may be very different form the original. Even small changes in the MPS can result in large changes in planned order releases. Vollman et. al., give an example where a small decrease in demand causes a formerly feasible MRP plan to become infeasible.

MRP II

Manufacturing Resource Planning (MRP II) embeds additional procedures to address the shortcomings of MRP. In addition, MRP II attempts to be an integrated manufacturing system by bringing together other functional areas such as marketing and finance. The additional functions of MRP II include forecasting, demand management, rough-cut capacity planning (RCCP), and capacity requirement planning (CRP), scheduling dispatching rules, and input/output control. MRP II works within a hierarchy that divides planning into long-range planning, medium range planning, and short-term control.

ERP Systems and Bolt-ons

Enterprise resource planning (ERP) systems are extensions of MRP systems that run on a single database in a client server enviornment. ERP systems support marketing and finance departments in addition to the production department. Significant coordination advantages arise when all functions draw and add to the same data. SAP is currently the leading provider of ERP systems. Many companies such as i2 Technologies and Manugistics have developed bolt-ons programs that run on top of ERP systems. These companies address specific problems that are not solved by ERP. For example, a better forecasting system or a finite-capacity scheduler can be added to SAP. Lately SAP has developed many of the capabilities that were formerly available only through bolt-ons.

Purchase Management

Purchasing

Purchasing describes the process of buying. It is the learning of the requirement, identifying and selecting a supplier, negotiation price. Purchasing is an element of the wider function of procurement and it includes many activities such as ordering, expediting, receipt and payment. Purchasing is responsible for obtaining the materials, parts, supplies and services needed to produce of a product or provide a service. Purchasing can be divided into two broad categories, large and small purchases, based on seven characteristics of purchased product – volume, specificity, technological complexity, essentiality, fragility, variability, and economic value.

Bulk Purchase

In case of bulk purchases there are high volume items, large amount, and more frequent utilization with more specific use. Bulk purchases are handled in large organisations and multinational organisations with the standardized purchasing process, where as some other organizations use separate purchasing process. There are frequent misuse and lack of control in purchasing process in those organizations in which same standardized process is used for both bulk and small purchasing. Large purchases are typically non-urgent in nature. Large-volume, continuous-usage items can be covered by blanket purchase orders, which often involve annual negotiation of prices.

Small Purchase

In case of small purchase there are low volume items, small amount, less frequency of utilization, high variety and low technical complexity. Mainly small purchases include machine parts, auto parts, machine repairs, in frequent sullies of offices and miscellaneous goods. Small purchases are urgent in nature.

There are two basic types of purchasing in the business world: purchasing for resale or purchasing for consumption or conversion. Purchasing for resale or resale purchasing is mainly performed by retailers and wholesalers (called merchants). Purchasing for internal consumption or conversion is called industrial buying. The industrial buyers generally face different and complex problems with comparisons of merchandise buyers or resellers. For instance, the industrial buyers have to spend time to anticipate in determining what products should be produced or manufactured and what product should be purchased from outside or suppliers. They also correlate their purchasing with sale forecasts and production schedules. In some books, you will find the terms like purchasing, procurement, supply chain, materials management, supply material and logistics interchangeably. But there is a hair-line difference in all these terms.

Important Terms

- Purchasing: Purchasing describes the process of buying. It covers the knowledge of the requirements, identifying and selecting a supplier and negotiating price.
- Procurement: It is a broader term. It includes purchasing products required for production, stores, traffic, receiving, inspection and salvage.
- Materials Management: It includes planning, organising, communicating, directing and controlling of all those activities mainly concerned with the flow of materials into an organisation. Material management views material flows as a system.
- Logistics Management: It is the planning and controlling of the flow of raw material in a cost effective manner from the suppliers or point of origin to the manufacturing and then flow of finished goods for consumption in the customers' hands.

Purchasing Management

Purchasing management is concerned with the planning and controlling of the acquisition of suppliers' goods and resources, to fulfill the administrative and strategic objectives of the organization. In practice, purchasing managers have to deal with both customers internal as well as external. He/she has to respond creatively to internal customers' need on the one hand and to maintain a mutually profitable relationship with suppliers on the other. This dual-role perspective of purchasing management has, in recent years, been increasingly recognized as comprising complex tasks in the integration of internal/external and upstream/downstream supply chain management activities. The part of supply chain management that focuses on the management of inbound goods and services into a firm.

Importance of Purchase Management

For Cost Effective Production

Purchasing is responsible for learning of the internal requirements, locating and selecting suppliers, obtaining the materials, parts, supplies and services needed to produce a product or provide a service. A purchase manager is responsible for negotiation of price with suppliers too. You can get some idea of the importance of purchasing when you consider that in manufacturing industry more than 60 percent of the cost of finished goods comes from purchased parts and materials. Furthermore, the percentages for purchased inventories are even higher for retail and wholesale companies, sometimes exceeding 90 percent.

Nonetheless, the importance of purchasing is more than just the cost of goods purchased; other important factors include the quality of goods and services and the timing of deliveries of goods or services, both of which can have a significant impact on operations. The industries like construction, petroleum refineries, sugar, automobile have more than 75 percentages of materials cost as an input percent cost.

For Strategic Purpose

Purchasing is a strategic issue. The manufacturers have to procure capital items like plant and machinery for manufacturing facilities. It requires heavy investment. So, purchasing is an important function. But in some organisations, especially small scale, purchasing is considered as a clerical activity. They assign this job to the persons simply who are loyal to the organisation. But it is a wrong way. In purchasing, the executives must by dynamic, innovative, creative and must have analytical decision making. The emergence of the supply chain management concept has enlightened managers about the strategic role played by purchasing. Purchasing helps to determine a firm's cost structure through negotiations with suppliers. If the executives are efficient in bargaining then they can save for the organisations and this will help the organisations to cut costs and helpful in getting competitive advantage in the market. Purchasing initiatives can lead to reducing inventory and improving the quality of incoming parts and components through vendor selection and supplier development. Purchasing also supports new product development by encouraging supplier involvement in product development.

Organization can realize major benefits from their focus on purchasing management as mentioned below:

From a Top Management Perspective

There are five rights that every management expects from their purchasing executives:

- Right Quantity

- Right Quantity
- Right quality
- Right Time
- Right Supplier
- Right Cost

From Functional Perspective

- Uninterrupted flow of materials and services,
- Buying at competitive prices,
- Avoiding under-inventory and over-inventory,
- To have good relationship with other departments.

In nutshell, purchase management has the following benefits:

- Cost reduction or improvement (required utmost to be competitive in market).
- Improved material delivery (required for smooth flow of production).
- Shorter cycle time, including product development cycle times (helpful in fast production).
- Quality improvement (required to satisfy or win the hearts of the customers ultimately).

Manufactures spend an average of 55 cents out of every dollar of revenues on goods and services, purchasing and clearly a major area for potential cost savings. This fact was recognized first by many Japanese companies in the 1980s when superior management of relationships with supplies gave Japanese automobile companies a $300 to $600 per car cost advantage.

- What car/automobile companies buy: Tires, Brakes leathers, Clutches, Wires, Steel plates, Glasses, Paint, Fabric, Aluminum sheets, Electronic components, Carpets etc.
- What soft-drink producers buy: Bottles, Sweetner, Carbonation, Flavouring substances, Caps, Cardboards, Plastic Containers, etc.
- What software companies buy: Computers, Hardware, Chairs, Tables, Wires, Data Cables, etc.
- What hotels/restaurants buy: Vegetables, Utensils, Air conditioners, Gas Stoves, Carpets, etc.

So, we see that different industries require different types of materials according to their requirements.

Purchasing Activities

There are two major forms of purchasing activities that take place in an organization:

1. Tactical purchasing
2. Strategic sourcing

Tactical Purchasing

The organisations require some materials for the smooth flow of production. The day to day management of materials flow is called tactical purchasing. These activities generally ensure that products and services are delivered to the right internal people at the right time but are often not carried out using a long term horizon.

Strategic Sourcing

The purchasing which affects the long-term profitability is called strategic purchasing. Strategic sourcing is a part of purchasing activities but in a border sense. In the strategic sourcing process there may include members from other than purchasing department like from engineering, quality, design, manufacturing, marketing and accounting department for managing, developing and integrating with supplier capabilities to achieve competitive advantages like cost reduction, technology development, quality improvement and cycle time reduction.

Types of Purchase

There are mainly two types of purchases; the individual purchase and the organizational purchase:

Individual Purchase

Individual or personal purchase includes those types of items or products which are purchased for personal or family consumption.

Factors influencing individual purchase behavior - In general mainly there are four types of influence factors:

- Cultural Factors
- Social Factors
- Personal Factors
- Psychological Factors

Organizational Purchase

A purchase will be considered to be organizational if it is made in the name of a company or organization, regardless of size, from a medium sized company up to a multinational or state company. Organization consists of business, industries, retailers, wholesaler, government and non- government organizations.

- Business and industries purchase materials for business use or as a raw material to produce other product.
- Wholesalers/Retailers/traders buy product for resell at profit.
- Government organisations purchase products for use in offices or provide services to people.
- Non-government organizations purchase products to provide services to their client.

Consumer Purchasing / Decision Making	Industrial Purchasing / Decision- Making
Less risky	More risky
Emotional decision-making	Rational / Analytical decision-making
Personal purchasing is sometimes unplanned or on the spot or abrupt buying influenced by promotional activities	Scientific purchasing as whole organization's profitability affects

Purchasing Cycle

The purchasing cycle begins with a request from within the organization to purchase material, equipment, supplies, or other items from outside the organization, and the cycle ends when the purchasing department is notified that a shipment has been received in satisfactory condition, and managerial accounting is actively involved in each step. The main steps in the cycle are as under:

- Recognition of need.
- Description of need.
- Selection of suppliers.
- Determination of prices.
- Preparation of purchase order.
- Placing the order with a selected supplier.
- Monitoring and follow up the order.
- Receiving the ordered materials.
- Checking and approving for payment to supplier.

Characteristics of a Purchasing Manger

The following pre-requisite traits are required for a purchase manager:

Interpersonal Skills

The purchase manger must have good communication skills. There are many aspects of interpersonal communication such as handling suppliers, respect of other opinion and so on. He or she must be efficient in the same.

Analytical Decision Making

Purchase manager may face many problems in his or her job like placing order, selection of best supplier, to maintain healthy relationship with supplier, and purchase right materials in right quantity at right time and so on. So, a good purchase manager must have analytical decision making.

Loyal to the Organisation

The purchasing manager is involved in large activities of purchasing materials consistently involving very large financial deals. So, he has to be loyal to the organisation and he has to prove his loyalty from time to time.

Computer Literacy

The purchase manager must be well skilled in computer as he requires use of computer in many activities. If he is computer literate, then he can work efficiently.

Technical Skills

Now-a-days, in production a very highly sophisticated technology is used. Purchase manager must have technical understanding of the business. The purchase manager has enough technical background to understand the production process, the supplier's processes and scheduling system in order to making improvement.

Ability to Make Decision

The purchasing manager has to take quick decisions in line with procurement strategy of organization vis-à-vis liaison with other departments. He or she has to take decisions with quality, market, economic, social and political environment and issues taken into account.

Innovative

Innovation is very necessary for survive in the market in present competitive market condition. So, a purchase manager should take innovative decisions related to purchase techniques, maintaining quality, inventory stock, inventory control, re-ordering level and order processing.

Bargaining Power

It must be the prime motive of the purchase manager that organization can purchase more and best materials with less cost. For this a purchase manager should have good bargaining power.

Materials Management

Material management is defined as the planning, acquiring, storing, moving and controlling of materials as per the requirement of the organisation. Materials management is basically related with the smooth flow of materials. The major activities covered under materials management are the anticipation of the materials required in the organisation from time-to- time. It involves ordering and obtaining materials from the suppliers, introducing the materials to the organisation and monitoring the status of materials. It helps to optimize the usage of facilities, personnel and funds and to provide service to the user in the line with the organizational aims. Materials management is the coordination and control of the various material activities. The key material activities are:

- Purchasing Activities: It involves mainly identification of materials needs, market research, maintaining materials records etc.

- Procurement Activities: It involves material specifications, materials studies, receiving materials etc.
- Inventory Management: It involves planning and controlling of materials handling, storing materials and managing material supplies etc.
- Supply Management: It involves monitoring in-plant material handling, strategic planning of materials etc.

Classification of Manufacturing Materials

The manufacturing materials can be classified into following categories:

- Raw Materials: It is the materials that the company is required to transform into finished goods. It is very important. The shortage of halts can stop the production and can cause high losses. It is different for different industries. As for example, for textile industry the cotton is main input. For automobile industry, the spare parts are very important.
- Manufactured Parts: These parts are the output of the organizations. These are the finished materials built by the company.
- Work in Process: These are semi-finished products found at various stages in the production process.
- Packaged Materials: These are materials that are packaged together to prevent damage during transportation and deterioration when they are stored.
- MRO Supplies: These materials are required for maintenance, repairing, and operating supplies used in the manufacturing process regularly for the smooth manufacturing, i.e. soap, lubricating oil, grease, plastic and rubber parts, screw driver, nuts etc.
- Loose Materials: These are materials that are partially fabricated and that should be handled individually.

Objectives of Materials Management Department

The primary objectives of Materials Management department are:

- Low Procurement price.
- High inventory turnover.
- Low cost of acquisition and possession.
- Continuity of supply.
- Consistent quality.
- Low payroll costs.
- Favorable supplier relations.
- Maintenance of good records.

The secondary objectives of Materials Management are:

- New materials.
- Processes and products Economic make or buy decisions.
- Standardization.
- Product improvement.

1. Relationship between Materials Management Department and other Departments

Materials Management Department plays a very important role in an organization and it must have good relationship with other departments. The departments that are mostly involved are: Production, Engineering design, Quality control, and Finance Department.

2. Materials Management Department and Production Department

The materials management department must have good relationship with production department. Materials Management is responsible for the purchase of all materials required by the production department. If the needed materials are not supplied at right time then the production process can halt and generate huge losses. So, for the smooth functioning of the production department, the materials department must be vigilant about the latest requirements.

3. Materials Management and Engineering Design Department

If both materials management and engineering design department work together then the much required innovative strategies can be formulated and implemented. Both departments can work together for standardization of materials. The suggestions of the materials management are very important for engineering department.

4. Materials Management and Quality Control Department

The selection and rejection of the materials purchased depends upon the parameters set by the quality control department. So, if both the departments have cooperation and cordial relationship then the delay in the purchasing of raw materials can be avoided.

5. Materials Management and Finance department

Usually, finance department release fund to materials department for the materials purchased. It is the responsibility of the both departments to clear payments to the suppliers smoothly, without much delay unnecessarily.

Risks to be Considered by Purchase Material Manager

The purchase and materials manager must avoid the following consequences:

- Receiving materials before they are required, causing more inventory cost and chance of deterioration in quality;
- Not receiving materials at the time of requirement, causing loss of productivity;

- Incorrect materials take off from drawing and design document;
- Subsequent design changes;
- Damage/loss of items;
- Failure on installation
- Selection of type of contract for specific material procurement;
- Vender evaluation criteria;
- Pilling up of the inventory and controlling of the same;
- Management of surplus materials; and
- Any one of the above or all of the above, or combinations.

Materials Handling

Material handling systems consist of discrete or continuous resources to move entities from one location to another. They are more common in manufacturing systems compared to service systems. Material movement occurs everywhere in a factory or warehouse— before, during, and after processing. Apple notes that material handling can account for up to 80 percent of production activity. Although material movement does not add value in the manufacturing process, half of the company's operation costs are material handling costs.

Materials Handling System Design

Therefore, keeping the material handling activity at a minimum is very important for companies.

Due to the increasing demand for a high variety of products and shorter response times in today's manufacturing industry, there is a need for highly flexible and efficient material handling systems. In the design of a material handling system, facility layout, product routings, and material flow control must be considered. In addition, various other factors must be considered in an integrated manner. The next topic describes the ten principles of material handling as developed by the Material Handling Industry of America (MHIA). It presents a guideline for selecting equipment, designing a layout, standardizing, managing, and controlling the material movement as well as the handling system.

Ten Principles of Material Handling

If material handling is designed properly, it provides an important support to the production process. Following is a list of ten principles as developed by the MHIA, which can be used as a guide for designing material handling systems.

Planning

A plan is a prescribed course of action that is defined in advance of implementation. In its simplest form, a material handing plan defines the material (what) and the moves (when and where); together, they define the method (how and who). Five key aspects must be considered in developing a plan:

1. The plan should be developed in consultation between the planner(s) and all who will use and benefit from the equipment to be employed.
2. Success in planning large-scale material handling projects generally requires a team approach involving suppliers, consultants when appropriate, and end-user specialists from management, engineering, computer and information systems, finance, and operations.
3. The material handling plan should reflect the strategic objectives of the organization, as well as the more immediate needs.
4. The plan should document existing methods and problems, physical and economic constraints, and future requirements and goals.
5. The plan should promote concurrent engineering of product, process design, process layout, and material handling methods, as opposed to independent and sequential design practices.

Standardization

Material handling methods, equipment, controls, and software should be standard- ized within the limits of achieving overall performance objectives and without sacrificing needed flexibility, modularity, and throughput. Standardization means less variety and customization in the methods and equipment employed. There are three key aspects of achieving standardization:

1. The planner should select methods and equipment that can perform a variety of tasks under a variety of operating conditions and in anticipation of changing future requirements.
2. Standardization applies to sizes of containers and other load-forming com- ponents, as well as operating procedures and equipment.
3. Standardization, flexibility, and modularity must not be incompatible.

Work

The measure of work is material handling flow (volume, weight, or count per unit of time) multiplied by the distance moved. Material handling work should be minimized without sacrificing productivity or the level of service required of the operation. Five key points are important in optimizing the work:

1. Simplifying processes by reducing, combining, shortening, or eliminating unnecessary moves will reduce work.
2. Consider each pickup and set-down— that is, placing material in and out of storage— as distinct moves and components of the distance moved.
3. Process methods, operation sequences, and process/equipment layouts should be prepared that support the work minimization objective.

4. Where possible, gravity should be used to move materials or to assist in their movement while respecting consideration of safety and the potential for product damage.
5. The shortest distance between two points is a straight line.

Ergonomics

Ergonomics is the science that seeks to adapt work or working conditions to suit the abilities of the worker. Human capabilities and limitations must be recognized and respected in the design of material handling tasks and equipment to ensure safe and effective operations. There are two key points in the ergonomic principles:

1. Equipment should be selected that eliminates repetitive and strenuous manual labor and that effectively interacts with human operators and users. The ergonomic principle embraces both physical and mental tasks.

Gravity Roller Conveyor

2. The material handling workplace and the equipment employed to assist in that work must be designed so they are safe for people.

Unit Load

A unit load is one that can be stored or moved as a single entity at one time, such as a pallet, container, or tote, regardless of the number of individual items that make up the load. Unit loads shall be appropriately sized and configured in a way that achieves the material flow and inventory objectives at each stage in the supply chain. When unit load is used in material flow, six key aspects deserve attention:

1. Less effort and work are required to collect and move many individual items as a single load than to move many items one at a time.
2. Load size and composition may change as material and products move through stages of manufacturing and the resulting distribution channels.
3. Large unit loads are common both pre- and post-manufacturing in the form of raw materials and finished goods.
4. During manufacturing, smaller unit loads, including as few as one item, yield less in-process inventory and shorter item throughput times.

5. Smaller unit loads are consistent with manufacturing strategies that embrace operating objectives such as flexibility, continuous flow, and just-in-time delivery.
6. Unit loads composed of a mix of different items are consistent with just-in-time and/or customized supply strategies as long as item selectivity is not compromised.

Space Utilization

Space in material handling is three-dimensional and therefore is counted as cubic space. Effective and efficient use must be made of all available space. This is a three-step process:

1. Eliminate cluttered and unorganized spaces and blocked aisles in work areas.
2. In storage areas, balance the objective of maximizing storage density against accessibility and selectivity. If items are going to be in the ware- house for a long time, storage density is an important consideration. Avoid honeycombing loss. If items enter and leave the warehouse frequently, their accessibility and selectivity are important. If the storage density is too high to access or select the stored product, high storage density may not be beneficial.

Consider the use of overhead space when transporting loads within a facility. Cube per order index (COI) storage policy is often used in a warehouse. COI is a storage policy in which each item is allocated ware- house space based on the ratio of its storage space requirements (its cube) to the number of storage/retrieval transactions for that item. Items are listed in a non-decreasing order of their COI ratios. The first item in the list is allocated to the required number of storage spaces that are closest to the input/output (I/O) point; the second item is allocated to the required number of storage spaces that are next closest to the I/O point, and so on. Figure shows an interactive play space in the "Ten principles of Materials Handling" CD that allows a learner to understand the fundamental concepts of the COI policy.

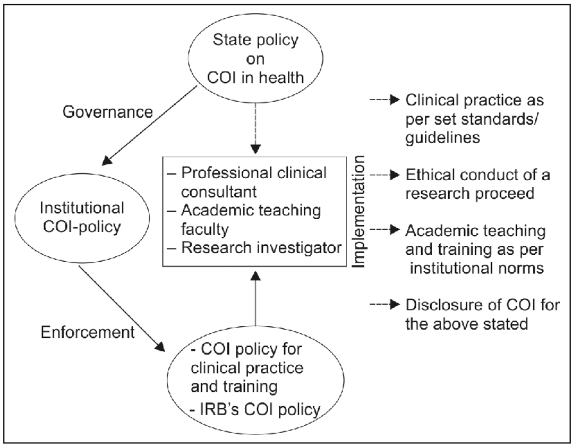
Retrieving material in blocked aisle

Honeycombing loss

System

A *system* is a collection of interacting or interdependent entities that form a unified whole. Material movement and storage activities should be fully integrated to form a coordinated operational system that spans receiving, inspection, storage, production, assembly, packaging, unitizing, order selection, shipping, transportation, and the handling of returns. Here are five key aspects of the system principle:

1. Systems integration should encompass the entire supply chain, including reverse logistics. It should include suppliers, manufacturers, distributors, and customers.
2. Inventory levels should be minimized at all stages of production and distribution, while respecting considerations of process variability and customer service.
3. Information flow and physical material flow should be integrated and treated as concurrent activities.
4. Methods should be provided for easily identifying materials and products, for determining their location and status within facilities and within the supply chain, and for controlling their movement. For instance, bar coding is the traditional method used for product identification. Radio frequency identification (RFID) uses radio waves to automatically identify objects as they move through the supply chain. The big difference between the two automatic data capture technologies is that bar coding is a line-of-sight technology. In other words, a scanner has to "see" the bar code to read it, which means people usually have to orient the bar code toward a scanner for it to be read. RFID tags can be read as long as they are within the range of a reader, even if there is no line of sight. Bar codes have other shortcomings, as well. If a label is ripped, soiled, or falls off, there is no way to scan the item. Also, standard bar codes identify only the manufacturer and product, not the unique item. The bar code on one gallon of 2 percent milk is the same as on every other gallon of the same brand, making it impossible to identify which one might pass its expiration date first. RFID can identify items individually.



Example of COI policy

5. Customer requirements and expectations regarding quantity, quality, and on-time delivery should be met without exception.

Automation

Automation is concerned with the application of electro-mechanical devices, electronics, and computer-based systems to operate and control production and service activities. It suggests the linking of multiple mechanical operations to create a system that can be controlled by programmed instructions. Material handling operations should be mechanized and automated where feasible to improve operational efficiency, increase responsiveness, improve consistency and predictability, decrease operating costs and eliminate repetitive or potentially unsafe manual labor. There are four key points in automation:

1. Preexisting processes and methods should be simplified and reengineered before any efforts at installing mechanized or automated systems.
2. Computerized material handling systems should be considered where appropriate for effective integration of material flow and information management.
3. All items expected to be handled automatically must have features that accommodate mechanized and automated handling.
4. All interface issues should be treated as critical to successful automation, including equipment to equipment, equipment to load, equipment to operator, and control communications.

Environment

Environmental consciousness stems from a desire not to waste natural resources and to predict and eliminate the possible negative effects of our daily actions on the environment. Environmental impact and energy consumption should be considered as criteria when designing or selecting alternative equipment and material handling systems. Here are the three key points:

1. Containers, pallets, and other products used to form and protect unit loads should be designed for reusability when possible and biodegradability as appropriate.
2. Systems design should accommodate the handling of spent dunnage, empty containers, and other byproducts of material handling.
3. Materials specified as hazardous have special needs with regard to spill protection, combustibility, and other risks.

Life Cycle

Life-cycle costs include all cash flows that will occur between the time the first dollar is spent to plan or procure a new piece of equipment, or to put in place a new method, until that method andr equipment is totally replaced. A thorough economic analysis should account for the entire life cycle of all material handling equipment and resulting systems. There are four key aspects:

1. Life-cycle costs include capital investment, installation, setup and equipment programming, training, system testing and acceptance, operating (labor, utilities, etc.), maintenance and repair, reuse value, and ultimate disposal.
2. A plan for preventive and predictive maintenance should be prepared for the equipment, and the estimated cost of maintenance and spare parts should be included in the economic analysis.
3. A long-range plan for replacement of the equipment when it becomes obsolete should be prepared.

4. Although measurable cost is a primary factor, it is certainly not the only factor in selecting among alternatives. Other factors of a strategic nature to the organization that form the basis for competition in the marketplace should be considered and quantified whenever possible.

These ten principles are vital to material handling system design and operation. Most are qualitative in nature and require the industrial engineer to employ these principles when designing, analyzing, and operating material handling systems.

Types of Material Handling Equipment

In this topic, we list various equipments that actually transfer materials between the multiple stages of processing. There are a number of different types of material handling devices (MHDs), most of which move materials via material handling paths on the shop floor. However, there are some MHDs—such as cranes, hoists, and overhead conveyors—that utilize the space above the machines. The choice of a specific MHD depends on a number of factors, including cost, weight, size, and volume of the loads; space availability; and types of workstations. So, in some cases the MHS interacts with the other subsystems. If we isolate MHS from other subsystems, we might get an optimal solution relative to the MHDs but one that is suboptimal for the entire system.

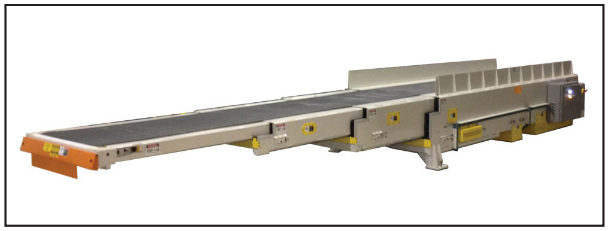
There are seven basic types of MHDs: conveyors, palletizers, trucks, robots, automated guided vehicles, hoists cranes and jibs, and warehouse material handling devices. In this topic, we will introduce the seven basic types of MHDs. In the following section, we will discuss how to choose the "right" equipment and how to operate equipment in the "right" way.

Conveyors

Conveyors are fixed-path MHDs. In other words, conveyors should be considered only when the volume of parts or material to be transported is large and when the transported material is relatively uniform in size and shape. Depending on the application, there are many types of conveyors—accumulation conveyor, belt conveyor, bucket conveyor, can conveyor, chain conveyor, chute conveyor, gravity conveyor, power and free conveyor, pneumatic or vacuum conveyor, roller conveyor, screw conveyor, slat conveyor, tow line conveyor, trolley conveyor, and wheel conveyor. Some are pictured in figure. Our list is not meant to be complete, and other variations are possible. For example, belt conveyors may be classified as troughed belt conveyors (used for transporting bulky material such as coal) and magnetic belt conveyors (used for moving ferrous material against gravitational force). For the latest product information on conveyors and other types of material handling equipment, we strongly encourage the reader to refer to recent issues of Material Handling Engineering and Modern

Conveyors used in sortation applications

Accumulation conveyor



Extendable dock conveyor

Belt conveyor

Materials Handling: These publications not only have articles illustrating use of the material handling equipment but also numerous product advertisements.

Palletizers

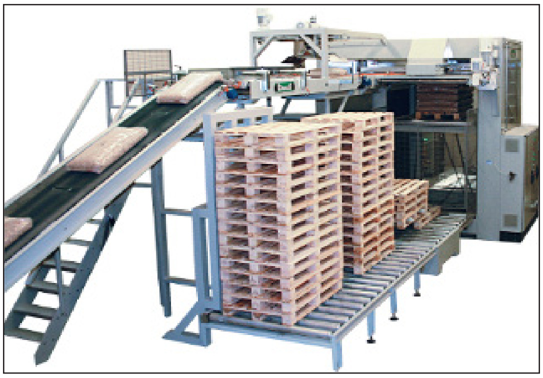
Palletizers are high-speed automated equipment used to palletize containers coming off production or assembly lines. With operator-friendly touch-screen controls, they palletize at the rate of a hundred cases per minute, palletize two lines of cases simultaneously, or simultaneously handle multiple products.

Chute and tilt-tray conveyor

Overhead conveyor used in automobile assembly plant

Trucks

Trucks are particularly useful when the material moved varies frequently in size, shape, and weight, when the volume of the parts or material moved is low, and when the number of trips required for each part is relatively small. There are several trucks in the market with different weight, cost, functionality, and other features. Hand truck, fork lift truck, pallet truck, platform truck, counter-balanced truck, tractor-trailer truck, and automated guided vehicles (AGVs) are some examples of trucks.



High-speed palletize

Robots

Robots are programmable devices that resemble the human arm. They are also capable of moving like the human arm and can perform functions such as weld, pick and place, load and unload. Some advantages of using a robot are that they can perform complex repetitive tasks automatically and they can work in hazardous and uncomfortable environments that a human operator cannot work. The disadvantage is that robots are relatively expensive.

Automated Guided Vehicles

AGVs have become very popular, especially in the past decade, and will continue to be the dominant type of MHD in the years to come. The first system was installed in 1953, and the technology continues to expand. AGVs can be regarded as a type of specially designed robots. Their paths can be controlled in a number of different ways. They can be fully automated or semi-automated. AGVs are becoming more flexible with a wider range of applications using more diverse vehicle types, load transfer techniques, guide path arrangements, controls, and control interfaces. They can also be embedded into other MHDs. A sample of AGVs and their applications are illustrated in figure.

Examples of industrial trucks

Hoists, Cranes and Jibs

These MHDs are preferred when the parts to be moved are bulky and require more space for transportation. Because the space above the machines is typically utilized only for carrying power and coolant lines, there is abundant room to transport bulky material. The movement of material in the overhead space does not affect production process and worker in a factory. The disadvantages of these MHDs are that they are expensive and time-consuming to install.

Use of robots in pick and place and welding operations

Warehouse Material Handling Devices

These are typically referred to as storage and retrieval systems. If they are automated to a high degree, they are referred to as automated storage and retrieval systems (AS/RS). The primary functions of warehouse material handling devices are to store and retrieve materials as well as transport them between the pick/deposit (P/D) stations and the storage locations of the materials. An AS/RS is shown in figure.

AS/RSs are capital-intensive systems. However, they offer a number of advantages, such as low labor and energy costs, high land or space utilization, high reliability and accuracy, and high throughput rates.

Use of AGVs in distribution and manufacturing activities

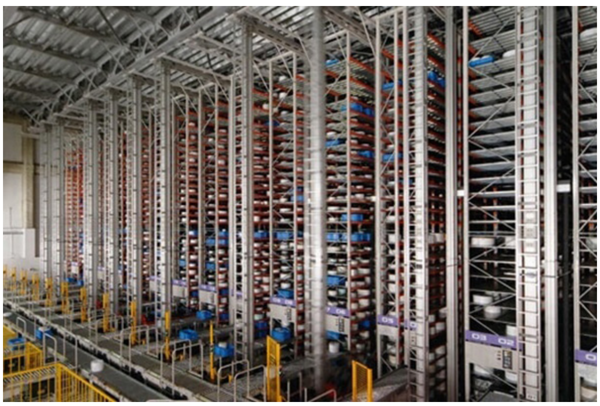
Autonomous Vehicle Storage and Retrieval System

Manual, electric, and pneumatic hoists

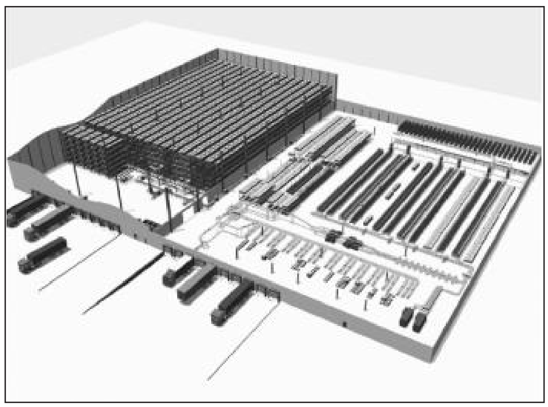
Autonomous vehicle storage and retrieval systems (AVS/RS) represent a relatively new technology for automated unit load storage systems. In this system, the autonomous vehicles function as storage/retrieval (S/R) devices. Within the storage rack, the key distinction of AVS/R systems relative to traditional crane-based automated storage and retrieval systems (AS/RS) is the movement patterns of the S/R device. In AS/RS, aisle-captive storage cranes can move in the horizontal and vertical dimensions, simultaneously to store or retrieve unit loads. In an AVS/RS, vehicles use a fixed number of lifts for vertical movement and follow rectilinear flow patterns for horizontal travel. Although the travel patterns in an AS/RS are generally more efficient within storage racks, an AVS/RS has a significant potential advantage in the adaptability of system throughput capacity to transactions demand by changing the number of vehicles operating in a fixed storage configuration. For example, decreasing the number of vehicles increases the transaction cycle times and utilization, which are also key measures of system performance.

Gantry cranes

AGV and gantry crane used for loading containers on ships



AS/RS

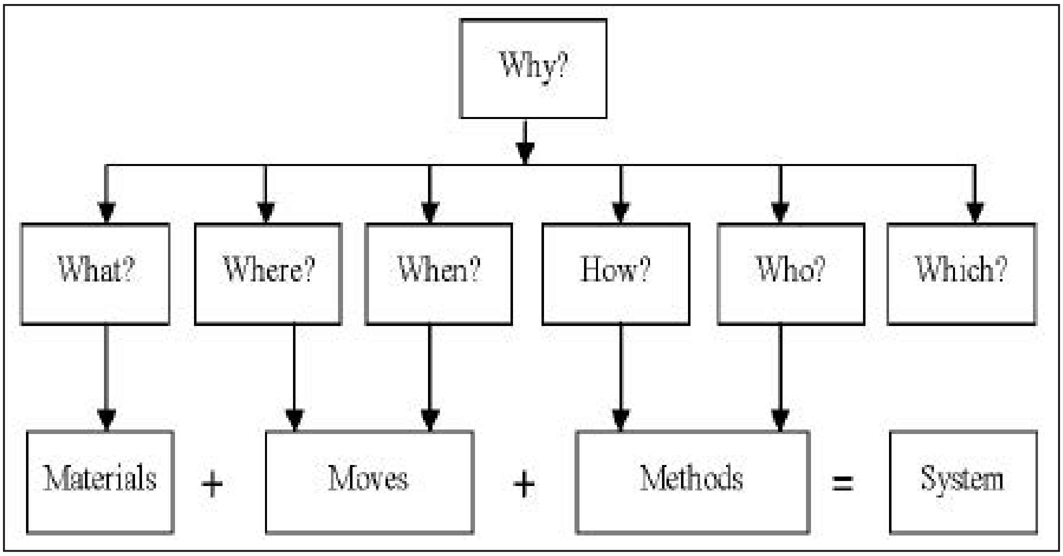


A typical AVS/RS

How to Choose the "Right" Equipment

Apple has suggested the use of the "material handling equation" in arriving at a material handling solution. The methodology illustrated in figure uses six major questions: why (select material handling equipment), what (is the material to be moved), where and when (is the move to be made), how (will the move be made), and who (will make the move). All these six questions are extremely important and should be answered satisfactorily.

The material handling equation can be specified as: Material + Move = Method, as shown in figure. Very often, when the material and move aspects are analyzed thoroughly, it automatically uncovers the appropriate material handling method. For example, analysis of the type and characteristics of material may reveal that the material is a large unit load on wooden pallets. Further analysis of the logistics, characteristics and type of move may indicate that 6 meters load/unload lift is required, distance traveled is 50 meters, and some maneuvering is required while transporting the unit load. This suggests that a fork lift truck would be a suitable material handling device. Even further analysis of the method may tell us more about the specific features of the fork lift truck. For example, narrow aisle fork lift truck, with a floor load capacity of 1/2 ton, and so on.



Material handling equation

A Multi-objective Model for Operation Allocation and Material Handling Equipment Selection in FMS Design.

From both a conceptual as well as a computational point, only a few mathematical programming models have been proposed for the material handling system selection problem. Most of the studies have focused on material handling equipment optimization, rather than the entire material handling system. Sujono and Lashkari proposed a multi-objective model for selecting MHDs and allocating material handling transactions to them in flexible manufacturing system (FMS) design. They propose a model that integrates operation allocation (OA) and MHD selection problem. Their study is an extension of the Paulo et al. and Lashkari et al. studies. The main differences from the previous models are the new definition of the variables and the introduction of a new variable that links the selection of a machine to perform manufacturing operation with the material handling requirements of that operation. In addition, they include all the costs associated with material handling operations and sub-operations, and the complete restructuring of the constraints that control the selection of the material handling equipment and their loading, in the objective function. Their model is presented as follows.

$h \in \{1,\ 2,\ldots,H\}$: major MH operations

$\hat{h} \in \{1,\ 2,\ldots,\ \hat{H}\}$: MH suboperations

$e \in\ E_{jh\hat{h}}\{1,\ 2,\ldots,E\}$: set of MH equipment that can handle the combination of MH operation/ suboperation at machine j

$j \in J_{ips}\{1,\ 2,\ldots,m\}$: set of machines that can perform operation s of part type i under process plan p

Parameters

b_j: time available on machine j
OC_{ipj}: cost of performing operation s of part type i under process plan p on machine j ($)

d_i : demand for part type i (units)
SC_j: setup cost of machine j ($)
t_{ijp}: time for performing operation s of part type i under process plan p on machine j
T_{ijhhe}: MH cost of performing the combination of MH operation/suboperation for part type i on machine j using MH equipment e ($)
L_e: time available on MH equipment e
I_{hhe}: time for MH equipment e to perform the combination of MH operation/suboperation
$\hat{W}_{it}$: relative weight of the product variable t on part type i
W_{et}: relative weight of the product variable t on MH equipment e
W_{hhe}: relative degree of capability of MH equipment e to perform the combination of MH operation/suboperation
C_{ei}: compatibility between MH equipment e and part type i

Decision Variables

$Z(ip) \in \{1,\ 0\}$: 1 if part type i uses process plan p; 0 otherwise
$Y_{sj}(ip) \in \{1,\ 0\}$: 1 if machine j performs operation s of part type i under process plan p; 0 otherwise
$A_{ijph\hat{h}} \in \{1,\ 0\}$: 1, if part type i under process plan p requires the combination of MH operation/suboperation at machine j ; 0 otherwise
$X_{ijphh\hat{e}} \in \{1,\ 0\}$: 1 if the combination of MH operation/suboperation requires MH equipment e at machine j where operation s of part type i under process plan p is performed; 0 otherwise
$M_j \in \{1,\ 0\}$: 1 if machine j is selected; 0 otherwise
$D_e \in \{1,\ 0\}$: 1 if MH equipment e is selected; 0 otherwise

The first part of the objective function is presented as equation:

$$F_1 = \sum_{i=1}^{n} d_i \sum_{p=1}^{P(i)} \sum_{s=1}^{S(ip)} \sum_{j \in J_{ips}} OC_{ipj} Y_{sj}(ip) + \sum_{j=1}^{m} SC_j M_j$$
$$+ \sum_{i=1}^{n} d_i \sum_{p=1}^{P(i)} \sum_{s=1}^{S(ip)} \sum_{j \in j_{ips}} \sum_{h=1}^{H} \sum_{\hat{h}=1}^{\hat{H}} \sum_{e \in E_{jh\hat{h}}} T_{ijh\hat{h}e} X_{ijph\hat{h}e} .$$

The second part of the objective function is formulated as equation:

$$F_2 = \sum_{e=1}^{E} \sum_{h=1}^{H} \sum_{\hat{h}=1}^{\hat{H}} W_{h\hat{h}e} \sum_{i=1}^{n} C_{ei} \sum_{p=1}^{P(i)} \sum_{s=1}^{S(ip)} \sum_{j \in J_{ips}} X_{ijph\hat{h}e}$$

Where

$$C_{ei} = 1 - \frac{\sum_{t=1}^{T} \left| W_{et} - \hat{W}_{it} \right|}{4T}.$$

Here, T = 5 and refers to the five major variables used to identify the dimensions of the characteristics mentioned by Ayres. Integer numbers are used to assign values to the subjective factors, W parameters, Wet, $W_{h\hat{h}e}$ and $\hat{W}_{it}$. The rating scales range from 0 to 5 for Wet and $W_{h\hat{h}e}$ and 1 to 5 for $\hat{W}_{it}$. A 5 for Wet means that the piece of equipment is best suited to handle parts with a very high rating of product variable t. A 0 means, do not allow this piece of equipment to handle parts with product variable t. A 5 for $W_{h\hat{h}e}$ means that it is excellent in performing the operation/suboperation combination. And a 0 means that it is incapable of performing the operation/suboperation combination. A 5 for $\hat{W}_{it}$ means that the part type exhibits a very high level of the key product variable t. And a 0 means that the part type exhibits a very low level of the key product variable t.

The first part of objective function's three terms indicates the manufacturing operation costs, the machine setup costs, and the MH operation costs, respectively. The second part of the objective function computes the overall compatibility of the MH equipment. As a result, the formulation of the problem is a multi-objective model seeking to strike a balance between the two objectives. There are nine constraints in this model:

1. Each part type can use only one process plan:

$$\sum_{p=1}^{P(i)} Z(ip) = 1 \quad \forall i.$$

2. For a given part type i under process plan p, each operation of the selected process plan is assigned to only one of the available machines:

$$\sum_{j \in J_{ips}} Y_{sj}(ip) = Z(ip) \quad \forall i, p, s.$$

3. Once a machine is selected for operation s of part type i under process plan p, then all the ($h\hat{h}$) combinations corresponding to (sj) must be performed:

$$Y_{sj}(ip) = A_{sjh\hat{h}}(ip) \quad \forall i, p, s, j, h, \hat{h}.$$

4. Each $h\hat{h}$ combination can be assigned to only piece of available and capable MH equipment:

$$\sum_{e \in E_{jh\hat{h}}} X_{ijph\hat{h}e} = A_{ijph\hat{h}} \quad \forall i, p, s, j, h, \hat{h}.$$

5. At least one operation must be allocated to a selected machine:

$$\sum_{i=1}^{n} \sum_{p=1}^{P(i)} \sum_{s=1}^{S(ip)} \sum_{h=1}^{H} \sum_{\hat{h}=1}^{\hat{H}} \sum_{e \in E_{jh\hat{h}}} X_{ijph\hat{h}e} \geq M_j \quad \forall_j.$$

6. The allocated operations cannot exceed the corresponding machine's capacity:

$$\sum_{i=1}^{n} d_i \sum_{p=1}^{P(i)} \sum_{s=1}^{S(ip)} \sum_{h=1}^{H} \sum_{\hat{h}=1}^{\hat{H}} \sum_{e \in E_{jh\hat{h}}} t_{sj}(ip) X_{ijph\hat{h}e} \leq b_j M_j \quad \forall_j.$$

7. A specific MH equipment can be selected only if the corresponding type of equipment is selected:

$$De \leq D\hat{e} \quad \forall e,\ e.$$

8. Each MH equipment selected must perform at least one operation:

$$\sum_{i-1}^{n}\sum_{h=1}^{H}\sum_{\hat{h}=1}^{\hat{H}}\sum_{p=1}^{P(i)}\sum_{s=1}^{S(ip)}\sum_{j\in J_{ips}} X_{ijph\hat{h}e} \geq De \quad \forall e.$$

9. The MH equipment capacity cannot be exceeded:

$$\sum_{i-1}^{n} d_i \sum_{h=1}^{H}\sum_{\hat{h}=1}^{\hat{H}}\sum_{p=1}^{P(i)}\sum_{s=1}^{S(ip)}\sum_{j\in J_{ips}} X_{ijph\hat{h}e} \geq De \quad \forall e.$$

Warehousing

Many manufacturing and distribution companies maintain large warehouses to store in-process inventories or components received from an external supplier. They are involved in various stages of the sourcing, production, and distribution of goods, from raw materials through the finished goods. The true value of warehousing lies in having the right product in the right place at the right time. Thus, warehousing provides the time-and-place utility necessary for a company and is often one of the most costly elements. Therefore, its successful management is critical.

Just-in-Time (JIT) Manufacturing

It has been argued that warehousing is a time-consuming and non–value-adding activity. Because additional paperwork and time are required to store items in storage spaces and retrieve them later when needed, the JIT manufacturing philosophy suggests that one should do away with any kind of temporary storage and maintain a pull strategy in which items are produced only as and when they are required. That is, they should be produced at a certain stage of manufacturing, only if they are required at the next stage.

JIT philosophy requires that the same approach be taken toward components received from suppliers. The supplier is considered as another (previous) stage in manufacturing. However, in practice, because the demand is continuous, that means that goods need to be always pulled through the supply chain to respond to demand quickly. The handling of returned goods is becoming increasingly important (e.g., Internet shopping may increase the handling of returned goods), and due to the uncertainty inherent in the supply chain, it is not possible to completely do away with temporary storage.

Warehouse Functions

Every warehouse should be designed to meet the specific requirements of the supply chain of which it is a part. In many cases, the need to provide better service to customers and be responsive to their needs appears to be the primary reason. Nevertheless, there are certain operations that are common to most warehouses:

- Temporarily store goods: To achieve economies of scale in production, transportation, and handling of goods, it is often necessary to store goods in warehouses and release them to customers as and when the demand occurs.
- Put together customer orders: Goods are received from order picking stock in the required quantities and at the required time to the warehouse to meet customer orders. For example, goods can be received from suppliers as whole pallet quantities, but are ordered by customers in less than pallet quantities.
- Serve as a customer service facility: In some cases, warehouses ship goods to customers and therefore are in direct contact with them. So, a warehouse can serve as a customer service facility and handle replacement of damaged or faulty goods, conduct market surveys, and even provide after sales service. For example, many Korean electronic goods manufacturers let warehouses handle repair and do after sales service in North America.
- Protect goods: Sometimes manufactured goods are stored in warehouses to protect them against theft, fire, floods, and weather elements because warehouses are generally secure and well equipped.
- Segregate hazardous or contaminated materials: Safety codes may not allow storage of hazardous materials near the manufacturing plant. Because no manufacturing takes place in a warehouse, this may be an ideal place to segregate and store hazardous and contaminated materials.
- Perform value-added services: In many warehouses after picking, goods are brought together and consolidated as completed orders ready to be dispatched to customers. This can involve packing into dispatch outer cases and cartons, and stretch- and shrink- wrapping for load protection and stability, inspecting, and testing. Here, inspection and testing do not add value to the product. However, we have included them because they may be a necessary function because of company policy or federal regulations.
- Store seasonal inventory: It is always difficult to forecast product demand accurately in many businesses. Therefore, it may be important to carry inventory and safety stocks to meet unexpected surges in demand. Some companies that produce seasonal products—for example, lawn mowers and snow throwers—may have excess inventory left over at the end of the season and have to store the unsold items in a warehouse.

A typical warehouse consists of two main elements:

1. Storage medium
2. Material handling system

In addition, there is a building that encloses the storage medium, goods, and the S/R system. Because the main purpose of the building is to protect its contents from theft and weather elements, it is made of strong, lightweight material. So, warehouses come in different shapes, sizes, and heights, depending on a number of factors, including the kind of goods stored inside, volume, type of S/R systems used. For example, the Nike warehouse in Laakdal, Belgium, covers a total area of

1 million square feet. Its high-bay storage is almost 100 feet in height, occupies roughly half of the total warehouse space, and is served by 26 man-aboard stacker cranes.

Inverse Storage

There is limited landfill space available for dumping wastes created throughout the supply chain. And the increasing cost of landfills, environmental laws and regulation, and the economic viability of environmental strategies are pushing manufacturers nowadays to consider reverse supply chain—also known as reverse logistics —management.

Manufacturers now must take full responsibility for their products through the product's life cycle, or they may be subject to legal action. For example, new laws regarding the disposal of motor or engine oil, vehicle batteries, and tires place the disposal responsibility on the manufacturer once these products have passed their useful life. Many manufacturers also realize that reverse logistics offers the opportunity to recycle and reuse product components and reduce the cost and the amount of waste. Therefore, manufacturers are developing disposition stocking areas and collecting used or expired original products from the customer and reshipping to their stocking places. For example, Kodak's single-use camera has a remarkable success story involving the inverse logistics philosophy. The products are collected in a stocking place to be remanufactured. In the United States, 63 percent return rate has been achieved for recycling.

Supply Chain Management

Supply chain management (SCM) is the management of a network of interconnected businesses involved in the provision of product and service packages required by the end customers in a supply chain. Supply chain management spans all movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption.

Another definition is provided by the APICS Dictionary when it defines SCM as the "design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally."

Origin of the Supply Chain Management

The term "supply chain management" entered the public domain when Keith Oliver, a consultant at Booz Allen Hamilton, used it in an interview for the Financial Times in 1982. The term was slow to take hold and the lexicon was slow to change. It gained currency in the mid-1990s, when a flurry of articles and books came out on the subject. In the late 1990s it rose to prominence as a management buzzword, and operations managers began to use it in their titles with increasing regularity.

Common and accepted definitions of supply chain management are:

- Managing upstream and downstream value added flow of materials, final goods and related information among suppliers; company; resellers; final consumers is supply chain management.
- Supply chain management is the systematic, strategic coordination of the traditional

business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole.

- A customer focused definition is given by Hines "Supply chain strategies require a total systems view of the linkages in the chain that work together efficiently to create customer satisfaction at the end point of delivery to the consumer. As a consequence costs must be lowered throughout the chain by driving out unnecessary costs and focusing attention on adding value. Throughput efficiency must be increased, bottlenecks removed and performance measurement must focus on total systems efficiency and equitable reward distribution to those in the supply chain adding value. The supply chain system must be responsive to customer requirements."
- Global supply chain forum - supply chain management is the integration of key business processes across the supply chain for the purpose of creating value for customers and stakeholders.
- According to the Council of Supply Chain Management Professionals (CSCMP), supply chain management encompasses the planning and management of all activities involved in sourcing, procurement, conversion, and logistics management. It also includes the crucial components of coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. More recently, the loosely coupled, self-organizing network of businesses that cooperate to provide product and service offerings has been called the *Extended Enterprise*.
- A supply chain, as opposed to supply chain management, is a set of organizations directly linked by one or more of the upstream and downstream flows of products, services, finances, and information from a source to a customer. Managing a supply chain is 'supply chain management'.
- Supply chain management software includes tools or modules used to execute supply chain transactions, manage supplier relationships and control associated business processes.
- Supply chain event management (abbreviated as SCEM) is a consideration of all possible events and factors that can disrupt a supply chain. With SCEM possible scenarios can be created and solutions devised.

In many cases the supply chain includes the collection of goods after consumer use for recycling. Including 3PL or other gathering agencies as part of the RM re-patriation process is a way of illustrating the new end-game strategy.

Problems Addressed

Supply chain management must address the following problems:

- Distribution Network Configuration: number, location and network missions of suppliers, production facilities, distribution centers, warehouses, cross-docks and customers.
- Distribution Strategy: questions of operating control (centralized, decentralized or shared); delivery scheme, e.g., direct shipment, pool point shipping, cross docking, direct store

delivery (DSD), closed loop shipping; mode of transportation, e.g., motor carrier, including truckload, Less than truckload (LTL), parcel; railroad; intermodal transport, including trailer on flatcar (TOFC) and container on flatcar (COFC); ocean freight; airfreight; replenishment strategy (e.g., pull, push or hybrid); and transportation control (e.g., owner-operated, private carrier, common carrier, contract carrier, or third-party logistics (3PL)).

- Trade-offs in Logistical Activities: The above activities must be well coordinated in order to achieve the lowest total logistics cost. Trade-offs may increase the total cost if only one of the activities is optimized. For example, full truckload (FTL) rates are more economical on a cost per pallet basis than LTL shipments. If, however, a full truckload of a product is ordered to reduce transportation costs, there will be an increase in inventory holding costs which may increase total logistics costs. It is therefore imperative to take a systems approach when planning logistical activities. These trades-offs are key to developing the most efficient and effective Logistics and SCM strategy.
- Information: Integration of processes through the supply chain to share valuable information, including demand signals, forecasts, inventory, transportation, potential collaboration, etc.
- Inventory Management: Quantity and location of inventory, including raw materials, work-in-process (WIP) and finished goods.
- Cash-flow: Arranging the payment terms and methodologies for exchanging funds across entities within the supply chain.

Supply chain execution means managing and coordinating the movement of materials, information and funds across the supply chain. The flow is bi-directional.

Activities or Functions

Supply chain management is a cross-function approach including managing the movement of raw materials into an organization, certain aspects of the internal processing of materials into finished goods, and the movement of finished goods out of the organization and toward the end-consumer. As organizations strive to focus on core competencies and becoming more flexible, they reduce their ownership of raw materials sources and distribution channels. These functions are increasingly being outsourced to other entities that can perform the activities better or more cost effectively. The effect is to increase the number of organizations involved in satisfying customer demand, while reducing management control of daily logistics operations. Less control and more supply chain partners led to the creation of supply chain management concepts. The purpose of supply chain management is to improve trust and collaboration among supply chain partners, thus improving inventory visibility and the velocity of inventory movement.

Several models have been proposed for understanding the activities required to manage material movements across organizational and functional boundaries. SCOR is a supply chain management model promoted by the Supply Chain Council. Another model is the SCM Model proposed by the Global Supply Chain Forum (GSCF). Supply chain activities can be grouped into strategic, tactical, and operational levels. The CSCMP has adopted The American Productivity & Quality Center (APQC) Process Classification Framework a high-level, industry-neutral enterprise process model that allows organizations to see their business processes from a cross-industry viewpoint.

Strategic Level

- Strategic network optimization, including the number, location, and size of warehousing, distribution centers, and facilities.
- Strategic partnerships with suppliers, distributors, and customers, creating communication channels for critical information and operational improvements such as cross docking, direct shipping, and third-party logistics.
- Product life cycle management, so that new and existing products can be optimally integrated into the supply chain and capacity management activities.
- Segmentation of products and customers to guide alignment of corporate objectives with manufacturing and distribution strategy.
- Information technology chain operations.
- Where-to-make and make-buy decisions.
- Aligning overall organizational strategy with supply strategy.
- It is for long term and needs resource commitment.

Tactical Level

- Sourcing contracts and other purchasing decisions.
- Production decisions, including contracting, scheduling, and planning process definition.
- Inventory decisions, including quantity, location, and quality of inventory.
- Transportation strategy, including frequency, routes, and contracting.
- Benchmarking of all operations against competitors and implementation of best practices throughout the enterprise.
- Milestone payments.
- Focus on customer demand and Habits.

Operational Level

- Daily production and distribution planning, including all nodes in the supply chain.
- Production scheduling for each manufacturing facility in the supply chain (minute by minute).
- Demand planning and forecasting, coordinating the demand forecast of all customers and sharing the forecast with all suppliers.
- Sourcing planning, including current inventory and forecast demand, in collaboration with all suppliers.
- Inbound operations, including transportation from suppliers and receiving inventory.
- Production operations, including the consumption of materials and flow of finished goods.

- Outbound operations, including all fulfillment activities, warehousing and transportation to customers.
- Order promising, accounting for all constraints in the supply chain, including all suppliers, manufacturing facilities, distribution centers, and other customers.
- From production level to supply level accounting all transit damage cases & arrange to settlement at customer level by maintaining company loss through insurance company.
- Managing non-moving, short-dated inventory and avoiding more products to go short-dated.

Importance

Organizations increasingly find that they must rely on effective supply chains, or networks, to compete in the global market and networked economy. In Peter Drucker's new management paradigms, this concept of business relationships extends beyond traditional enterprise boundaries and seeks to organize entire business processes throughout a value chain of multiple companies.

During the past decades, globalization, outsourcing and information technology have enabled many organizations, such as Dell and Hewlett Packard, to successfully operate solid collaborative supply networks in which each specialized business partner focuses on only a few key strategic activities. This inter-organizational supply network can be acknowledged as a new form of organization. However, with the complicated interactions among the players, the network structure fits neither "market" nor "hierarchy" categories. It is not clear what kind of performance impacts different supply network structures could have on firms, and little is known about the coordination conditions and trade-offs that may exist among the players. From a systems perspective, a complex network structure can be decomposed into individual component firms. Traditionally, companies in a supply network concentrate on the inputs and outputs of the processes, with little concern for the internal management working of other individual players. Therefore, the choice of an internal management control structure is known to impact local firm performance.

In the 21st century, changes in the business environment have contributed to the development of supply chain networks. First, as an outcome of globalization and the proliferation of multinational companies, joint ventures, strategic alliances and business partnerships, significant success factors were identified, complementing the earlier "Just-In-Time", Lean Manufacturing and Agile manufacturing practices. Second, technological changes, particularly the dramatic fall in information communication costs, which are a significant component of transaction costs, have led to changes in coordination among the members of the supply chain network.

Many researchers have recognized these kinds of supply network structures as a new organization form, using terms such as "Keiretsu", "Extended Enterprise", "Virtual Corporation", "Global Production Network", and "Next Generation Manufacturing System". In general, such a structure can be defined as "a group of semi-independent organizations, each with their capabilities, which collaborate in ever-changing constellations to serve one or more markets in order to achieve some business goal specific to that collaboration".

Historical Developments

Six major movements can be observed in the evolution of supply chain management studies: Creation, Integration, and Globalization, Specialization Phases One and Two, and SCM 2.0.

Creation Era

The term supply chain management was first coined by Keith Oliver in 1982. However, the concept of a supply chain in management was of great importance long before, in the early 20th century, especially with the creation of the assembly line. The characteristics of this era of supply chain management include the need for large-scale changes, re-engineering, downsizing driven by cost reduction programs, and widespread attention to the Japanese practice of management.

Integration Era

This era of supply chain management studies was highlighted with the development of Electronic Data Interchange (EDI) systems in the 1960s and developed through the 1990s by the introduction of Enterprise Resource Planning (ERP) systems. This era has continued to develop into the 21st century with the expansion of internet-based collaborative systems. This era of supply chain evolution is characterized by both increasing value-adding and cost reductions through integration.

In fact a supply chain can be classified as a Stage 1, 2 or 3 networks. In stage 1 type supply chain, various systems such as Make, Storage, Distribution, Material control, etc. are not linked and are independent of each other. In a stage 2 supply chain, this are integrated under one plan and is ERP enabled. A stage 3 supply chain is one in which vertical integration with the suppliers in upstream direction and customers in downstream direction are achieved. An example of this kind of supply chain is Tesco.

Globalization Era

The third movement of supply chain management development, the globalization era, can be characterized by the attention given to global systems of supplier relationships and the expansion of supply chains over national boundaries and into other continents. Although the use of global sources in the supply chain of organizations can be traced back several decades (e.g., in the oil industry), it was not until the late 1980s that a considerable number of organizations started to integrate global sources into their core business. This era is characterized by the globalization of supply chain management in organizations with the goal of increasing their competitive advantage, value-adding, and reducing costs through global sourcing. However it was not until the late 1980s that a considerable number of organizations started to integrate global sources into their core business.

1. Specialization Era (Phase I): Outsourced Manufacturing and Distribution:

In the 1990s, industries began to focus on "core competencies" and adopted a specialization model. Companies abandoned vertical integration, sold off non-core operations, and outsourced those functions to other companies. This changed management requirements by extending the supply chain well beyond company walls and distributing management across specialized supply chain partnerships.

This transition also re-focused the fundamental perspectives of each respective organization. OEMs became brand owners that needed deep visibility into their supply base. They had to control the entire supply chain from above instead of from within. Contract manufacturers had to manage bills of material with different part numbering schemes from multiple OEMs and support customer requests for work -in-process visibility and vendor-managed inventory (VMI).

The specialization model creates manufacturing and distribution networks composed of multiple, individual supply chains specific to products, suppliers, and customers who work together to design, manufacture, distribute, market,

sell, and service a product. The set of partners may change according to a given market, region, or channel, resulting in a proliferation of trading partner environments, each with its own unique characteristics and demands.

2. Specialization Era (Phase II): Supply Chain Management as a Service:

Specialization within the supply chain began in the 1980s with the inception of transportation brokerages, warehouse management, and non-asset-based carriers and has matured beyond transportation and logistics into aspects of supply planning, collaboration, execution and performance management.

At any given moment, market forces could demand changes from suppliers, logistics providers, locations and customers, and from any number of these specialized participants as components of supply chain networks. This variability has significant effects on the supply chain infrastructure, from the foundation layers of establishing and managing the electronic communication between the trading partners to more complex requirements including the configuration of the processes and work flows that are essential to the management of the network itself.

Supply chain specialization enables companies to improve their overall competencies in the same way that outsourced manufacturing and distribution has done; it allows them to focus on their core competencies and assemble networks of specific, best-in-class partners to contribute to the overall value chain itself, thereby increasing overall performance and efficiency. The ability to quickly obtain and deploy this domain-specific supply chain expertise without developing and maintaining an entirely unique and complex competency in house is the leading reason why supply chain specialization is gaining popularity.

Outsourced technology hosting for supply chain solutions debuted in the late 1990s and has taken root primarily in transportation and collaboration categories. This has progressed from the Application Service Provider (ASP) model from approximately 1998 through 2003 to the On-Demand model from approximately 2003-2006 to the Software as a Service (SaaS) model currently in focus today.

Supply Chain Management 2.0 (SCM 2.0)

Building on globalization and specialization, the term SCM 2.0 has been coined to describe both the changes within the supply chain itself as well as the evolution of the processes, methods and tools that manage it in this new “era”.

Web 2.0 is defined as a trend in the use of the World Wide Web that is meant to increase creativity, information sharing, and collaboration among users. At its core, the common attribute that Web 2.0 brings is to help navigate the vast amount of information available on the Web in order to find what is being sought. It is the notion of a usable pathway. SCM 2.0 follows this notion into supply chain operations. It is the pathway to SCM results, a combination of the processes, methodologies, tools and delivery options to guide companies to their results quickly as the complexity and speed of the supply chain increase due to the effects of global competition, rapid price fluctuations, surging oil prices, short product life cycles, expanded specialization, near-/far- and off-shoring, and talent scarcity.

SCM 2.0 leverages proven solutions designed to rapidly deliver results with the agility to quickly manage future change for continuous flexibility, value and success. This is delivered through competency networks composed of best-of-breed supply chain domain expertise to understand which elements, both operationally and organizationally, are the critical few that deliver the results as well as through intimate understanding of how to manage these elements to achieve desired results. Finally, the solutions are delivered in a variety of options, such as no-touch via business process outsourcing, mid-touch via managed services and software as a service (SaaS), or high touch in the traditional software deployment model.

Business Process Integration

Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes. An example scenario: the purchasing department places orders as requirements become known. The marketing department, responding to customer demand, communicates with several distributors and retailers as it attempts to determine ways to satisfy this demand. Information shared between supply chains partners can only be fully leveraged through process integration.

Supply chain business process integration involves collaborative work between buyers and suppliers, joint product development, common systems and shared information. According to Lambert and Cooper, operating an integrated supply chain requires a continuous information flow. However, in many companies, management has reached the conclusion that optimizing the product flows cannot be accomplished without implementing a process approach to the business. The key supply chain processes stated by Lambert are:

- Customer relationship management
- Customer service management
- Demand management style
- Order fulfillment
- Manufacturing flow management
- Supplier relationship management
- Product development and commercialization
- Returns management

Much has been written about demand management. Best-in-Class companies have similar characteristics, which include the following: a) Internal and external collaboration b) Lead time reduction initiatives c) Tighter feedback from customer and market demand d) Customer level forecasting

One could suggest other key critical supply business processes which combine these processes stated by Lambert such as:

- Customer service management

- Procurement
- Product development and commercialization
- Manufacturing flow management/support
- Physical distribution
- Outsourcing/partnerships
- Performance measurement
- Warehousing management

Customer Service Management Process

Customer Relationship Management concerns the relationship between the organization and its customers. Customer service is the source of customer information. It also provides the customer with real-time information on scheduling and product availability through interfaces with the company's production and distribution operations. Successful organizations use the following steps to build customer relationships:

- Determine mutually satisfying goals for organization and customers.
- Establish and maintain customer rapport.
- Produce positive feelings in the organization and the customers.

Procurement Process

Strategic plans are drawn up with suppliers to support the manufacturing flow management process and the development of new products. In firms where operations extend globally, sourcing should be managed on a global basis. The desired outcome is a win-win relationship where both parties benefit, and a reduction in time required for the design cycle and product development. Also, the purchasing function develops rapid communication systems, such as electronic data interchange (EDI) and Internet linkage to convey possible requirements more rapidly. Activities related to obtaining products and materials from outside suppliers involve resource planning, supply sourcing, negotiation, order placement, inbound transportation, storage, handling and quality assurance, many of which include the responsibility to coordinate with suppliers on matters of scheduling, supply continuity, hedging, and research into new sources or programs.

Product Development and Commercialization

Here, customers and suppliers must be integrated into the product development process in order to reduce time to market. As product life cycles shorten, the appropriate products must be developed and successfully launched with ever shorter time-schedules to remain competitive. According to Lambert and Cooper, managers of the product development and commercialization process must:

1. Coordinate with customer relationship management to identify customer-articulated needs;

2. Select materials and suppliers in conjunction with procurement;
3. Develop production technology in manufacturing flow to manufacture and integrate into the best supply chain flow for the product/market combination.

Manufacturing Flow Management Process

The manufacturing process produces and supplies products to the distribution channels based on past forecasts. Manufacturing processes must be flexible to respond to market changes and must accommodate mass customization. Orders are processes operating on a just-in-time (JIT) basis in minimum lot sizes. Also, changes in the manufacturing flow process lead to shorter cycle times, meaning improved responsiveness and efficiency in meeting customer demand. Activities related to planning, scheduling and supporting manufacturing operations, such as work-in-process storage, handling, transportation, and time phasing of components, inventory at manufacturing sites and maximum flexibility in the coordination of geographic and final assemblies postponement of physical distribution operations.

Physical Distribution

This concerns movement of a finished product/service to customers. In physical distribution, the customer is the final destination of a marketing channel, and the availability of the product/service is a vital part of each channel participant's marketing effort. It is also through the physical distribution process that the time and space of customer service become an integral part of marketing, thus it links a marketing channel with its customers (e.g., links manufacturers, wholesalers, retailers).

Outsourcing or Partnerships

This is not just outsourcing the procurement of materials and components, but also outsourcing of services that traditionally have been provided in-house. The logic of this trend is that the company will increasingly focus on those activities in the value chain where it has a distinctive advantage, and outsource everything else. This movement has been particularly evident in logistics where the provision of transport, warehousing and inventory control is increasingly subcontracted to specialists or logistics partners. Also, managing and controlling this network of partners and suppliers requires a blend of both central and local involvement. Hence, strategic decisions need to be taken centrally, with the monitoring and control of supplier performance and day-to-day liaison with logistics partners being best managed at a local level.

Performance Measurement

Experts found a strong relationship from the largest arcs of supplier and customer integration to market share and profitability. Taking advantage of supplier capabilities and emphasizing a long-term supply chain perspective in customer relationships can both be correlated with firm performance. As logistics competency becomes a more critical factor in creating and maintaining competitive advantage, logistics measurement becomes increasingly important because the difference between profitable and unprofitable operations becomes more narrow. A.T Kearney Consultants noted that firms engaging in comprehensive performance measurement realized improvements in overall productivity. According to experts, internal measures are generally collected and analyzed by the firm including:

1. Cost
2. Customer Service
3. Productivity measures
4. Asset measurement
5. Quality

External performance measurement is examined through customer perception measures and "best practice" benchmarking, and includes 1) customer perception measurement, and 2) best practice benchmarking.

Warehousing Management

As a case of reducing company cost & expenses, warehousing management is carrying the valuable role against operations. In case of perfect storing & office with all convenient facilities in company level, reducing manpower cost, dispatching authority with on time delivery, loading & unloading facilities with proper area, area for service station, stock management system etc.

Components of supply chain management are as follows:

1. Standardization
2. Postponement
3. Customization

Theories

Currently there is a gap in the literature available on supply chain management studies: there is no theoretical support for explaining the existence and the boundaries of supply chain management. A few authors such as Halldorsson, et al., Ketchen and Hult and Lavassani, et al. have tried to provide theoretical foundations for different areas related to supply chain by employing organizational theories. These theories include:

- Resource-based view (RBV)
- Transaction Cost Analysis (TCA)
- Knowledge-Based View (KBV)
- Strategic Choice Theory (SCT)
- Agency Theory (AT)
- Institutional theory (InT)
- Systems Theory (ST)

- Network Perspective (NP)
- Materials Logistics Management (MLM)
- Just-in-Time (JIT)
- Material Requirements Planning (MRP)
- Theory of Constraints (TOC)
- Performance Information Procurement Systems (PIPS)
- Performance Information Risk Management System (PIRMS)
- Total Quality Management (TQM)
- Agile Manufacturing
- Time Based Competition (TBC)
- Quick Response Manufacturing (QRM)
- Customer Relationship Management (CRM)
- Requirements Chain Management (RCM)
- Available-to-promise (ATP)

However, the unit of analysis of most of these theories is not the system "supply chain", but another system such as the "firm" or the "supplier/buyer relationship". Among the few exceptions is the relational view, which outlines a theory for considering dyads and networks of firms as a key unit of analysis for explaining superior individual firm performance.

Supply Chain Centroids

In the study of supply chain management, the concept of centroids has become an important economic consideration. A centroid is a place that has a high proportion of a country's population and a high proportion of its manufacturing, generally within 500 mi (805 km). In the U.S., two major supply chain centroids have been defined, one near Dayton, Ohio and a second near Riverside, California.

The centroid near Dayton is particularly important because it is closest to the population center of the US and Canada. Dayton is within 500 miles of 60% of the population and manufacturing capacity of the U.S., as well as 60 percent of Canada's population. The region includes the Interstate 70/75 interchange, which is one of the busiest in the nation with 154,000 vehicles passing through in a day. Of those, anywhere between 30 percent and 35 percent are trucks hauling goods. In addition, the I-75 corridor is home to the busiest north-south rail route east of the Mississippi.

Tax Efficient Supply Chain Management

Tax efficient supply chain management is a business model which considers the effect of tax in design and implementation of supply chain management. As the consequence of globalization, businesses which are cross-national should pay different tax rates in different countries. Due to the differences, global players have the opportunity to calculate and optimize supply chain based on tax efficiency legally. It is used as a method of gaining more profit for company which owns global supply chain.

Supply Chain Sustainability

Supply chain sustainability is a business issue affecting an organization's supply chain or logistics network and is frequently quantified by comparison with SECH ratings. SECH ratings are defined as *social, ethical, cultural and health* footprints. Consumers have become more aware of the environmental impact of their purchases and companies' SECH ratings and, along with non-governmental organizations (NGOs), are setting the agenda for transitions to organically-grown foods, anti-sweatshop labor codes and locally-produced goods that support independent and small businesses. Because supply chains frequently account for over 75% of a company's carbon footprint many organizations are exploring how they can reduce this and thus improve their SECH rating.

For example, in July, 2009 the U.S. based Wal-Mart corporation announced its intentions to create a global sustainability index that would rate products according to the environmental and social impact made while the products were manufactured and distributed. The sustainability rating index is intended to create environmental accountability in Wal-Mart's supply chain, and provide the motivation and infrastructure for other retail industry companies to do the same.

More recently, the US Dodd-Frank Wall Street Reform and Consumer Protection Act signed into law by President Obama in July 2010 contained a supply chain sustainability provision in the form of the Conflict Minerals law. This law requires SEC-regulated companies to conduct third party audits of the company supply chains, determine whether any tin, tantalum, tungsten or gold (together referred to as *conflict minerals*) is made of ore mined/sourced from the Democratic Republic of the Congo (DRC), and create a report (available to the general public and SEC) detailing the supply chain due diligence efforts undertaken and the results of the audit. Of course, the chain of suppliers/vendors to these reporting companies will be expected to provide appropriate supporting information.

Components

Management Components

The SCM components are the third element of the four-square circulation framework. The level of integration and management of a business process link is a function of the number and level, ranging from low to high, of components added to the link. Consequently, adding more management components or increasing the level of each component can increase the level of integration of the business process link. The literature on business process re-engineering, buyer-supplier relationships, and SCM suggests various possible components that must receive managerial attention when managing supply relationships. Lambert and Cooper identified the following components:

- Planning and control
- Work structure
- Organization structure

- Product flow facility structure
- Information flow facility structure
- Management methods
- Power and leadership structure
- Risk and reward structure
- Culture and attitude

However, a more careful examination of the existing literature leads to a more comprehensive understanding of what should be the key critical supply chain components, the "branches" of the previous identified supply chain business processes, that is, what kind of relationship the components may have that are related to suppliers and customers. Bowersox and Closs states that the emphasis on cooperation represents the synergism leading to the highest level of joint achievement. A primary level channel participant is a business that is willing to participate in the inventory ownership responsibility or assume other aspects of financial risk, thus including primary level components. A secondary level participant (specialized) is a business that participates in channel relationships by performing essential services for primary participants, including secondary level components, which support primary participants. Third level channel participants and components that support the primary level channel participants and are the fundamental branches of the secondary level components may also be included.

Consequently, Lambert and Cooper's framework of supply chain components does not lead to any conclusion about what are the primary or secondary (specialized) level supply chain components. That is, what supply chain components should be viewed as primary or secondary, how should these components be structured in order to have a more comprehensive supply chain structure, and how to examine the supply chain as an integrative one.

Reverse Supply Chain

Reverse logistics is the process of managing the return of goods. Reverse logistics is also referred to as "Aftermarket Customer Services". In other words, anytime money is taken from a company's warranty reserve or service logistics budget one can speak of a reverse logistics operation.

Systems and Value

Supply chain systems configure value for those that organize the networks. Value is the additional revenue over and above the costs of building the network. Co-creating value and sharing the benefits appropriately to encourage effective participation is a key challenge for any supply system. Tony Hines defines value as follows: "Ultimately it is the customer who pays the price for service delivered that confirms value and not the producer who simply adds cost until that point."

Global Applications

Global supply chains pose challenges regarding both quantity and value:

- Globalization.

- Increased cross border sourcing.
- Collaboration for parts of value chain with low-cost providers.
- Shared service centers for logistical and administrative functions.
- Increasingly global operations, which require increasingly global coordination and planning to achieve global optimums.
- Complex problems involve also midsized companies to an increasing degree.

These trends have many benefits for manufacturers because they make possible larger lot sizes, lower taxes, and better environments (culture, infrastructure, special tax zones, sophisticated OEM) for their products. Meanwhile, on top of the problems recognized in supply chain management, there will be many more challenges when the scope of supply chains is global. This is because with a supply chain of a larger scope, the lead time is much longer. Furthermore, there are more issues involved such as multi-currencies, different policies and different laws. The consequent problems include:

1. Different currencies and valuations in different countries;
2. Different tax laws (tax efficient supply chain management);
3. Different trading protocols;
4. Lack of transparency of cost and profit.

Inventory Management

Inventories are materials stored, waiting for processing, or experiencing processing. They are ubiquitous throughout all sectors of the economy. Observation of almost any company balance sheet, for example, reveals that significant portion of its assets comprises inventories of raw materials, components and subassemblies within the production process, and finished goods. Most managers don't like inventories because they are like money placed in a drawer, assets tied up in investments that are not producing any return and, in fact, incurring a borrowing cost. They also incur costs for the care of the stored material and are subject to spoilage and obsolescence. In the last two decades there have been a spate of programs developed by industry, all aimed at reducing inventory levels and increasing efficiency on the shop floor. Some of the most popular are conwip, kanban, just-in- time manufacturing, lean manufacturing, and flexible manufacturing. Nevertheless, in spite of the bad features associated with inventories, they do have positive purposes. Raw material inventories provide a stable source of input required for production.

A large inventory requires less replenishment and may reduce ordering costs because of economies of scale. In- process inventories reduce the impacts of the variability of the production rates in a plant and protect against failures in the processes. Final goods inventories provide for better customer service. The variety and easy availability of the product is an important marketing consideration. there are other kinds of inventories, including spare parts inventories for maintenance and excess capacity built into facilities to take advantage of the economies of scale of construction.

Because of their practical and economic importance, the subject of inventory control is a major consideration in many situations. Questions must be constantly answered as to when and how much raw material should be ordered, when a production order should be released to the plant, what level of safety stock should be maintained at a retail outlet, or how in-process inventory is to be maintained in a production process. These questions are amenable to quantitative analysis with the help of inventory theory.

In any business or organization all functions are interlinked and connected to each other and are often overlapping. Some key aspects like supply chain management, logistics and inventory from the backbone of the business delivery function. Therefore these functions are extremely important to marketing managers as well as finance controllers.

Inventory management is a very important function that determines the health of the supply chain as well as the impacts the financial health of the balance sheet. Every organization constantly strives to maintain optimum inventory to be able to meet its requirements and avoid over or under inventory that can impact the financial figures.

Inventory is always dynamic. Inventory management requires constant and careful evaluation of external and internal factors and control through planning and review. Most of the organizations have a separate department or job function called inventory planners who continuously monitor, control and review inventory and interface with production, procurement and finance departments.

The Reasons for Keeping Stock

There are three basic reasons for keeping and inventory:

- Time - The time lags present in the supply chain, from supplier to user at every stage, requires that you maintain certain amounts of inventory to use in this "lead time".
- Uncertainty - Inventories are maintained as buffers to meet uncertainties in demand, supply and movements of goods.
- Economies of scale - Ideal condition of "one unit at a time at a place where a user needs it, when he needs it" principle tends to incur lots of costs in terms of logistics. So bulk buying, movement and storing brings in economies of scale, thus inventory.

Mathematical Treatment

The inventory system involves the following steps:

- Development of a mathematical model of the system;
- Obtaining a solution of the system;
- Determination of the properties of the system;
- Derive relationships between different related parameters of inventory;
- Study of optimality.

The above steps have been taken into account during the analysis of the problems presented in the thesis. It is and initial work to develop a Mathematical model of the inventory. This model is based on various assumptions and approximations. It is a difficult device to operate accurately. In practice, it is not easy to construct a truly realistic model with completely accuracy and very often it may not be amenable to a mathematical treatment. Hence it is necessary to take some approximation and simplification while constructing a feasible model.

In addition to, the inventory problem contains a set of parameters which optimize the total cost of the system. Sometimes it is difficult to obtain the values of these parameters due to general nature of the problem undertaken or due to some other reasons. So in these cases, simple differential calculus, numerical techniques, scientific calculator, search techniques, different algorithms of various software's may be used to optimize the objective function.

Economic Parameters

The various economical parameters associated with our thesis are given below:

Ordering or Setup or Replenishment Cost

Ordering costs, also known as setup costs, are essentially costs incurred every time you place an order. Examples include:

- Clerical costs of preparing purchase orders – There are many kinds of clerical costs, such as invoice processing, accounting, and communication costs.
- Cost of finding suppliers and expediting orders – Costs spent on these will likely be inconsistent, but they are important expenses for the business.
- Transportation costs – The costs of moving the goods to the warehouse or store. These costs are highly variable across different industries and items.
- Receiving costs – These include costs of unloading goods at the warehouse, and inspecting the goods to make sure they are the correct items and free of defects.
- Cost of electronic data interchange (EDI) – These are systems used by large businesses and especially retailers, which allow ordering process costs to be significantly reduced.

Holding Costs

Also known as carrying costs, these are costs involved with storing inventory before it is sold.

- Inventory financing costs - This includes everything related to the investment made in inventory, including costs like interest on working capital. Financing costs can be complex depending on the business.
- Opportunity cost of the money invested in inventory – This is found by factoring in the lost alternatives of tying money up in inventory, such as investing in term deposits or mutual funds.
- Storage space costs – These are costs related to the place where the inventory is stored, and will vary by location. There will be the cost of the storage facility itself, or lease payments if it is not owned. Then there are facility maintenance costs like lighting, heating, and ventilation. Depreciation and property taxes are also included in this.

- Inventory services costs – This includes the cost of the physical handling of the goods, as well as insurance, security, and IT hardware, and applications if these are used. Expenses related to inventory control and cycle counting are further examples.
- Inventory risk costs – A major cost is shrinkage, which is the loss of products between purchasing from the supplier and final sale due to any number of reasons: theft, vendor fraud, shipping errors, damage in transit or storage. The other main example is obsolescence, which is the cost of goods going past their use-by dates, or otherwise becoming outdated.

Shortage Cost

These costs also called stock-out costs, occur when businesses become out of stock for whatever reason.

- Disrupted production – When the business involves producing goods as well as selling them, a shortage will mean the business will have to pay for things like idle workers and factory overhead, even when nothing is being produced.
- Emergency shipments – For retailers, stock-outs could mean paying extra to get a shipment on time, or changing suppliers.
- Customer loyalty and reputation – These costs are hard to pinpoint, but there are certainly losses to these when customers are unable to get their desired product or service on time.

Purchase Cost

It is unit cost of an item obtained either from and external source or from the unit replenishment cost of internal production. It is not necessarily constant. The unit purchasing price depends on the quantity procured happening in many practical situations. For examples, in a competitive market, there is a price discounting on purchasing of big lot size so also there is a reduction of replenishment cost per unit when production happens in large scale.

Selling Price

It is unit price of an item sold to a customer on demand. It results revenue from selling the commodity. It is necessarily not constant but sometimes depends on the decision maker.

Salvage Value

Salvage value also called residual or scrap value is the estimated worth of an asset at the end of its useful life. In other words, salvage value is the price management believes it can sell an asset for after the asset is deemed unusable because of time, abuse, and obsolescence. For non-accountants, the term scrap value makes more sense because this is the value of the asset after it can no longer be used. Scrap value is the amount of money that can be salvaged from the used assets.

Salvage value is used in calculating depreciation and making equipment purchase decisions. Management will often consider the estimated salvage value of an asset when deciding to make a new equipment purchase because a salvage value will often lower the total cost of the asset over time since the salvage value can be recouped when the asset is later sold.

Demand

Demand in economics is how many goods and services are bought at various prices during a certain period of time. Demand is the consumer's need or desire to own the product or experience the service. It's constrained by the willingness and ability of the consumer to pay for the good or service at the price offered.

Demand is the underlying force that drives everything in the economy. Fortunately for economics, people are never satisfied.

They always want more. This drives economic growth and expansion. Without demand, no business would ever bother producing anything.

Lead Time

The time gap between the placing of an order and receiving of the inventory is called lead time. In other word a lead time is the latency between the initiation and execution of a process. It may not be necessarily a constant.

Time Horizon

It is the time duration during which an optimal policy is to be determined to maximize the profit or minimize the total inventory cost. It may be finite or infinite depending upon the nature of the inventory system.

Replenishment

It is the rate of quantities added to the stock. The replenishment quantity may be constant or variable depending upon the nature of the inventory system. Instantaneous replenishment happens when the stock is added up from external resource point in no time.

Buffer or Safety Stock

As demand is uncertain and uncontrolled, some extra stock is advised to be maintained to overcome any shortages occur during the lead time. This extra stock is called as Buffer stock.

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4

Production Planning, Control and Scheduling

Production planning refers to the planning of manufacturing and production modules in an industry or company. The process of controlling, arranging and optimizing workloads and work in a manufacturing or production process is known as scheduling. This chapter has been carefully written to provide an easy understanding of the varied facets of production planning, control and scheduling.

Planning and Control

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

In any manufacturing enterprise, the main objective of production department is to produce the things in desired quantity at desired time so that they may be made available to end users when they demand it. Production, being a very complex process is very difficult to manage for the people. This includes a large number of activities and operations which need to be planned appropriately and in turn controlled for the effective production of the output. The main purpose of production planning and control (PPC) is to establish routes and schedules for the work that will ensure the optimum utilization of materials, workers, and machines and to provide the means for ensuring the operation of the plant in accordance with these plans.

There are different types of production systems. The choice of production system depends upon the nature of products, variety of products and volume of products. Entrepreneurs, after finalizing the production system to be used are required to go for the production planning and control (PPC) which essentially depends upon the type of production system.

Production planning and control is necessarily concerned with implementing the plans, i.e. the detailed scheduling of jobs, assigning of workloads to machines (and people), the actual flow of work through the system. Production is an organized activity of converting row materials into useful products. Production system requires the optimal utilization of natural resources like men, money, machine, materials and time. Production planning and control coordinate with different departments: such as production, marketing, logistics, warehouse and other departments depending upon the nature of organization. Production planning and control receives data related to orders from marketing departments. Production plan based on marketing and production data is prepared in production planning and control. This production plan provides clear idea about utilization of manufacturing resources for production. Prepared production plan is delivered to production department. Production department manufacture products according to that plan.

The ultimate objective of production planning and control, like that of all other manufacturing controls, is to contribute to the profits of the enterprise. As with inventory management and control, this is accomplished by keeping the customers satisfied through the meeting of delivery schedules.

The main objectives of PPC may be summarized as followings:

- It is used to establish target and check the deviations by comparing on some performance measures.
- Decides the nature and magnitude of different input factors to produce the output.
- Coordinates different resources of production system in the most effective and economic manner and to coordinate among different departments.
- Elimination of bottleneck.
- Utilization of inventory in the optimal way.
- Smooth flow of material.
- To produce in right quantity and quality at right time.
- Scheduling production activities to meet delivery schedule.
- Expediting the system under production.
- To ensure flexibility in production system to accommodate changes and uncertainty.
- Optimizes the use of resources for minimum overall production cost.
- To ensure the production of right product at right time in right quantity with specification rightly suited to customers.
- Stable production system, with least chaos, confusion and undue hurry.

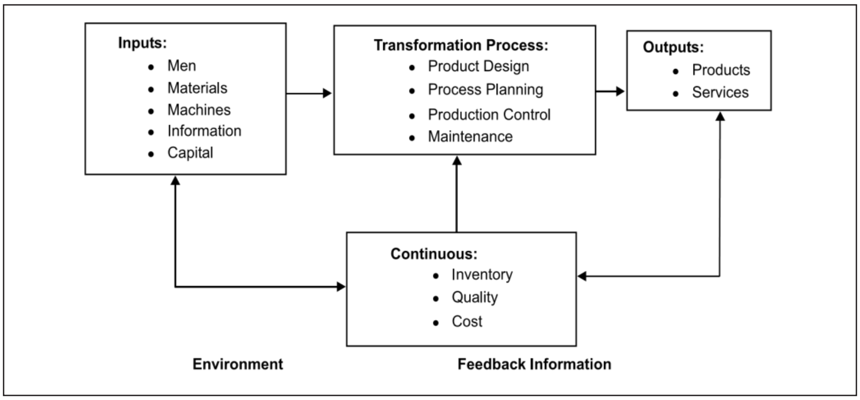
Production

Production refers to the transformation of inputs into finished goods/ or creation of services in order to satisfy the customer needs. This uses different inputs mainly including 6M's namely, man, material, machine, money, method and management. Production involves application of processes by which the inputs can be transformed into desired product (output) of potential utility while improving properties and adding economic values through the best method without compromising on quality.

Different forms of production based on the processes used:

- Production by extraction or separation: like petrol, kerosene, sugar etc.
- Production by assembly: car, television, furniture.

Edwood Buffa defines production as “a process by which goods and services are created” Some examples of production are: manufacturing custom-made products like, boilers with a specific capacity, constructing flats, some structural fabrication works for selected customers etc. At each stage of processing, there will be value addition. It is easy to understand a production system from the figure. There are various inputs which essentially pass through a transformation/conversion process and finally converted into some outputs which have a value for the end users.



Systematic production system

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

Production management involves the managerial decisions regarding design of the product and design of the production system i.e. determination of production processes and production planning and control.

Blueprint of Production System

An enterprise in the beginning needs to define its production system that is considered as the framework within which all production related activities and operations take place. Manufacturing process is the transformation process through which inputs are converted into outputs. An appropriate designing of production system ensures the coordination of various production activities and operations. There is no single pattern of production system which is universally applicable in all kinds of enterprises. This varies from one enterprise to another depending upon many parameters.

Types of Production systems

There are mainly three types of production systems mentioned as below:

1. Continuous/Mass production
2. Job or unit production
3. Intermittent/Batch production

Continuous or Mass Production

It is used when we need to produce standardized products with a standard set of process and operation sequence in anticipation of demand. This ensures continuous production of output. It is also termed as mass flow production or assembly line production. This system results in less work in process (wip) inventory and high product quality but involves high capital investment in machinery and equipment. This ensures very high rate of production as we need not to intervene once the production has begun. The system is appropriate in plants where large volume of small variety of output is produced. e.g. oil refineries, cement manufacturing and sugar factory etc.

Characteristics of Continuous/Mass production:

- As same product is manufactured for sufficiently long time, machines can be laid down in order of processing sequence.
- Standard methods and machines are used during part manufacture.
- Most of the equipment's are semi-automatic or automatic in nature.
- Material handling is also automatic (such as conveyors).
- Semi-skilled workers are normally employed as most of the facilities are automatic.
- As product flows along a pre-defined line, planning and control of the system is much easier.
- Cost of production per unit is very low owing to the high rate of production.
- In process inventories are low as production scheduling is simple and can be implemented with ease.

Job or Unit Production

It involves production as per customer's specifications. This ensures the simultaneous production of large number of batches/orders. Each batch or order comprises of a small lot of identical products and is different from other batches. It requires comparatively smaller investment in machines and equipment. It is flexible and can be adapted to changes in product design and order size without much inconvenience. This system is most suitable where heterogeneous products are produced against specific orders. In this system products are made to satisfy a specific order.

However that order may be produced- only once or at irregular time intervals as and when new order arrives or at regular time intervals to satisfy a continuous demand.

Characteristics of Job or Unit Production:

- Machines and methods employed should be general purpose as product changes are quite frequent.
- Man power should be skilled enough to deal with changing work conditions.
- Schedules are actually nonexistent in this system as no definite data is available on the product. In process inventory will usually be high as accurate plans and schedules do not exist.

- Product cost is normally high because of high material and labor costs.
- Grouping of machines is done on functional basis (i.e. as lathe section, milling section etc.) This system is very flexible as management has to manufacture varying product types. Material handling systems are also flexible to meet changing product requirements.

Intermittent or Batch Production

This is concerned with the production of different types of products in small quantities usually termed as batches. A batch contains the similar products but in small quantity. This is used to meet a specific order or to meet a continuous demand. Batch can be manufactured either- only once or repeatedly at irregular time intervals as and when demand arise or repeatedly at regular time intervals to satisfy a continuous demand. Under this system the goods may be produced partly for inventory and partly for customer's orders. For example, components are made for inventory but they are combined differently for different customers. e.g. automobile plants, printing presses, electrical goods plant are examples of this type of manufacturing.

Characteristics of Intermittent/Batch Production:

- As final product is somewhat standard and manufactured in batches, economy of scale can be availed to some extent.
- Machines are grouped on functional basis similar to the job shop manufacturing.
- Semi-automatic, special purpose automatic machines are generally used to take advantage of the similarity among the products.
- Labor should be skilled enough to work upon different product batches.
- In process inventory is usually high owing to the type of layout and material handling policies adopted.
- Semi-automatic material handling systems are most appropriate in conjunction with the semi-automatic machines.

In addition to the above, a large number of manufacturing plants include both intermittent and continuous processes and are classified as composite or combination operations. Such a plant may have sub assembly departments making parts in a continuous operation, while the final assembly department works on an intermittent basis.(as in the furniture and custom packaging industries)

Types of Manufacturing Processes

The above mentioned production systems require different types of manufacturing process and require different conditions for their working. Selection of manufacturing process is a strategic decision as any change in the same is very costly and time consuming affair. Therefore the manufacturing process is selected at the stage of planning a business venture. This must be selected keeping in view two important parameters (1) meeting the specification of the final product and (2) to be cost effective.

The manufacturing process is classified into four types:

1. Jobbing manufacturing process
2. Batch manufacturing process
3. Mass or flow manufacturing process
4. Process type manufacturing process

1. Jobbing manufacturing process: This is used to produce one or few units of the products as per the requirement and specification of the customer. Production is to meet the delivery schedule and costs are fixed prior to the contract made with the customer.

2. Batch manufacturing process: This is used to produce limited quantities of each of the different types of products in the form of batches. These batches of different products are manufactured on same set of machines. Different batches/products are produced separately one after the other.

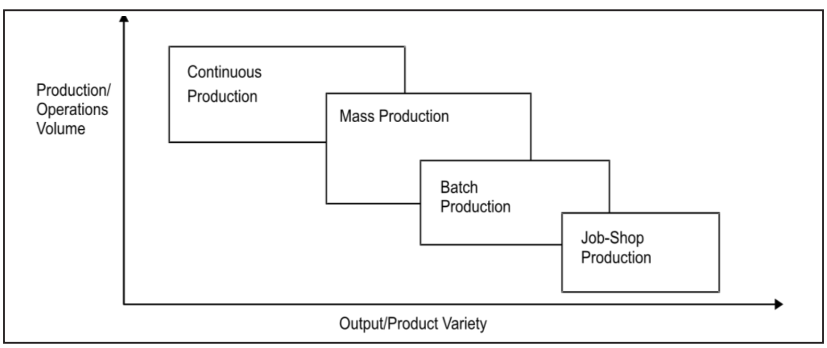
3. Mass or flow manufacturing process: This is used to produce a large quantity of same product at a time that is stocked for sale. All machines and required equipments are arranged according to the sequence of operations; termed as line arrangement/flow. This ensures very high rate of production. One line arrangement can produce only one type of product, therefore, a different line arrangement is needed for a different product.

4. Process type manufacturing process: This is used to produce the products which need a particular process/definite sequence of operations. E.g. petroleum. In this, production run is conducted for an indefinite period.

Factors Affecting the Choice of Manufacturing Process

Following factors need to be considered before making a choice of manufacturing process.

1. Effect of volume/variety: This is one of the major considerations in selection of manufacturing process. When the volume is low and variety is high, intermittent process is most suitable and with increase in volume and reduction in variety continuous process become suitable. The following figure indicates the choice of manufacturing process as a function of volume and variety.



Classification of production systems

2. Capacity of the plant: Predicted sales volume is the key factor to make a choice between batch and line process. In case of line process, fixed costs are substantially higher than variable costs.

The reverse is true for batch process thus at low volume it would be cheaper to install and maintain a batch process and line process becomes economical at higher volumes.

3. Lead time: The continuous process normally results faster deliveries as compared to batch process. Therefore lead-time and level of competition certainly influence the choice of production process.

4. Flexibility and Efficiency: The manufacturing process needs to be flexible enough to adapt contemplated changes and volume of production should be large enough to lower costs.

Hence it is very important for entrepreneur to consider all above mentioned factors before taking a decision pertaining to the type of manufacturing process to be adopted. As far as Small Scale Enterprises are concerned, they usually adopt batch processes due to less volume of production and low investment.

Once the entrepreneur has made a final choice pertaining to the product design, production system and process, his next critical decision is the production and planning control (PPC) decision.

Meaning of Production Planning and Control

PPC is a very critical decision which is necessarily required to ensure an efficient and economical production. Planned production is an important feature of any manufacturing industry. Production planning and control (PPC) is a tool to coordinate and integrate the entire manufacturing activities in a production system. This essentially comprises of planning production before actual production activities start and then exercising control over those activities to ensure that the planned production is realized in terms of quantity, quality, delivery schedule and cost of production.

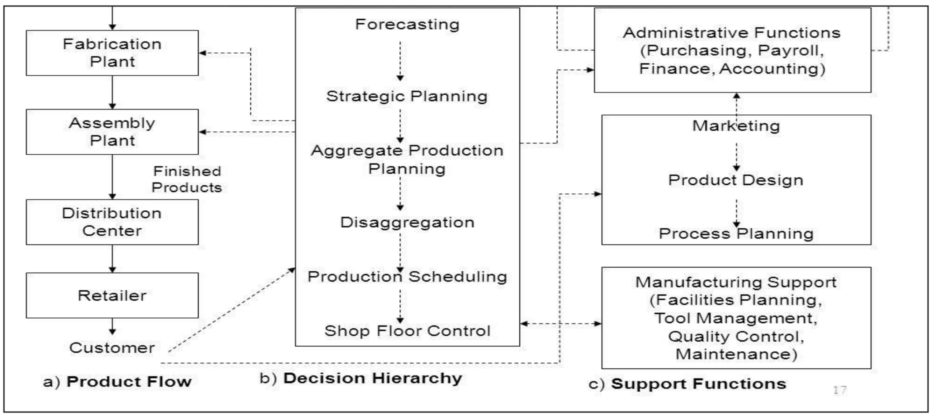
According to Gorden and Carson, PPC usually involve the organization and planning of manufacturing process. Principally, it includes entire organization. The various activities involved in production planning are designing the product, determining the equipment and capacity requirement, designing the layout of physical facilities and material and material handling system, determining the sequence of operations and the nature of the operations to be performed along with time requirements and specifying certain production and quantity and quality levels.

Production planning also includes the plans of routing, scheduling, dispatching inspection, and coordination, control of materials, methods machines, tools and operating times. Its ultimate objective is the to plan and control the supply and movement of materials and labour, machines utilization and related activities, in order to bring about the desired manufacturing results in terms of quality, quantity, time and place. This provides a physical system together with a set of operating guidelines for efficient conversion of raw materials, human skills and other inputs to finished product.

Procedure of Production Planning and Control

The PPC is entirely based on the pre-design format. It attempts to execute and implement all activities/operations according to the set plan. All operations should be executed in a proper manner with a close vigil on all facts ensuring that the time period and the stipulated costs should not go beyond the reach and it should be done under the excepted/agreed policies. These costs are including the cost of assets, capital cost of the facility, and labour. The PPC consists of the following steps:

- Forecasting the demands of the customers for the products and services.
- In advance preparing the production budget.
- Design the facility layout.
- Specify the types of machines and equipment.
- Appropriate production requirements of the raw materials, labour, and machinery.
- Drawing the apt schedule of the production.
- Confirming the shortage or any excess of the end product.
- Future plans are drawn for any sudden surge in the demand for the product.
- The rate and scale of production is setup. Which needs to be broken into realistic time periods and scheduling. The specified job needs to be done in the amount of time provided so that the production can move to next step.



PPC essentially consists of three Stages:

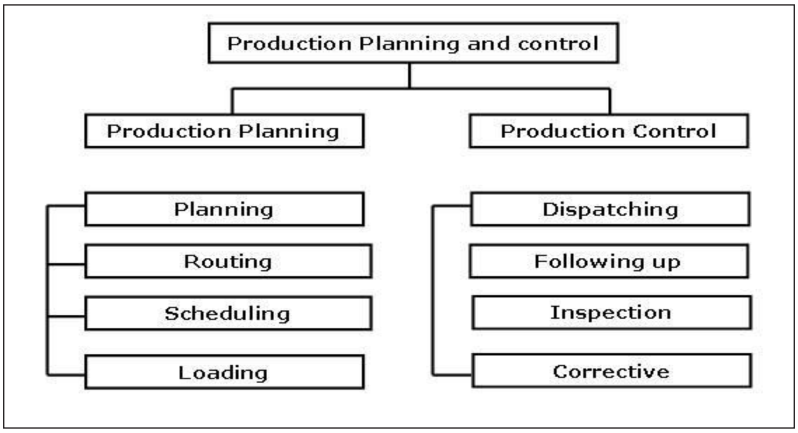
1. Planning stage
2. Action stage
3. Monitoring stage

All these three stages are very important from the point of view to production because without planning no production work can take off at all. The foremost thing which is required for any production is a proper planning.

Elements of Production Planning and Control

This is important to note that production plan is the first and the foremost element of PPC. Planning refers to deciding in advance what is to be done in future. A separate planning department is established in the organization which is responsible for the preparation of policies and plans with regard to production to be undertaken in due course. The planning department prepares various charts, manuals production budgets etc., on the basis of information received from management. These plans and charts or production budgets are given practical shape by carrying various elements under production control. If production planning is defective, production control is bound to be adversely affected. For achieving the production targets, production planning provides sound basis for production control.

One needs to remember that production plans are prepared in advance at top level whereas, production control is exercised at machine shop floor (bottom level) where actual production is taking place. Some important elements of PPC have been depicted in the figure as below:



The important elements may be listed as following:

1. Materials: planning for procurement of raw material, component and spare parts in the right quantities and specifications at the right time from the right source at the right place. Purchasing, storage, inventory control, standardization, variety reduction, value analysis and inspection are the other activities associated with material.

2. Method: choosing the best method of processing form several alternatives. It also includes determining the best sequence of operations (process plan) and planning for tooling, jigs and fixtures etc.

3. Machines and equipment: manufacturing methods are related to production facilities available in production systems. It involves facilities planning, capacity planning, allocations, and utilization of plant and equipment, machines etc.

4. Manpower: planning for manpower (labour and managerial levels) having appropriate skills and expertise.

5. Routing; determining the flow of work material handling in the plant, and sequence of operations or processing steps. This is related to consideration of appropriate shop layout plant layout, temporary storage location for raw materials, component and semi-finished goods, and of materials handling system.

   Route Sheet: a route sheet is a document providing information and instructions for converting the raw material in finished part or product. It defines each step of the production operations and lay down the precise path or route through which the product will flow during the conversion process. Route sheet contains following information:

a. The operation required at their desired sequence;

b. Machines or equipment to be used for each operations;

c. Estimated set-up time and operation time per piece;

d. Tools, jigs, and fixtures required for operations;

e. Detailed drawings of the part, sub-assemblies and final assemblies;

f. Specification, dimensions, tolerances, surface finishes and quality standard to be achieved';

g. Specification of raw material to be used;

h. Speed, feed etc. to be used in machines tools for operations to be carried on;

i. Inspection procedure and metrology tools required for inspection;

j. Packing and handling instructions during movement of parts and subassemblies through the operation stages.

6. Estimating: Establishing operation times leading to fixations of performance standards both for worker and machines. Estimating involves deciding the quantity of the product which needs to be produced and cost involved in it on the basis of sale forecast.

7. Loading: machine loading is the process of converting operation schedule into practices in conjunctions with routing. Machine loading is the process assigning specific jobs to machines, men, or work centers based on relative priorities and capacity utilization. Loading ensures maximum possible utilization of productive facilities and avoid bottleneck in production. It's important to either overloading or under loading the facilities, work centers or machines to ensure maximum utilization of resources.

8. Scheduling: scheduling ensure that parts and sub-assemblies and finished goods are completed as per required delivery dates. It provides a timetable for manufacturing activities.

   Purpose of scheduling:

   - To prevent unbalance use of time among work and centers and department.
   - To utilize labour such a way that output is produced within established lead time or cycle time so as to deliver the products on time and complete production in minimum total cost.

9. Dispatching: This is concerned with the execution of the planning functions. It gives necessary authority to start a particular work which has already planned under routing and scheduling functions. Dispatching is release of orders and instructions for starting of production in accordance with routing sheet and scheduling charts.

10. Inspection: This function is related to maintenance of quality in production and of evaluating the efficiency of the processes, methods and labours so that improvement can be made

to achieve the quality standard set by product design.

11. Evaluating: The objective of evaluating is to improve performance. Performance of machines, processes and labour is evaluated to improve the same.
12. Cost control: Manufacturing cost is controlled by wastage reduction, value analysis, inventory control and efficient utilization of all resources.

Requirements for an Effective Production Planning and Control

In an organization, PPC system can be effective only if the following aspects are given due considerations before implementation:

1. Appropriate organization structure with sufficient delegation of authority and responsibility at various levels of manpower.
2. Right person should be deputed at right place for right job.
3. Maximum level of standardization of inventory, tooling, manpower, job, workmanship, equipment, etc.
4. Appropriate management decision for production schedule, materials controls, inventory and manpower turnover and product mix.
5. Flexible production system to adjust any changes in demand, any problem in production or availability of materials maintenance requirements, etc.
6. Estimation of accurate leads times for both manufacturing and purchase.
7. Management information system should be reliable, efficient and supporting.
8. Capacity to produce should be sufficient to meet the demand.
9. The facility should be responsive enough to produce new products change of products mix and be able to change the production rates.

The above elements are very important and necessary to make the production planning system effective and efficient.

Utility of PPC Productions

The implementation of PPC based production system yields various advantages to any organization for various functional activities, which include the following:

1. Last hour rush is avoided: Production is well planned and controlled as per the given time schedules. Therefore, production control reduces the number of emergency order and overtime works on plant and thus reduces the overheads.
2. Problems areas of bottleneck get reduced: The incomplete work or work-in-transit does not get piled up because production control balances the line and flow of work.
3. Cost reduction: An appropriate production control increases the men-machines utilization,

which maintains in process inventories at a satisfactory level, leads to a better control on raw material inventories, reduces costs of storage and materials handling, helps in maintaining quality and limits rejections and thus ultimately reduces the unit cost of production.

4. Optimum utilization of resources: It reduces the time loss of the workers waiting for materials and makes most effectives use of equipment.
5. Better coordination of plants activities: PPC coordinates the activities of the plant that leads to control concerted effort by workforce.
6. Benefits to workers: PPC results into better efficiency and productivity, which leads to adequate wages stable employment, job security, improved working conditions increased job satisfaction and ultimately high morale.
7. Improved services to customers: PPC leads to better services to the customers as it ensures production in accordance with the time schedules and therefore, deliveries are made as per the committed schedules.

Scope of Production Planning and Control

1. Nature of Inputs: To manufacture a product, different types of inputs are used. The quality of the product depends upon the nature of the inputs are used. Hence the planning is done to determine the nature of various types of inputs which is a complicated process.
2. Quantity of Inputs: To achieve a level of production, determination of quantity of the inputs and their composition is very important. A product can be prepared only when there is an estimate of the required composition of inputs.
3. Proper Coordination: It ensures the proper coordination among the workforce, machines and equipment. This leads to avoidance of wastages and smooth flow of production.
4. Better Control: Production planning is the method of control. For a better control, planning is a precondition. Only then, one can compare the performance and calculate the deviations which lead control of the production.
5. Ensure Uninterrupted Production: The planning of materials ensures the regular supply of raw materials and other components. The regular flow of materials and supplies are helpful in the uninterrupted production.
6. Capacity Utilization: There is a need to use the available resources effectively. It is helpful in bringing down various costs of production.
7. Timely Delivered: If there is good production planning and control, there will be timely production and the finished product will be rushed to the market in time. This also ensures the better relationship with the customers.

Factors Affecting Production Planning and Control

1. Use of Computers: Modern factories are using office automation equipment like PC, punch cards etc. It helps accurate computation of required of men and machine.

2. Seasonal Variations: Demand of certain products is affected by seasons, for instance umbrellas and raincoats during the monsoons and outputs. Production planning and control must take such changes into consideration while planning and control activities of inputs and outputs.

3. Test Marketing: In an aggressive marketing strategy new products are to be test marketed in order to know the trends. This is a short- cycle operation, intermittent in nature and often upsets regular production.

4. After Sales Service: This has become an important parameter for success. In after sales services, many items are returned for repair. These are unscheduled Work and also overload the production line.

5. Losses due to Unpredictable Factors: Losses occur due to accidents, fire and theft of production inputs, mainly materials and Components. These are unpredictable. Shortage of input due to such factors upset the planned production schedule in time and quantity.

6. Losses due to Predictable Factors: There are losses of inputs, due to natural engineering phenomena like production losses and changes in consumption of materials and occurrence of defectives.

Production Scheduling

Production Planning is one of the logical steps in managing the supply chain. In creating a production plan, a company looks at the big picture (the aggregate) rather than the level of the individual product or item, predicting a level of manufacturing output in accordance with predicted sales and other company goals and constraints.

Because production planning occurs at an aggregate level, creating a production plan involves grouping products into product families. These groupings are based on products' similarities in design, manufacturing process, and resource usage. You can assign planning percentages to the members of the product family, and use the relationship between product family items and its members in forecast explosion, consumption, master scheduling, and capacity and materials planning. Production Planning enables forecasts for the product family to be exploded down to the product family members (based on the planning percentages and effectively dates for the member items) in a process similar to that of exploding a forecast for a model.

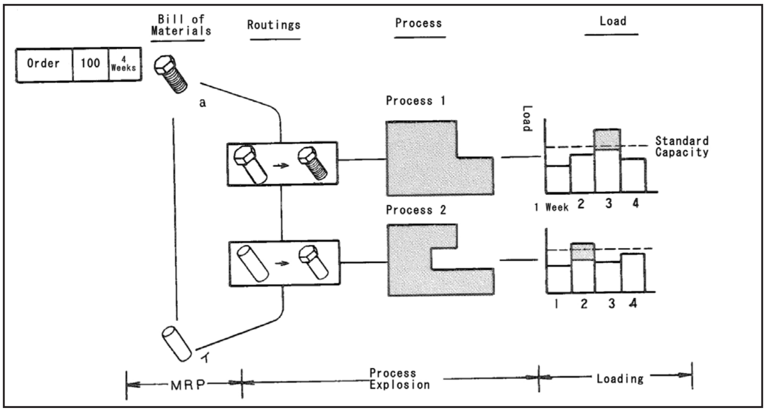
Sales orders for member items consume the forecast for the member items as well as for the product family. Throughout the application, processing is done at both the aggregate and the detail level.

Loading

A load means the quantity of work, and allocating the quantity of work to the processes necessary to manufacture each item is called loading.

It is performed in the CRP (Capacity Requirements Planning) of the manufacturing planning. Each item planned in MRP is first explored to the processes necessary to manufacture it, which is usually called process explosion. Next loading is performed for the explored process. In loading, each load is usually piled up by time (hour), by which a setup time and a real operating time are determined. The real operating time may be set by manufacturing lot or by real operating time per item unit. In the former case, the time of hour is piled up as load, while in the latter case; loading is performed after calculating the real operating time per manufacturing unit by multiplying the number of manufacturing items by real operating time.

In addition, the calculated load is piled up for a certain period, which is determined by selecting either the earliest start date or the last start date as a base date. This method enables loading for each process or each period.



Sequencing

Sequencing is the process of scheduling jobs on machines in such a way so as to minimize the overall time, cost and resource usage thereby maximizing profits.

Let,

$n \rightarrow$ Number of jobs

$m \rightarrow$ Number of machines

Then,

theoretically possible sequences $= (n!)^m$

e.g. if n = 4 and m = 3

then,

Number of sequences = $(4!)^3 = 16,777,216$

Not possible practically to check out all sequences to find the optimal one. Hence the need of finding some suitable procedure for sequencing the jobs.

Priority Sequencing

When jobs compete for work centres capacity, which job should be done next? Priority sequence rules are applied to all jobs waiting in the queue. Then when the work centre becomes open for the job, the one with the highest priority is assigned. "Priority Sequencing" is a systematic procedure for assigning priorities to waiting jobs thereby determining the sequence in which the jobs will be performed.

Sequencing Problems

The sequencing problem arises whenever there is a need for determining an optimum order of performing a number of jobs by number of facilities according to some pre-assigned order so as to optimise the output in terms of cost, time or profit.

Production of finished goods from raw materials consists of several operations to be performed in a given sequence. Frequently, similar operations required for several products are performed at the same work stations particularly in intermittent or batch production. Under such situations, it is required to select a preferred order for products passing through a work station. The problem becomes complicated when the several work stations serve many products. In such a problem, the criteria are minimum total processing time.

The general sequencing problem is stated as: There are n jobs (1, 2, 3...n) each of which must be processed through each of m machines $(m_1, m_2, m_3, \ ......m_n)$ one at a time. The order of processing each job through the machines is given and also the time taken to process each job on each machine is known.

The problem is to determine the order of processing of n jobs so that the total elapsed time for all the jobs will be minimum. The general sequencing problem is to determine the optimal sequence from amongst $(n!)^m$ sequences that minimises the total elapsed time.

Basic Assumptions:

1. Only one operation is carried out on a machine at a time.
2. Processing times are known and do not change.
3. Processing times are independent of order of processing the job.
4. The time required in moving jobs from one machine to another is negligibly small.
5. Each operation once started must be performed till completion.
6. Each preceding operation must be completed, before beginning of the next immediate operation.
7. Only one machine of each type is available.
8. A job is processed as soon as possible, but only in the order specified.
9. 'No passing rule' is strictly followed. i.e. same order of jobs is maintained over each machine. e.g. If n jobs are to be processed on two machines A B in order $A \rightarrow B$, then each job should go to machine A first then to machine B.

Sequencing Models

All type of sequencing problems may be categorized in one of the following models:

- Sequencing n jobs on 1 machine.

- Sequencing n jobs on 2 machine.
- Sequencing n jobs on 3 machine.
- Sequencing n jobs on m machine.

Sequencing n Jobs on 1 Machine

Five rules to find out optimal sequence:

1. SPT rule (Shortest Processing Time).
2. WSPT rule (Weighted Shortest Processing Time).
3. EDD rule (Earliest Due Date).
4. Hodgson's Algorithm.
5. Slack Rule.

To illustrate above rules an example is being considered:

Example: Consider 8 jobs with processing times, due dates and importance weights as shown below:

Job(i):	1	2	3	4	5	6	7	8
Processing time (ti):	5	8	6	3	10	14	7	3
Due Date (di):	15	10	15	25	20	40	45	50
Importance Weight (wi):	1	2	3	1	2	3	2	1

SPT Rule

In this rule, job with shortest processing time is considered first then next and so on. It simply means that arranging processing time in ascending order, the job sequence could be found.

Job(i):	4	8	1	3	7	2	5	6
Processing time (ti):	3	3	5	6	7	8	10	14

Using SPT rule the sequence of jobs will be 4-8-1-3-7-2-5-6.

Completion of these jobs are at times 3, 6, 11, 17, 24, 32, 42, 56 respectively.

1. Mean Flow Time = $\frac{3+6+11+17+24+32+42+56}{8} = \frac{191}{8} = 23.9$ units

2. Weighted Mean Flow Time

$$= \frac{1*3+1*6+1*11+3*17+2*24+2*32+2*42+3*56}{1+1+1+3+2+2+2+3} = \frac{435}{15} = 29 \text{ units}$$

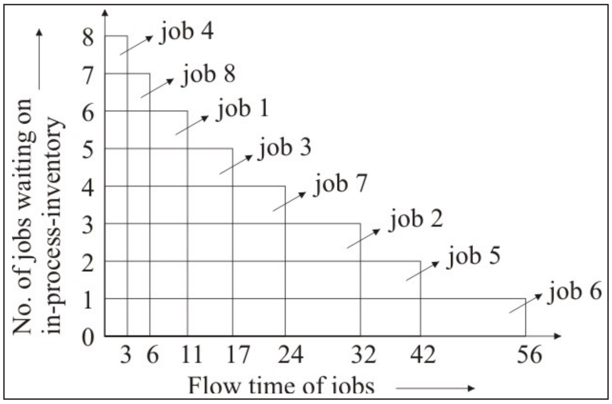
3. Average in-process inventory

$$= \frac{8*3+7*3+6*5+5*6+4*7+3*8+2*10+1*14}{56} = \frac{191}{56} = 3.41 \text{ jobs}$$

4. Waiting time for each job:

Job(i):	4	8	1	3	7	2	5	6
Waiting time:	0	3	6	11	17	24	32	42

$$\text{Mean Waiting time} = \frac{0+3+6+11+17+24+32+42}{8} = \frac{135}{8} = 16.875 \text{ units}$$



Average in-process inventory

5. Lateness of each job = Completion time of job - Due date of job

Lateness of job 4 = 3 − 25 = −22

Lateness of job 8 = 6 − 50 = −44

Lateness of job 1 = 11 − 15 = −4

Lateness of job 3 = 17 − 15 = +2

Lateness of job 7 = 24 − 45 = −21

Lateness of job 2 = 32 − 10 = +22

Lateness of job 6 = 56 − 40 = +16

Positive Lateness is called tardiness.

$$\text{Mean Lateness} = \frac{-22-44-4+2-21+22+22+16}{8} = \frac{-29}{8} = -3.625 \text{ units}$$

$$\text{Mean tardiness} = \frac{0+0+0+2+0+22+22+16}{8} = \frac{62}{8} = 7.8 \text{ units}$$

No. of tasks actually late = 4 (job no. 3,2,5,6) = No. of tardy jobs

Maximum lateness = 22 units (job 5 and 2 both).

WSPT Rule

In this rule, job with shortest 'processing time per unit of importance' is considered first then next and so on. It simply means that arranging 'processing time per unit of importance' in ascending order, the job sequence could be found.

Job(i)	Processing time (t_i)	Importance weight (w_i)	$\frac{t_i}{w_i}$
1	5	1	$\frac{5}{1} = 5(\text{VII})$
2	8	2	$\frac{8}{2} = 4(\text{V})$
3	6	3	$\frac{6}{3} = 2\ (\text{I})$
4	3	1	$\frac{3}{1} = 3(\text{II})$
5	10	2	$\frac{10}{2} = 5\ (\text{VIII})$
6	14	3	$\frac{14}{3} = 4.7(\text{VI})$
7	7	2	$\frac{7}{2} = 3.5(\text{IV})$
8	3	1	$\frac{3}{1} = 3(\text{III})$

Using WSPT rule the sequence of jobs will be 3-4-8-7-2-6-1-5

Respective Flowtime = 6, 9, 12, 19, 27, 41, 46, 56

$$\text{Mean Flow Time} = \frac{6+9+12+19+27+41+46+56}{8} = \frac{216}{8} = 27 \text{ units}$$

$$\text{Weighted Mean Flow Time} = \frac{3*6+1*9+1*12+2*19+2*27+3*41+1*46+2*56}{3+1+1+2+2+3+1+2}$$

$$= \frac{412}{15} = 27.47 \text{ units}$$

Similarly,

Mean Lateness = -0.5

Mean Tardiness = 10.6

No. of Tardy Jobs = 4 (job No. 2,6,1,5)]

Max. Tardiness = 36 units

EDD Rule

In this rule, jobS are sequenced in the order of increasing due dates of jobs.

Using EDD rule the sequence of jobs will be 2-1-3-5-4-6-7-8.

Mean Flow Time = 32

Weighted Mean Flow Time = 31.7

Mean Lateness = + 4.5 units

Mean Tardiness = + 5 units

Maximum Lateness = 9 units

No. of late jobs = 6 (job no. 3.5.4.6.7.8) = No. of tardy jobs

Hodgson's Algorithm

This algorithm is aplicable only if the number of tardy jobs is more than 1. Using EDD rule number of tardy jobs could be found.

As per EDD rule, the sequence of jobs will be 2-1-3-5-4-6-7-8 with 6 tardy jobs which is more than 1 job. Hence Hodgson's algorithm is applicable.

Job(i):	2	1	3	5	4	6	7	8
Processing time (ti):	8	5	6	10	3	14	7	3
Completion time (ci):	8	13	19	29	32	46	53	56
Due Date (di):	10	15	15	20	25	40	45	50
Lateness ($li = ci - di$):	-2	-2	+4	+9	+7	+6	+8	+6

Since job 3 is first tardy job and is in 3rd position, examine first 3 jobs to identify the one with longest processing time. Job 2 has longest processing time of 8 units. Hence remove it and make the table again.

Job(i):	1	3	5	4	6	7	8
Processing time (ti):	5	6	10	3	14	7	3
Completion time (ci):	5	11	21	24	38	45	48
Due Date (di):	15	15	20	25	40	45	50
Lateness ($li = ci - di$):	-10	-4	+1	-1	-2	0	-2

5th job is tardy. Since longest processing time up to 5th job i.e. from 1st, 3rd and 5th job is that of 5th job, we will remove it.

Now as per Hodgson's algorithm, the sequence of jobs will be 1-3-4-6-7-8-2-5

$$\text{Mean Lateness} = 1.625$$
$$\text{Mean Tardiness} = 9$$
$$\text{Max. Lateness} = 36 \text{ units} \left(\text{both 2nd and 5th job}\right)$$
$$\text{Number of tardy jobs} = 2\left(\text{job 2 and 5}\right)$$

Slack Rule

Slack time = Due time of job - its processing time

This rule is based on sequencing jobs in ascending order of slack time.

Job(i):	1	2	3	4	5	6	7	8
Processing time (ti):	5	8	6	3	10	14	7	3
Due Date (di):	15	10	15	25	20	40	45	50
Slack time ($di - ti$):	10	2	9	22	10	26	38	47

Taking slack times in ascending order, the sequence of jobs will be 2-3-1-5-4-6-7-8.

$$\text{Completion times are } 8, 14, 19, 29, 32, 46, 53 \;\; 56$$
$$\text{Mean tardiness} = 5 \text{ units}$$
$$\text{Mean Flow time} = 32.1 \text{ units}$$
$$\text{Weighted Mean Flow time} = 31.1 \text{ units}$$

Rule	Objective (to minimize)	Mean Flow time	Weighted Mean Flow time	Mean Lateness	Maximum Tardiness	No. of tardy jobs	Mean tardiness
SPT	1. Mean flow time 2. Mean in process inventory 3. Mean waiting time 4. Mean lateness	23.9	29	-3.6	22	4	7.8
WSPT	Mean flow time	27	27.5	-0.5	36	4	10.6
EDD	Maximum job lateness	32	31.7	4.5	9	6	5
Hodgson	Number of tardy jobs	29.1	29.9	1.6	36	2	9
Slack	Mean tardiness	32.1	31.1	4.6	9	6	5

Sequencing n Jobs on 2 Machine

The problem is defined as, there are only two machines A and B. Each job is processed in the order A and B.

The processing times of n jobs (1, 2, 3...... n) on each of the two machines is known. Let $A_1, A_2 \ldots\ldots A_n$, are processing times on A and $B_1, B_2 \ldots\ldots\ldots B_n$ are processing times on B. The problem is to find the order in which the n jobs are to be processed to minimise the total elapsed time (T) to complete all the n jobs.

Procedure using Johnson's Algorithm

- Step 1: Select the smallest processing time from the given list of processing times $A_1, A_2 \ldots\ldots A_n$ and $B_1, B_2 \ldots\ldots\ldots B_n$.
- Step 2: If the minimum processing time is A_r (i.e., Job number r on Machine A), do the rth job first in the sequence. If the minimum processing time is B_s (i.e., job number s on Machine B), do the sth job last in the sequence.
- Step 3: After doing this step, (n-1) jobs are left to be sequenced. Repeat step (1) and step (2) till all the jobs are ordered.
- Step 4: Find the total processing time as per the sequence determined and also determine idle time associated with machines.

Sequencing n Jobs on 3 Machine

There are three machines M1, M2 and M3. Each job has to go through three machines in the order M1, M2 and M3.

Conditions to be satisfied to solve the above problem by Johnson's method:

1. The smallest processing time on machine M1 ≥ largest processing time on machine M2.
2. The smallest processing time on machine M3 ≥ largest processing time on machine M2. If either or both of the above stated conditions are satisfied, the given problem can be solved by Johnson's algorithm.

Procedure using Johnson's Algorithm

Step I: Convert the three machine problem into two machine problem by introducing two fictitious machines G and H such that

$$G_i = M1_i + M2_i$$

$$H_i = M2_i + M3_i \left(\text{ where } i = 1,\ 2,\ 3,\ \ldots n \right)$$

Step II: Once the problem is converted to n job 2 machine the sequence is determined using Johnson's algorithm for n Jobs and 2 machines.

Step III: For the optimal sequence determined, find out the minimum total elapsed time and idle times associated with machines.

Tie Breaking Rules

1. If there are equal smallest processing times one for each machine, place the job on machine 1, first in the sequence and one in machine 2 last in the sequence.
2. If the equal smallest times are both for machine 1, select the job with lower processing time in machine 2 for placing first in the sequence.

3. If the equal smallest times are both from machine 2, select the one with lower processing time in machine 1, for placing last in the sequence.

Processing n Jobs through m Machines

Let there be n jobs which are to be processed through m machines $M_1, M_2 \dots M_m$ in the order $M_1, M_2 \dots M_m$.

Let T_{ij} denote the time taken by ith job on the jth machine.

Procedure

Step I: Find Min T_{i1} (Minimum time for the first machine).

Min T_{im} (Minimum time on the last machine).

Max (T_{ij}) For j = 2,3,... m-1 and i = 1,2....n) (Maximum time on intermediate machines).

Step II: Check for the following conditions. (i) Minimum time T_{i1} for the first machine M_m ≥ Maximum time (T_{ij}) on intermediate machines (M_2 to M_{m-1}) (ii) Minimum time Tim for the last machine Mm ≥ Maximum time (T_{ij}) on intermediate machines (M_2 to M_{m-1}) i.e., the minimum processing time on the machines M_1 and M_m (First and last machines) should be ≥ maximum time on any of the 2 to m-1 machines.

Step III: If the conditions in step II are not satisfied, the problem cannot be solved by this method, otherwise go to next step.

Step IV: Convert the n job m machine problem into n job 2 machine problem by considering two fictitious machines G and H. Such that,

$$TG_{ij} = T_{i1} + T_{i2} + \dots\dots + T_{i(m-1)}$$

$$TH_{ij} = T_{i2} + T_{i3} + \dots\dots + T_{im}$$

Step V: Now obtain the sequence for n jobs using Johnson's Algorithm.

Step VI: Determine the minimum total elapsed time and idle times associated with machines.

Project Scheduling

The project schedule is the tool that communicates what work needs to be performed, which resources of the organization will perform the work and the timeframes in which that work needs to be performed. The project schedule should reflect all of the work associated with delivering the project on time. Without a full and complete schedule, the project manager will be unable to communicate the complete effort, in terms of cost and resources, necessary to deliver the project.

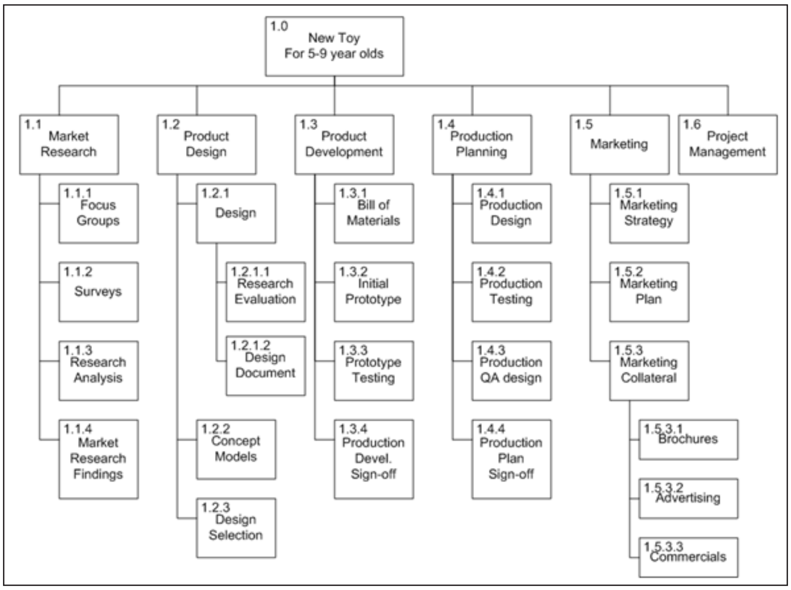
Online project management software allows project managers to track project schedules, resources, budgets and project related assets in real time. The project schedule can be viewed and updated by team members associated with the project, keeping everyone well informed on the overall project status.

Work Breakdown Structure (WBS)

The building blocks of a schedule start with a Work Breakdown Structure (WBS). The WBS is a hierarchical reflection of all the work in the project in terms of deliverables. In order to produce these deliverables, work must be performed.

A typical approach in developing a WBS is to start at the highest level, with the product of the project. For example, you are assigned as the project manager of a New Product Development project. The new product you are developing is a new toy for children age's five through nine. The objective of this product development project is to increase the revenue of the organization by ten percent.

Example of WBS:



Above is an example of a WBS for this new toy. Each level of the WBS is a level of detail created by decomposition. Decomposition is the process of breaking down the work into smaller, more manageable components. The elements at the lowest level of the WBS are called tasks. In the example above, brochures, advertising and commercials are all work packages or tasks.

Marketing collateral is on a summary level called a control account in project management parlance. In Project Insight, project management software, control accounts are called 'summary tasks.' Summary tasks are roll ups of the tasks underneath them.

The decomposition of a schedule will continue at varying rates. 'Brochures' is a task identified at the fourth level of decomposition, while the 'marketing plan' is also a task, but defined at the third level of decomposition.

As a project manager, the level of decomposition will be dependent on the extent to which you will need to manage. Project Insight supports as many levels of hierarchy as are needed. The expectation is that each task will have a single owner and the owner is expected to manage and report on the work necessary to deliver the task. In Project Insight, this is called the 'task owner.' If you cannot assign a single owner, or you need to have additional visibility into the progress of that task, additional decomposition is recommended.

Once all the deliverables of the project have been identified, tasks will be performed in order to create the deliverables. In some cases, these activities are the physical deliverables, but in other cases they are the actions that need to be performed. A physical deliverable, for example, might be an image (an actual file) that is needed for the brochure. Listing out each of the tasks to be performed will result in an activity list as demonstrated below.

Product Development Activity

The work package 'focus group' actually consists of three (3) separate tasks—'identify focus group targets,' 'prepare focus group objectives' and 'perform focus group.' The work package 'surveys,' on the other hand, is not broken down into tasks. In our example, it may have been determined that the task owner that is performing the surveys does not need to report on any of the details of that task. As stated earlier, decomposition will continue to the level that is necessary to effectively manage the project.

5

Product Analysis

The examination of the cost, quality, availability and features of a product is known as product analysis. Some of the aspects which are dealt with under this field are product development and product design. The topics elaborated in this chapter will help in gaining a better perspective about these aspects of product analysis.

Product and its Characteristics

Product is one of the important elements of marketing mix. A marketer can satisfy consumer needs and wants through product. A product consists of both good and service. Decisions on all other elements of marketing mix depend on product. For example, price is set for the product; promotional efforts are directed to sell the product; and distribution network is prepared for the product. Product is in the center of marketing programme. Therefore, product has a major role in determining overall success of marketing efforts.

A marketer tries to produce and sell such products that satisfy needs and wants of the target market. Other words used for product are good, commodity, service, article, or object. In marketing literature, product has comprehensive meaning.

Term product has been variously defined by the experts in the field.

Let us examine some standards:

1. Philip Kotler: "Product is anything that can be offered to someone to satisfy a need or a want."
2. William Stanton: "Product is complex of tangible and intangible attributes, including packaging, colour, price, prestige, and services that satisfy needs and wants of people."
3. W. Alderson: "Product is a bundle of utilities, consisting of various product features and accompanying services."
4. We can also define the term as: Product is a vehicle or medium that delivers service to customers.
5. Further it can be said: Product is a bundle of benefits-physical and psychological- that marketer wants to offer, or a bundle of expectations that consumers want to fulfil. Marketer can satisfy needs and wants of target consumers by products. Product includes both good and service. Normally, product is taken as a tangible object, such as a pen, television set, bread, book, vehicle, table, etc. But, tangible product is a package of services or benefits.

Marketer should consider product benefits and services, instead of product itself. Importance lies in the services rendered by the product, and not tangible object itself. People are not interested just possessing products, but the services rendered by the products.

For examples, we do not buy a pen, but writing service. Similarly, we do not buy a car, but transportation service. Just owning product is not enough. It must serve our need and want. Thus, physical product is just a vehicle or medium that offer services, benefits, and satisfaction to us.

Product can also be referred as a bundle of satisfaction, physical and psychological both. Product includes:

1. Core Product: Core product includes basic contents, benefits, qualities, or utilities.
2. Product-related Features: They include colour, branding, packing, labeling, and varieties.
3. Product-related Services: They include after-sales services, installation, guarantee and warrantee, free home delivery, free repairing, and so forth. As per the definition, anything which can satisfy need and want of consumers is a product. Thus, product may be in form of physical object, person, idea, activity, or organisation that can provide any kind of services that satisfy some customer needs or wants.

Product Dimensions

Different people view product differently. Similarly, their expectations are different. The different views or ways to see or perceive the product can be said as product dimensions.

There are three dimensions, as stated below:

Managerial Dimension

According to management, a product is viewed as the total product. It includes all those tangible and non-tangible aspects that management wants to offer. Managerial dimension of product covers mainly core products, product-related features, and product-related services.

Consumer Dimension

To consumers, a product is a bundle of expectations. They view product as a source of expectations or satisfaction. Thus, for consumer, total benefits received from product are important. This view is very important for a marketer.

Social Dimension

Society considers the product as a source of long-term welfare of people. Society expects high standard of living, safety, protection of environment, and peace in society.

Characteristics of Product

Careful analysis of concept of product essentially reveals following features:

1. Product is one of the elements of marketing mix or programme.

2. Different people perceive it differently. Management, society, and consumers have different expectations.
3. Product includes both good and service.
4. Marketer can actualize its goals by producing, selling, improving, and modifying the product.
5. Product is a base for entire marketing programme.
6. In marketing terminology, product means a complete product that can be sold to consumers. That means branding, labeling, colour, services, etc., constitute the product.
7. Product includes total offers, including main qualities, features, and services.
8. It includes tangible and non-tangible features or benefits.
9. It is a vehicle or medium to offer benefits and satisfaction to consumers.
10. Important lies in services rendered by the product, and not ownership of product. People buy services, and not the physical object.

Types of Product

A company sells different products (goods and services) to its target market.

They can be classified into two groups, such as:

1. Consumer Product
2. Industrial Products

Consumer Products

Consumer products are those items which are used by ultimate consumers or households and they can be used without further commercial and engineering processes.

Consumer products can be divided into four types as under:

1. Convenient Products: Such products improve or enhance users' convenience. They are used in a day-to-day life. They are frequently required and can be easily purchased. For example, soaps, biscuits, toothpaste, razors and shaving creams, newspapers, etc. They are purchased spontaneously, without much consideration, from nearby shops or retail malls.
2. Shopping Products: These products require special time and shopping efforts. They are purchased purposefully from special shops or markets. Quality, price, brand, fashion, style, getup, colour, etc., are important criteria to be considered. They are to be chosen among various alternatives or varieties. Gold and jewelleries, footwear, clothes, and other durables (including refrigerator, television, wrist washes, etc.)
3. Durable Products: Durable products can last for a longer period and can be repeatedly used by one or more persons. Television, computer, refrigerator, fans, electric irons, vehicles,

etc., are examples of durable products. Brand, company image, price, qualities (including safety, ease, economy, convenience, durability, etc.), features (including size, colour, shape, weight, etc.), and after-sales services (including free installation, home delivery, repairing, guarantee and warrantee, etc.) are important aspects the customers consider while buying these products.

4. Non-durable Products: As against durable products, the non-durable products have short life. They must be consumed within short time after they are manufactured. Fruits, vegetables, flowers, cheese, milk, and other provisions are non-durable in nature. They are used for once. They are also known as consumables. Mostly, many of them are non-branded. They are frequently purchased products and can be easily bought from nearby outlets. Freshness, packing, purity, and price are important criteria to purchase these products.

5. Services: Services are different than tangible objects. Intangibility, variability, inseparability, perishability, etc., are main features of services. Services make our life safe and comfortable. Trust, reliability, costs, regularity, and timing are important issues.

The police, the post office, the hospital, the banks and insurance companies, the cinema, the utility services by local body, the transportation facilities, and other helpers (like barber, cobbler, doctor, mechanic, etc.,) can be included in services. All marketing fundamental are equally applicable to services. ‘Marketing of services’ is the emerging facet of modern marketing.

Industrial Products

Industrial products are used as the inputs by manufacturing firms for further processes on the products, or manufacturing other products. Some products are both industrial as well as consumer products. Machinery, components, certain chemicals, supplies and services, etc., are some industrial products.

Again, strict classification in term of industrial consumer and consumer products is also not possible, For example, electricity, petroleum products, sugar, cloth, wheat, computer, vehicles, etc., are used by industry as the inputs while the same products are used by consumers for their daily use as well.

Some companies, for example, electricity, cements, petrol and coals, etc., sell their products to industrial units as well as to consumers. As against consumer products, the marketing of industrial products differs in many ways.

Industrial products include:

1. Machines and components
2. Raw-materials and supplies
3. Services and consultancies
4. Electricity and Fuels, etc.

Stages of Product Selection

Product Selection and Development Process are very complex process, which begins with idea generation and continues till commercialization. The process requires coordination between various departments. The process can be broken up into the following stages:

Exploration

New ideas are sought from the sales force, since that is the department which is in constant direct contact with customers.

The analysis of customer needs also takes into account competitors' products and services. New ideas are also generated from the consultants, shareholders, management employees, report on foreign markets and products, trade journals, R&D laboratories, other research, etc. However, technical feasibilities and market potential have to be kept in mind while examining new ideas.

Screening

While choosing the most effective ideas, guesswork or hunches are not reliable. To ensure a more scientific and less risky selection process, it is necessary to keep in mind all possible quantitative, as well as, qualitative information. Keeping in mind the organizational objectives and available facilities, the following must points be considered while selecting an idea:

- Market potentiality;
- Technical feasibility of the idea;
- Does the idea fall under any intellectual property rights or patent regulations;
- Raw material supply position—at present and in the future;
- Do existing production facilities and resource availability remain suitable for commercialization of the new idea;
- The level of investment required;
- Can the company generate this level of required investment from internal sources;
- If borrowing is a must, cost of borrowing is a factor;
- Does profitability projection analysis suggest adequate return on investment.

(a)

$$PVI = \frac{CTS \times CCS \times AV \times / L}{TPC}$$

Where,

PVI = Project Value Index

CTS = Chances of Techincal Success, calculated on a rating scale, which may be arbitrary, say 0 to 10

CCS = Chances for Commerical Success, on a scale, say 0 to 10

AV = Annual Volume of total sales in units

P = Profit per unit

L = Life of Product (in years)

TPC = Total Project Cost

Profitability projection study can be made using following formulae:

However, a more simple approach, as under, may be considered to arrive at the net probable return per dollar:

(b)

I = (PN/ C)

Where,

I = Index of relative worth

P = Overall Probalilty of commerical attainment of goal

N = Estimateda net return for an arbitraryfive- year period

C = Estimated future cost

In addition, point system and graphs also can supplement the profitability projection analysis of new product.

Business Analysis

At this stage, technical and economic factors, like manhours, cash flow, inventory holding, etc., are analysed to evaluate commercial feasibility. This will ultimately facilitate the budgeting process.

Development

A working model is developed at this stage to evaluate the practicability of the new idea, by studying the acceptability of customers to the working model. Most companies use product life cycle model at this stage.

Testing

Redesigning of the working model into a production prototype and testing the market before bulk production.

Commercialization

At the final stage of a new product planning, decisions have to be made whether to make or buy components; production methods have to be developed; distribution networks activated and the new product has to integrate with the organization's normal activity, and satisfactory sales volume and profitability have to be achieved.

Product Design

The process of creating a new product for sale to customers is known as product design. Thought this definition tends to oversimplify, product design is actually a broad concept which encompasses a systematic generation and development of ideas that eventually leads to the creation of new products. Design experts work on concepts and ideas, eventually turning them into tangible products and inventions.

The product design expert works with art, science and technology to create these products. This increasingly complex process is now supported by evolving digital tools and techniques that reduce the involvement of a large team and help visualize a product in great deal before it is created.

Product Design Process

Every design team may follow a different process for product design and development. One process, outlined by Koberg and Bagnell, describes how to turn design ideas into products. The process flows from problem identification to brainstorming ideas, prototype creation and eventually creating the product. This is followed up the formal manufacture of the product and a critical evaluation to identify any improvements that may be needed.

This method includes three stages. The later two may need to be looked at repeatedly during the process.

Analysis

At the beginning of the process there needs to be extensive research involving concrete facts and figures. This data then feeds into possible solutions to the problem at hand, and the best way to achieve these solutions. Formally, two stages are involved here:

- Accept Situation – The designers commit to the project and identifying a solution. Available resources are consolidated to reach this goal most efficiently.
- Analyze – The team now collectively begins research to collect all relevant data to help reach a solution.

Concept

Once the problem and potential solutions are narrowed, the final solution is identified and conceptualized in detail. This includes working out adherence to standards and how closely the visualized solution meets identified customer needs. One basic stage here is:

- Define – Here, the team identifies the key issue or issues. Using the problem conditions as objectives and constraints as parameters within which to operate, the team narrows down the information.

Synthesis

At this stage, the solutions are turned into ideas and the best ones are highlighted. These ideas of design turn into prototypes on which actual products will be based. This stage can be broken down into 4 steps:

- Ideate – Different ideas and solutions are brainstormed here. The best idea bank is created when there is no bias or judgment towards ideas presented.
- Select – The ideas brainstormed are narrowed down to a few which can give the best results. Plans for production can now be created.
- Implement – A prototype can now be created and the plan becomes a product.
- Evaluate – In the final stage, the prototype should be tested and any tweaks necessary should be made. If the prototype does now perform as anticipated, further ideas may need to be brainstormed.

Product Design Stages

Detailed stages can be followed in a systematic manner to design successful products. These stages include:

The Design Brief

A statement of intent, the design brief states the problem to be addressed. It serves as a starting point from where the design team can orient themselves. By itself however, it does not offer sufficient information with which to begin the actual design process.

The Product Design Specification (PDS)

A vitally important but often overlooked and misunderstood stage; the PDS document lists the problem in detail. Before working on producing a solution, there needs to be a deep understanding of the actual problem identified. This document should be designed after conversations with the customer and an analysis of the market and competitors. The design team should refer back to it often for correct orientation at later stages.

The Concept Design

With the PDS document as a guide, the design team will now begin to outline a solution. At this stage, the design is largely conceptual, with a framework of key components in place with details to a later stage. The details included at this stage will depend on the type of product being designed. It is important to understand both upstream and downstream concerns relating to the product at this point. These may include activities such as manufacturing, sales and production costs among other things. This early understanding of the value chain will help eliminate or reduce rework and multiple iterations.

In this stage, concept generation and evaluation are both a vital consideration. Multiple concepts, each fulfilling the product requirements previously identified are identified and then evaluated to decide the best way forward.

The Concept Generation

At this point, a design team may involve a larger audience to help brainstorm the details of concepts drawn up in the previous stage. A group that includes various expertises may end up being the most successful in terms of creative ideas and solutions. It is pertinent to encourage all ideas to be voiced as these increases the chances of innovation.

The Concept Evaluation

With a number of potential concepts in hand, a suitable design now needs to be chosen that fulfills the product design specifications previously generated. This document should serve as a basis for final design decisions. Again, a multi skilled team should be involved here so that all angles of the chosen design can be evaluated. The concept that is closest in solving the problem identified and fulfils the most design requirements will now be developed in detail.

The Detailed Design

At this point, the final concept has been chosen and most obvious kinks have been worked out. The concept is now designed in detail with the necessary dimensions and specifications. At this stage, it may be important to produce one of more prototypes to test the product in close to real scenarios. It becomes vital for the design team to work in close cooperation with other units such as manufacturing and logistics to ensure the practical aspects of production and supply.

Eliminating Design Iterations

Although traditionally sequential, multiple iterations within these stages can be reduced by asking the following questions:

- Manufacturing – Can we make the product at our existing facility?
- Sales – Are we able to produce what the customer wants?
- Purchasing – Do we have required parts available or do they need to be ordered?
- Cost – What will the design cost us to make?
- Transport – is the product sized for available transportation methods? Will there be any special transportation needs?
- Disposal – How will the product be disposed of at the end of its life?

Product Design Types

Two basic categories encompass most product designs. These are:

Demand – Pull Innovation

Demand – Pull happens when a product design can directly take advantage of an opportunity in the market. A new design works towards solving an existing design issue. This happens either through a new product or a variation of an existing product.

Invention – Push Innovation

This innovation occurs with advancement in technology or intelligence. This is driven through research or a creative new product design.

Factors Affecting Product Design

Cost

One major factor that affects product design is the cost of production including material costs and labor costs. These in turn affect the pricing strategy, which needs to be in line with what the customer is prepared to pay for it.

Ergonomics

The product needs to be user friendly and afford convenience in its function. Using ergonomic measurements, minor or major changes may need to be made to product design to meet essential requirements.

Materials

Whether the requisite materials are available easily is an important consideration in product design. In addition, an eye needs to be kept on new developments in materials and technology.

Customer Requirements

One major and obvious influence on the design on the product is the customer and their requirements. It is vital to capture customer feedback on any prototype as well as during the planning and conceptual stages. Even a technologically advanced and exciting feature may need to be removed if it causes dislike or negative feelings in an end user.

Company Identity

The company's identity is a point of pride and as a matter of course, a product's very design or color schemes and features may be determined by this identity. The logo may need to be featured in a specific manner or subtle or overt features of the company identity may need to be built into the design.

Aesthetics

The product may need to appear stylish or of a certain shape. This form may end up determining the technology that it built into the product. This may in turn also affect the manufacturing process that needs to be followed.

Fashion

The current fashion and trends may also affect a certain product's design. Customers will want the most updated options and this need to be considered during product design.

Culture

If a product is for a certain market with its own individual culture, this needs to be kept in mind during product design. A product acceptable in one culture may end up being offensive or not desirable in another one.

Functions

How many problems is the product trying to solve? The number of uses and functions a product has will impact its design.

Environment

Another consideration to product design is its impact on the environment. The average customer these days may be more discerning and concerned about the environment than before. Things to consider here may include whether the materials used are recyclable, how the product will be disposed of at the end of its life or how the packaging can be disposed of.

Consideration in Product Design

Product design is a complex process, since all the relevant stakeholders have different requirements from the product. Examples of conflicting needs that will require attention during product design are:

Economic Viability

The manufacturer will want the product to be created at the lowest cost possible, in order to maximize profit and ensure sales. A prohibitively expensive product will have higher price tag and may drive away customers. Often, this may mean a product redesign or a compromise on quality.

Price, Appearance and Prestige Value

The customer will always want a well presented product with a functional yet aesthetically appealing design. They will also want it to be priced reasonably. The appearance may not always be vital to function, but if there are multiple nearly similar products in the market, the look of the product may become the deciding factor.

Functionality

There needs to be equal focus on the functionality of the product or how well it performs. This is a given as the product foremost needs to perform as it claims to. The end user may purchase for the external appearance. But long term satisfaction and repeat usage will only occur if the product performs at an optimal level.

Maintenance

Product designers, manufacturers and maintenance workers may all favor a modular construction for a product. The more easily different parts can be worked on individually, the more versatility the product offers. A re-design effort may only need to focus on changing certain parts rather than the whole, the manufacturer can easily tweak elements without changing entire production processes and maintenance workers may not need to disassemble everything, thereby reducing repair time and effort.

Product Development

Product development, also known as new product development or management, is a sequential order of steps which involves the idea generation, screening, designing, developing and marketing of newly produced or newly rebranded products or services. The motive behind product development is to grow, sustain and enhance market share of a company by meeting demands of consumers. Defining the target market for a product or service must occur earlier in the process of product development because every product is not meant for every client or customer segment. The necessity of conducting a quantitative market research at each and every step of the product development process is undeniable.

Basic Methods of Product Development

Product development is a creative process but it needs a systematic method to direct the process of getting a new product or service properly. The Product Development and Management Association (PDMA) and the Product Development Institute (PDI) stated guidelines to decide the best method for the development of new product or service. A method or framework aids in structuring the process of a particular product development.

Three basic product development methods are:

- Fuzzy Front End (FFE) Method
- Design Thinking Method
- Development Method for Manufactured Goods

Fuzzy Front End (FFE) Method

Fuzzy Front End (FFE) product development method, states the steps to be followed but the sequence of the steps will be decided by the management or marketing team depending on the type of the product or service which will be developed. The five steps of FFE method are:

Identifying the Design Criteria

In this step brainstorming of different ideas is conducted regarding the probable new products or services and a prospective product idea is identified from them. Only then an appropriate product development strategy can be applied.

Analyzing the Idea

This step requires an intense analysis of the product idea or concept. The feasibility or relevance of the business context to the business firm or to the consumer is determined by concept studies and market research.

Concept Generation

In this step, an identified or selected product idea or opportunity is transformed into a concrete or real concept.

Prototyping

Prototypes refer to the first and preliminary versions of any product or device which will be tested further and then marketed. At this step, rapid prototypes for the product concept are created instead of the final model of the product.

Product Development

The product development step ensures that the identified concept of the product has been assembled well with business value to make business sense.

Design Thinking Method

Design thinking method has repetitive steps designed to be followed in a certain order for the purpose of promoting collaboration and creativity. The five steps of design thinking method are:

1. Empathizing: The problem should be emphasized by learning about it from different points of views.
2. Defining: Defining the area and actual characteristic of the problem.
3. Generating Idea: Brainstorming to find the best solutions to solve the problem.
4. Prototyping: Eliminating useless or illogical solutions.
5. Testing: Asking for feedback.

Development Method for Manufactured Goods

Development method for manufactured goods has eight important steps:

Step 1: Generating idea

Generating idea is the continued methodical research for new product opportunities as well as updating the current product.

Step 2: Screening idea

Screening idea eliminates the infeasible and illogical product ideas through open-minded thinking.

Step 3: Developing and testing concept

Developing and testing concept is important. The idea or concept of the product must be examined or tested through customer feedback at this step. The product concept can be further developed on the basis of this feedback.

Step 4: Business analysis/marketing strategy

Business analysis/marketing strategy is basically founded on four P's, which are: product, price, placement, and promotion.

1. Product: The product or service designed to meet the demand of a target segment.
2. Price: Decisions regarding pricing have an impact on demand, supply, marketing strategy and profit margins.
3. Placement: Product placement is a technique of advertising applied by business companies to beautifully promote their products or services by appearing in a TV program, film or on other media.
4. Promotion: The objectives of promotion are to communicate information about the product to the target segment, describe the product's value and enhancing the demand for the product. Promotion consists of different kinds of advertisements, marketing campaigns and, public relations.

Step 5: Feasibility study/analysis

Feasibility study/analysis provides information that analyzes the critical factors affecting the success of the product. It involves arranging different segments of people that will test a prototype of the product and then evaluate the feedback. This feedback states the target segment's interest, experience, and expected product features and also the profitability and viability of the product in development.

Step 6: Product development/Product technical design

Product development/Product technical design combines the outcomes of the feasibility analyses. At this stage, the prototype of the product is turned into a suitable final product based on the feedback of the feasibility study by eliminating the shortcomings of the product and organizing and modifying the departments engaged in the product launch e.g. finance production or operations, research and development, marketing etc.

Step 7: Market testing or, Test marketing

Market testing or, Test marketing, is the next stage. The motive of this stage is to demonstrate the whole concept- marketing, packaging, advertising, and distribution.

Step 8: Commercialization/market entry

Commercialization/market entry is the phase where the final product is introduced to the target market segment. The entire information collected through the aforementioned seven stages of this method is utilized to produce market and distribute the final product.

Product development is an ever-changing process depending on the nature of the product or the manager who is managing the process. Some organizations have a dedicated team that conducts researches and tests on new products, while smaller organizations may outsource the new product development to a marketing agency.

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6

Quality Management and Control

The action of overseeing all activities and tasks which are needed to maintain a desired degree of excellence is known as quality management. The process through which the quality of the different factors which are a part of production are reviewed is known as quality control. This chapter closely examines the key concepts of quality management and control to provide an extensive understanding of the subject.

Quality management is the act of overseeing different activities and tasks within an organization to ensure that products and services offered, as well as the means used to achieve them are consistent. It helps to achieve and maintain a desired level of quality within the organization.

Quality management consists of four key components, which include:

- Quality Planning – The process of identifying the quality standards relevant to the project and deciding how to meet them.
- Quality Improvement – The purposeful change of a process to improve the confidence or reliability of the outcome.
- Quality Control – The continuing effort to uphold a process' integrity and reliability in achieving an outcome.
- Quality Assurance – The systematic or the planned actions necessary to offer sufficient reliability that a particular service or product will meet the specified requirements.

The aim of quality management is to ensure that all the organization's stakeholders work together to improve the company's processes, products, services, and culture to achieve the long-term success that stems from customer satisfaction.

The process of quality management involves a collection of guidelines that are developed by a team to ensure that the products and services that they produce are of the right standards or fit for purpose. The process starts when the organization sets quality targets to be met and which are agreed upon with the customer. The organization then defines how the targets will be measured. It then takes the actions that are required to measure the quality. They then identify any quality issue that arises and initiates improvements. The final step involves reporting the overall level of the quality achieved. The process ensures that the products and services produced by the team match the customers' expectations.

The quality improvement methods comprise three components: product improvement, process improvement, and people-based improvement. There are numerous methods of quality management and techniques that can be utilized. They include Kaizen, Zero Defect Programs, Six Sigma, Quality Circle, Taguchi Methods, the Toyota Production System, Kansei Engineering, TRIZ, BPR, OQRM, ISO, and Top Down & Bottom Up approaches among others.

A model example of great quality management is the implementation of the Kanban system by Toyota Corporation. Kanban is an inventory control system that was developed by Taiichi Ohno to create visibility for both the suppliers and buyers to help limit the upsurge of excess inventory on the production line at any given point in time. Toyota used the concept to execute its Just-in-time (JIT) system, which helps aligns raw material orders from suppliers directly with the production schedules. Toyota's assembly line rose in efficiency and the company received enough inventories at hand to meet customer orders as they were being generated.

Principles of Quality Management

There are several principles of quality management that the International Standard for Quality Management adopts. These principles are used by top management to guide an organization's processes towards improved performance. They include:

Customer Focus

The primary focus of any organization should be to meet and exceed the customers' expectations and needs. When an organization can understand the customers' current and future needs and cater to them, it results in customer loyalty, which in turn increases revenue. The business is also able to get new customer opportunities and satisfy them. When business processes are more efficient, quality is higher and more customers can be satisfied.

Leadership

Good leadership results in an organization's success. Great leadership establishes unity and purpose among the workforce and shareholders. Creating a thriving company culture provides an internal environment that allows employees to fully utilize their potential and get actively involved in achieving its objectives. The leaders should involve the employees in setting clear organization goals and objectives. It motivates employees, who can significantly improve their productivity and loyalty.

Engagement of People

Staff involvement is another fundamental principle. The management engages staff in creating and delivering value whether they are full-time, part-time, outsourced or in-house. An organization should encourage the employees to constantly improve their skills and maintain consistency. This principle also involves empowering the employees, involving them in decision making and recognizing their achievements. When people are valued, they work to their best potential because it boosts their confidence and their motivation. When employees are wholly involved, it makes them feel empowered and accountable for their actions.

Process Approach

The performance of an organization is crucial according to the process approach principle. The approach emphasizes on achieving efficiency and effectiveness in the organizational processes. The approach entails an understanding that good processes result in improved consistency, quicker activities, reduced costs, waste removal and continuous improvement. An organization is enhanced when leaders can manage and control the inputs and the outputs of an organization, as well as the processes used to produce the outputs.

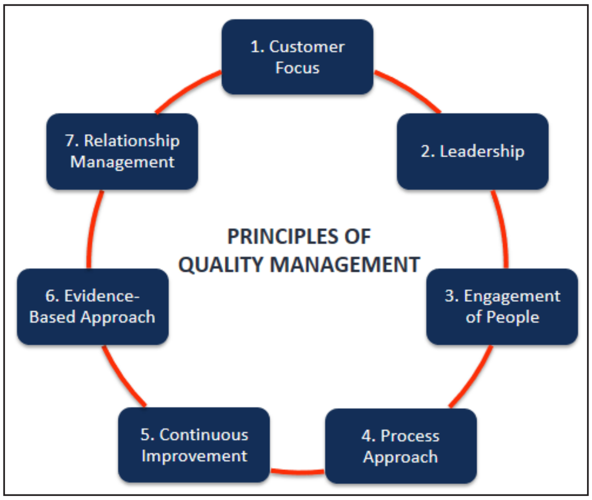
Continuous Improvement

Every organization should come up with an objective to be actively involved in continuous improvement. Businesses that improve continually experience improved performance, organizational flexibility and increased ability to embrace new opportunities. Businesses should be able to create new processes continually and adapt to new market situations.

Evidence-based Decision Making

Businesses should adopt a factual approach to decision-making. Businesses that make decisions based on verified and analyzed data have an improved understanding of the marketplace. They are able to perform tasks that produce desired results and even justify their past decisions. Factual decision making is vital to help understand the cause-and-effect relationships of different things and even explain potential unintended results and consequences.

Relationship Management



Relationship management is about creating mutually beneficial relations with supplier and retailers. Different interested parties can impact the company's performance. The organization should manage the supply chain process well and promote the relationship between the organization and its suppliers to optimize their impact on the company's performance. When an organization manages its relationship with interested parties well, it is more likely to achieve sustained business collaboration.

Benefits of Quality Management

- It helps an organization achieve greater consistency in tasks and activities that are involved in the production of products and services.
- It increases efficiency in processes, reduces wastage and improves the use of time and other resources.
- It helps improve customer satisfaction.
- It enables businesses to market their business effectively and exploit new markets.
- It makes it easier for businesses to integrate new employees and thus helps businesses manage growth more seamlessly.
- It enables a business to continuously improve their products, processes, and systems.

Total Quality Management

Total Quality Management is mainly concerned with continuous improvement in all work. It is a long term planning. It is the consistent improvement in the quality. It is a never ending process. Total Quality Management consists of three words: Total, Quality and Management.

- Total: Make up of the whole.
- Quality: Degree of excellence a product or service provides.
- Management: It is a process of planning, organising, directing and controlling.

Therefore, TQM is the art of managing the whole to achieve excellence. TQM covers all the set rules, regulations, guidelines and principles that contribute in improving the organization continuously. It is a continuous process of improvement for individuals, groups of people and the whole organisation. It is the application of quantitative methods and human resources to improve all the processes within an organization to satisfy the needs of customers consistently. TQM integrates all the fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach. It covers the most quality principles and practices proposed by quality gurus.

Total Quality Management (TQM) is a management approach for an organization, centered on quality, based on the participation and commitment of all the internal and external customers and aiming at strategically long-term success through customer satisfaction, and benefits to all members of the organization and to society.

Total Quality Management (TQM) is a top-management strategy aimed at embedding awareness of quality in all organizational processes.

Total Quality Management is a total system approach and it is an integral part of the strategic decision making of the top management. It works horizontally across all the functions and departments. It involves all the employees of three levels, i.e., top level, middle level and bottom level. It extends backward and forward and covers supply chain management as well as logistics management also. So, we can say that it is a consistent effort by everyone in the organisation to meet the expectations of the customers leading 100 per cent satisfaction. TQM requires that the company maintain the quality standard in all aspects of its business. This requires ensuring that things are done right the first time and that defects and waste are eliminated from operations.

Characteristics or Nature of TQM

TQM Starts from Top Management

The quality concept is initiated by the top management. The whole credit of the initiation of total quality management goes to the top management. Only the top management can create an environment that develops team-oriented environment and creates quality oriented culture that can prevent problems and continually improve.

It is a Consistent Process

To produce quality product and service is not an easy job. Sometimes it takes years to give the desired results. All the employees have to work consistently as a team in one direction to improve all the processes in the organisation.

It is a Part of Strategic Planning and Thinking

TQM policy is a long term planning. The quality policy must be the part of strategic planning to get the desired results.'

It is Customer Focused or Oriented

The end result of TQM is complete satisfaction of customers by giving them quality products and services. It is possible only when TQM programme is customer centric.

It is a Team Work

Success in terms of standard quality is possible only when the organizations has a culture of team formation and the employees work in teams and give their maximum. Teams can be formed vertically and horizontally. When top management is involving the lower level employees it is vertically and when the different departmental employees are involved then it is horizontally (employees of marketing, sales, production and finance departments are working for critical and complex projects). Teams are inter-organisational when the employees of other organisations are involved (like employees of banks, suppliers, audit companies, consultants etc.

It is Related with Consistent Improvement of Quality

To deliver quality products and services is not an easy job. All the processes have to be developed and standardised by consistent improvement.'

Every Employee is Involved in Quality Improvement Aspect

All the employees internal as well as external are involved in the TQM programme. Internal employees include all the employees included from top to bottom and external employees are suppliers, banks and other institutions which are involved in the TQM process.

Every Employee is Responsible for the Success of TQM

If all the employees are determined and committed for the quality products and services, then only quality could be delivered.

The TQM Practices Followed by Multinational Companies

All the MNC's like Sony, Toyota, Xerox, Motorola follow the Total Quality Management practices. The salient features of TQM approach followed by the best companies are as following:

- The companies create a sense of an environment of mutual trust, respect and dignity.
- The management act immediately on new ideas and suggestions.
- The companies are meeting and exceeding customers' requirements and expectations on consistent basis.
- The companies hear and learn from the dissatisfied/unhappy customers and responsible for complete customer satisfaction.
- The companies are committed to their both internal as well as external employees. They know the value of workers' involvement and intensive training.
- The companies develop the teams to have broad decision –making powers and responsibilities.
- They apologize for the complaints.
- The companies know that labour-management relations could do more for quality and productivity.
- The companies empower their employees to make them responsible.
- The companies implement statistical process control and monitor defect rates.

Approaches to Total Quality Management

Deming's Approach to TQM

The theoretical essence of the Deming approach to TQM concerns the creation of an organizational system that fosters cooperation and learning for facilitating the implementation of process management practices, which, in turn, leads to continuous improvement of processes, products, and services as well as to employee fulfillment, both of which are critical to customer satisfaction, and ultimately, to firm survival. Deming stressed the responsibilities of top management to take the lead in changing processes and systems. Leadership plays in ensuring the success of quality management, because it is the top management's responsibility to create and communicate a vision to move the firm toward continuous improvement. Top management is responsible for most quality problems; it should give employees clear standards for what is considered acceptable work, and provide the methods to achieve it. These methods include an appropriate working environment and climate for work-free of faultfinding, blame or fear. Deming also emphasized the importance of identification and measurement of customer requirements, creation of supplier partnership, use of functional teams to identify and solve quality problems, enhancement of employee skills, participation of employees, and pursuit of continuous improvement. Anderson et al. developed a theory of quality management underlying the Deming management method. They proposed that: The effectiveness of the Deming management method arises from leadership efforts toward the simultaneous creation of a cooperative and learning organization to facilitate the implementation of process-management practices, which, when implemented, support customer satisfaction and organizational survival through sustained employee fulfillment and continuous improvement of processes, products, and services.

The means to improve quality lie in the ability to control and manage systems and processes properly, and in the role of management responsibilities in achieving this. Deming (1986) advocated methodological practices, including the use of specific tools and statistical methods in the design, management, and improvement of process, which aim to reduce the inevitable variation that occurs from “common causes” and “special causes” in production. “Common causes” of variations are systemic and are shared by many operators, machines, or products. They include poor product design, non-conforming incoming materials, and poor working conditions. These are the responsibilities of management. “Special causes” relate to the lack of knowledge or skill, or poor performance. These are the responsibilities of employees. Deming proposed 14 points as the principles of TQM, which are listed below:

1. Create constancy of purpose toward improvement of product and service, with the aim to become competitive and to stay in business, and to provide jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on mass inspection to quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.
4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.
5. Improve constantly and forever the system of production and service, to improve quality and productivity, and thus constantly decrease costs.
6. Institute training on the job.
7. Institute leadership. The aim of supervision should be to help people and machines and gadgets to do a better job. Supervision of management is in need of overhaul, as well as supervision of production workers.
8. Drive out fear, so that people may work effectively for the company.

9. Break down barriers between departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations, and targets for the workforce asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the workforce.
11. Eliminate work standards (quotas) on the factory floor. Substitute leadership. (b) Eliminate management by objective. Eliminate management by numbers, numerical goals. Substitute leadership.
12. Remove barriers that rob the hourly worker of his right to pride of workmanship. The responsibility of supervisors must be changed from sheer numbers to quality. (b) Remove barriers that rob people in management and in engineering of their right to pride of workmanship. This means, inter alia, abolishment of the annual or merit rating and of management by objective.
13. Institute a vigorous program of education and self-improvement.
14. Put everybody in the company to work to accomplish the transformation. The transformation is everybody's job.

Juran's Approach to TQM

TQM is the system of activities directed at achieving delighted customers, empowered employees, higher revenues, and lower costs. Juran believed that main quality problems are due to management rather than workers. The attainment of quality requires activities in all functions of a firm. Firm-wide assessment of quality, supplier quality management, using statistical methods, quality information system, and competitive benchmarking are essential to quality improvement. Juran's approach is emphasis on team (QC circles and self-managing teams) and project work, which can promote quality improvement, improve communication between management and employees coordination, and improve coordination between employees. He also emphasized the importance of top management commitment and empowerment, participation, recognition and rewards.

According to Juran, it is very important to understand customer needs. This requirement applies to all involved in marketing, design, manufacture, and services. Identifying customer needs requires more vigorous analysis and understanding to ensure the product meets customers' needs and is fit for its intended use, not just meeting product specifications. Thus, market research is essential for identifying customers' needs. In order to ensure design quality, he proposed the use of techniques including quality function deployment, experimental design, reliability engineering and concurrent engineering.

Juran considered quality management as three basic processes (Juran Trilogy): Quality control, quality improvement, and quality planning. In his view, the approach to managing for quality consists of: The sporadic problem is detected and acted upon by the process of quality control; The chronic problem requires a different process, namely, quality improvement; Such chronic problems are traceable to an inadequate quality planning process. Juran defined a universal sequence of activities for the three quality processes, which is listed in table.

Juran defined four broad categories of quality costs, which can be used to evaluate the firm's costs related to quality. Such information is valuable to quality improvement. The four quality costs are listed as follows:

- Internal failure costs (scrap, rework, failure analysis, etc.), associated with defects found prior to transfer of the product to the customer;
- External failure costs (warranty charges, complaint adjustment, returned material, allowances, etc.), associated with defects found after product is shipped to the customer;
- Appraisal costs (incoming, in-process, and final inspection and testing, product quality audits, maintaining accuracy of testing equipment, etc.), incurred in determining the degree of conformance to quality requirements;
- Prevention costs (quality planning, new product review, quality audits, supplier quality evaluation, training, etc.), incurred in keeping failure and appraisal costs to a minimum.

Table: Universal Processes for Managing Quality

Quality planning	Quality control	Quality improvement
Establish quality goals Identify customers Discover customer needs Develop product features Develop process features Establish process controls transfer to operations	Choose control subjects Choose units of measure Set goals Create a sensor Measure actual performance Interpret the difference Take action on the difference	Prove the need Identify projects Organize project teams Diagnose the causes Provide remedies, prove remedies are effective Deal with resistance to change Control to hold the gains

Crosby's Approach to TQM

Crosby identified a number of important principles and practices for a successful quality improvement program, which include, for example, management participation, management responsibility for quality, employee recognition, education, reduction of the cost of quality (prevention costs, appraisal costs, and failure costs), emphasis on prevention rather than after-the-event inspection, doing things right the first time, and zero defects. Crosby claimed that mistakes are caused by two reasons: Lack of knowledge and lack of attention. Education and training can eliminate the first cause and a personal commitment to excellence (zero defects) and attention to detail will cure the second. Crosby also stressed the importance of management style to successful quality improvement. The key to quality improvement is to change the thinking of top managers-to get them not to accept mistakes and defects, as this would in turn reduce work expectations and standards in their jobs. Understanding, commitment, and communication are all essential. Crosby presented the quality management maturity grid, which can be used by firms to evaluate their quality management maturity. The five stages are: Uncertainty, awakening, enlightenment, wisdom and certainty. These stages can be used to assess progress in a number of measurement categories such as management understanding and attitude, quality organization status, problem handling, cost of quality as percentage of sales, and summation of firm quality posture. The quality management maturity grid and cost of quality measures are the main tools for managers to evaluate their quality status. Crosby offered a 14-step program that can guide firms in pursuing quality improvement. These steps are listed as follows:

1. Management commitment: To make it clear where management stands on quality.
2. Quality improvement team: To run the quality improvement program.
3. Quality measurement: To provide a display of current and potential nonconformance problems in a manner that permits objective evaluation and corrective action.
4. Cost of quality: To define the ingredients of the cost of quality, and explain its use as a management tool.
5. Quality awareness: To provide a method of raising the personal concern felt by all personnel in the company toward the conformance of the product or service and the quality reputation of the company.
6. Corrective action: To provide a systematic method of resolving forever the problems that are identical through previous action steps.
7. Zero defects planning: To investigate the various activities that must be conducted in preparation for formally launching the Zero Defects program.
8. Supervisor training: To define the type of training that supervisors need in order to actively carry out their part of the quality improvement program.
9. Zero defects day: To create an event that will make all employees realize, through a personal experience, that there has been a change.
10. Goal setting: To turn pledges and commitment into actions by encouraging individuals to establish improvement goals for themselves and their groups.
11. Error causal removal: To give the individual employee a method of communicating to management the situation that makes it difficult for the employee to meet the pledge to improve.
12. Recognition: To appreciate those who participate.
13. Quality councils: To bring together the professional quality people for planned communication on a regular basis.
14. Do it over again: To emphasize that the quality improvement program never ends.

Feigenbaum's Approach to TQM

Feigenbaum defined TQM as: An effective system for integrating the quality development, quality-maintenance, and quality-improvement efforts of the various groups in a firm so as to enable marketing, engineering, production, and service at the most economical levels which allow for full customer satisfaction. He claimed that effective quality management consists of four main stages, described as follows:

- Setting quality standards;

- Appraising conformance to these standards;
- Acting when standards are not met;
- Planning for improvement in these standards.

The quality chain, he argued, starts with the identification of all customers' requirements and ends only when the product or service is delivered to the customer, who remains satisfied. Thus, all functional activities, such as marketing, design, purchasing, manufacturing, inspection, shipping, installation and service, etc., are involved in and influence the attainment of quality. Identifying customers' requirements is a fundamental initial point for achieving quality. He claimed that effective TQM requires a high degree of effective functional integration among people, machines, and information, stressing a system approach to quality. A clearly defined total quality system is a powerful foundation for TQM. Total quality system is defined as follows:

> "The agreed firm-wide operating work structure, documented in effective, integrated technical and managerial procedures, for guiding the coordinated actions of the people, the machines, and the information of the firm in the best and most practical ways to assure customer quality satisfaction and economical costs of quality."

Feigenbaum emphasized that efforts should be made toward the prevention of poor quality rather than detecting it after the event. He argued that quality is an integral part of the day-today work of the line, staff, and operatives of a firm. There are two factors affecting product quality: The technological-that is, machines, materials, and processes; and the human-that is, operators, foremen, and other firm personnel. Of these two factors, the human is of greater importance by far. Feigenbaum considered top management commitment, employee participation, supplier quality management, information system, evaluation, communication, use of quality costs, use of statistical technology to be an essential component of TQM. He argued that employees should be rewarded for their quality improvement suggestions, quality is everybody's job. He stated that effective employee training and education should focus on the following three main aspects: Quality attitudes, quality knowledge, and quality skills.

Ishikawa's Approach to TQM

Ishikawa argued that quality management extends beyond the product and encompasses after-sales service, the quality of management, the quality of individuals and the firm itself. He claimed that the success of a firm is highly dependent on treating quality improvement as a never-ending quest. A commitment to continuous improvement can ensure that people will never stop learning. He advocated employee participation as the key to the successful implementation of TQM. Quality circles, he believed, are an important vehicle to achieve this. Like all other gurus he emphasized the importance of education, stating that quality begins and ends with it. He has been associated with the development and advocacy of universal education in the seven QC tools. These tools are listed below:

- Pareto chart;
- Cause and effect diagram (Ishikawa diagram);
- Stratification chart;

- Scatter diagram;
- Check sheet;
- Histogram;
- Control chart.

Ishikawa suggested that the assessment of customer requirements serves as a tool to foster cross-functional cooperation; selecting suppliers should be on the basis of quality rather than solely on price; cross-functional teams are effective ways for identifying and solving quality problems. Ishikawa's concept of TQM contains the following six fundamental principles:

- Quality first-not short-term profits first;
- Customer orientation-not producer orientation;
- The next step is your customer-breaking down the barrier of sectionalism;
- Using facts and data to make presentations-utilization of statistical methods;
- Respect for humanity as a management philosophy, full participatory management;
- Cross-functional management.

Cost of Quality

Cost of Quality is a methodology used to define and measure where and what amount of an organization's resources are being used for prevention activities and maintaining product quality as opposed to the costs resulting from internal and external failures. The Cost of Quality can be represented by the sum of two factors. The Cost of Good Quality and the Cost of Poor Quality equals the Cost of Quality, as represented in the basic equation below:

$$CoQ = CoGQ + Co$$

The Cost of Quality equation looks simple but in reality it is more complex. The Cost of Quality includes all costs associated with the quality of a product from preventive costs intended to reduce or eliminate failures, cost of process controls to maintain quality levels and the costs related to failures both internal and external.

Reasons to Implement Cost of Quality

Effective use and implementation of Cost of Quality methodology enables an organization to accurately measure the amount of resources being used for Cost of Good Quality and Cost of Poor Quality. With this valuable information the organization can determine where to allocate resources to improve product quality and the bottom line. To further illustrate the value of cost of quality, review the following example. The name of the company has been changed but the content represents actual events and results.

Alpha Company once measured Cost of Quality as the amount of warranty cost versus total sales. This method only examined the Cost of Poor Quality. This data did reveal a problem area in the facility. It was discovered that customer part shortages originating from one work cell were resulting in warranty costs of over $400,000 in one year. A team was formed to investigate and perform Root Cause Analysis (RCA) of the shortages and a plan was developed to redesign the work cell for an estimated cost of $60,000. With management approval, the work cell was redesigned with a revised layout, pick bins, dedicated locations for all the parts, process controls were defined and implemented and several additional improvements were made. The changes reduced tact times and the number of operators required for the process. This provided resources for the addition of quality technicians to regularly audit and maintain the process on all shifts. Within the first year of operation, shortages were reduced by 50% equalling a $200,000 reduction in warranty costs. The project resulted in a positive impact on the bottom line of $140,000 in the first year. Alpha Company has since implemented processes to measure and reduce scrap, improved process controls and introduced new quality metrics throughout the organization. They are now actively measuring and evaluating both the cost of good quality and poor quality.

In the example above, the Cost of Poor Quality (CoPQ) was having a major impact on the bottom line. Through an investment in the Cost of Good Quality (CoGQ), Alpha Company achieved a significant reduction in the Cost of Quality. There are opportunities for improvement in processes at most organizations. It has been estimated that the Cost of Quality usually amounts to between 15-40% of business costs. The goal of implementing Cost of Quality methodology is to maximize product quality while minimizing cost. Cost of Quality methodology provides the detailed information that management needs to accurately evaluate the effectiveness of their quality systems, identify problem areas and opportunities for improvement.

Measurement of Cost of Quality

The methods for calculating Cost of Quality vary from company to company. In many cases, organizations like the one described in the previous example, determine the Cost of Quality by calculating total warranty dollars as a percentage of sales. Unfortunately this method is only looking externally at the Cost of Quality and not looking internally. In order to gain a better understanding, a more comprehensive look at all quality costs is required.

The Cost of Quality can be divided into four categories. They include Prevention, Appraisal, Internal Failure and External Failure. Within each of the four categories there are numerous possible sources of cost related to good or poor quality. Some examples of typical sources of Cost of Quality are listed below.

The Cost of Good Quality (CoGQ)

1. Prevention Costs – costs incurred from activities intended to keep failures to a minimum. These can include, but are not limited to, the following:

    - Establishing Product Specifications,
    - Quality Planning,
    - New Product Development and Testing,

- Development of a Quality Management System (QMS),
- Proper Employee Training.

2. Appraisal Costs – costs incurred to maintain acceptable product quality levels. Appraisal costs can include, but are not limited to, the following:
   - Incoming Material Inspections
   - Process Controls
   - Check Fixtures
   - Quality Audits
   - Supplier Assessments

The Cost of Poor Quality (CoPQ)

3. Internal Failures – costs associated with defects found before the product or service reaches the customer. Internal Failures may include, but are not limited to, the following examples:
   - Excessive Scrap,
   - Product Re-work,
   - Waste due to poorly designed processes,
   - Machine breakdown due to improper maintenance,
   - Costs associated with failure analysis.
4. External Failures – costs associated with defects found after the customer receives the product or service. External Failures may include, but are not limited to, the following examples:
   - Service and Repair Costs,
   - Warranty Claims,
   - Customer Complaints,
   - Product or Material Returns,
   - Incorrect Sales Orders,
   - Incomplete BOMs,
   - Shipping Damage due to Inadequate Packaging.

These four categories can now be applied to the original Cost of Quality equation. Our original equation stated that the Cost of Quality is the sum of Cost of Good Quality and Cost of Poor Quality. This is still true however the basic equation can be expanded by applying the categories within both the Cost of Good Quality and the Cost of Poor Quality.

- The Cost of Good Quality is the sum of Prevention Cost and Appraisal Cost (CoGQ = PC + AC)
- The Cost of Poor Quality is the sum of Internal and External Failure Costs (CoPQ = IFC + EFC)

By combining the equations, Cost of Quality can be more accurately defined, as shown in the equation below:

$$COQ = (PC + AC) + (IFC + EFC)$$

One important factor to note is that the Cost of Quality equation is non-linear. Investing in the Cost of Good Quality does not necessarily mean that the overall Cost of Quality will increase. In fact, when the resources are invested in the right areas, the Cost of Quality should decrease. When failures are prevented/detected prior to leaving the facility and reaching the customer, Cost of Poor Quality will be reduced.

Quality Control

Quality Control (QC) may be defined as a system that is used to maintain a desired level of quality in a product or service. It is a systematic control of various factors that affect the quality of the product. It depends on materials, tools, machines, type of labor, working conditions etc. QC is a broad term, it involves inspection at particular stage but mere inspection does not mean QC. As opposed to inspection, in quality control activity emphasis is placed on the quality future production. Quality control aims at prevention of defects at the source, relies on effective feedback system and corrective action procedure. Quality control uses inspection as a valuable tool.

According to Juran "Quality control is the regulatory process through which we measure actual quality performance, compare it with standards, and act on the difference". Another definition of quality control is from ANSI/ASQC standard quality control is defined as "The operational techniques and the activities which sustain a quality of product or service that will satisfy given needs; also the use of such techniques and activities".

Alford and Beatty define QC as "In the broad sense, quality control is the mechanism by which products are made to measure up to specifications determined from customers, demands and transformed into sales engineering and manufacturing requirements, it is concerned with making things right rather than discovering and rejecting those made wrong".

Types of Quality Control

QC is not a function of any single department or a person. It is the primary responsibility of any supervisor to turn out work of acceptable quality. Quality control can be divided into three main sub-areas, those are:

1. Off-line quality control,
2. Statistical process control,
3. Acceptance sampling plans.

Off-line Quality Control

Its procedure deal with measures to select and choose controllable product and process parameters in such a way that the deviation between the product or process output and the standard will be minimized. Much of this task is accomplished through product and process design. Example: Taguchi method, principles of experimental design etc.

Statistical Process Control

SPC involves comparing the output of a process or a service with a standard and taking remedial actions in case of a discrepancy between the two. It also involves determining whether a process can produce a product that meets desired specification or requirements. On-line SPC means that information is gathered about the product, process, or service while it is functional. The corrective action is taken in that operational phase. This is real-time basis.

Acceptance Sampling Plans

A plan that determines the number of items to sample and the acceptance criteria of the lot, based on meeting certain stipulated conditions (such as the risk of rejecting a good lot or accepting a bad lot) is known as an acceptance sampling plan.

Steps in Quality Control

Following are the steps in quality control process:

1. Formulate quality policy.
2. Set the standards or specifications on the basis of customer's preference, cost and profit.
3. Select inspection plan and set up procedure for checking.
4. Detect deviations from set standards of specifications.
5. Take corrective actions or necessary changes to achieve standards.
6. Decide on salvage method *i.e.*, to decide how the defective parts are disposed of, entire scrap or rework.
7. Coordination of quality problems.
8. Developing quality consciousness both within and outside the organization.
9. Developing procedures for good vendor-vendee relations.

Objectives of Quality Control

Following are the objectives of quality control:

1. To improve the companies income by making the production more acceptable to the customers, *i.e.*, by providing long life, greater usefulness, maintainability etc.
2. To reduce companies cost through reduction of losses due to defects.
3. To achieve inter-changeability of manufacture in large scale production.
4. To produce optimal quality at reduced price.

5. To ensure satisfaction of customers with productions or services or high quality level, to build customer goodwill, confidence and reputation of manufacturer.
6. To make inspection prompt to ensure quality control.
7. To check the variation during manufacturing.

The broad areas of application of quality control are incoming material control, process control and product control.

Benefits of Quality Control

- Improving the quality of products and services.
- Increasing the productivity of manufacturing processes, commercial business, and corporations.
- Reducing manufacturing and corporate costs.
- Determining and improving the marketability of products and services.
- Reducing consumer prices of products and services.
- Improving and/or assuring on time deliveries and availability.
- Assisting in the management of an enterprise.

Seven Tools for Quality Control

To make rational decisions using data obtained on the product, or process, or from the consumer, organizations use certain graphical tools. These methods help us learn about the characteristics of a process, its operating state of affairs and the kind of output we may expect from it. Graphical methods are easy to understand and provide comprehensive information; they are a viable tool for the analysis of product and process data. These tools are effect on quality improvement. The seven quality control tools are:

1. Pareto charts
2. Check sheets
3. Cause and effect diagram
4. Scatter diagrams
5. Histogram
6. Graphs or flow charts
7. Control charts

Pareto Charts

Pareto charts help prioritize by arranging them in decreasing order of importance. In an environment of limited resources these diagrams help companies to decide on the order in which they should address problems. The Pareto analysis can be used to identify the problem in a number of forms.

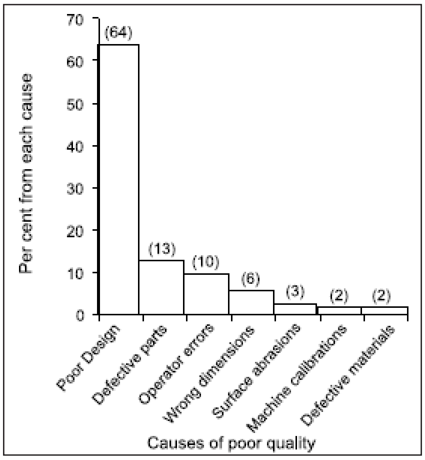
- Analysis of losses by material (number or past number).
- Analysis of losses by process *i.e.*, classification of defects or lot rejections in terms of the process.
- Analysis of losses by product family.
- Analysis by supplier across the entire spectrum of purchases.
- Analysis by cost of the parts.
- Analysis by failure mode.

Example: A Pareto chart of reasons for poor quality. Poor design will be the major reason, as indicated by 64%. Thus, this is the problem that the manufacturing unit should address first.

- Poor Design
- Defective Parts
- Operator Error
- Wrong Dimensions
- Surface Abrasion
- Machine Calibrations
- Defective Material

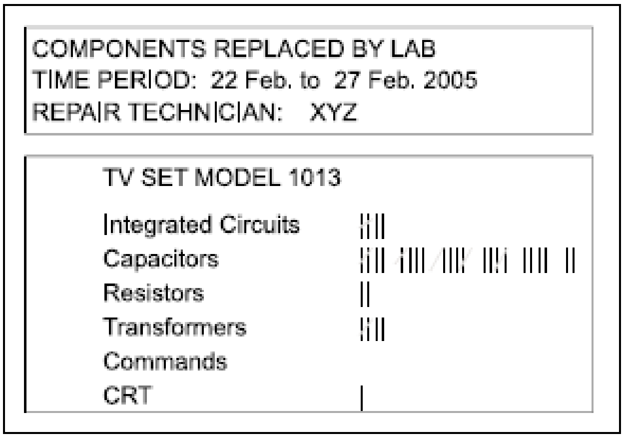
Check Sheets

Check sheets facilitate systematic record keeping or data collection observations are recorded as they happen which reveals patterns or trends. Data collection through the use of a checklist is often the first step in analysis of quality problem. A checklist is a form used to record the frequency of occurrence of certain product or service characteristics related to quality. The characteristics may be measurable on a continuous scale such as weight, diameter, time or length.



Pareto chart

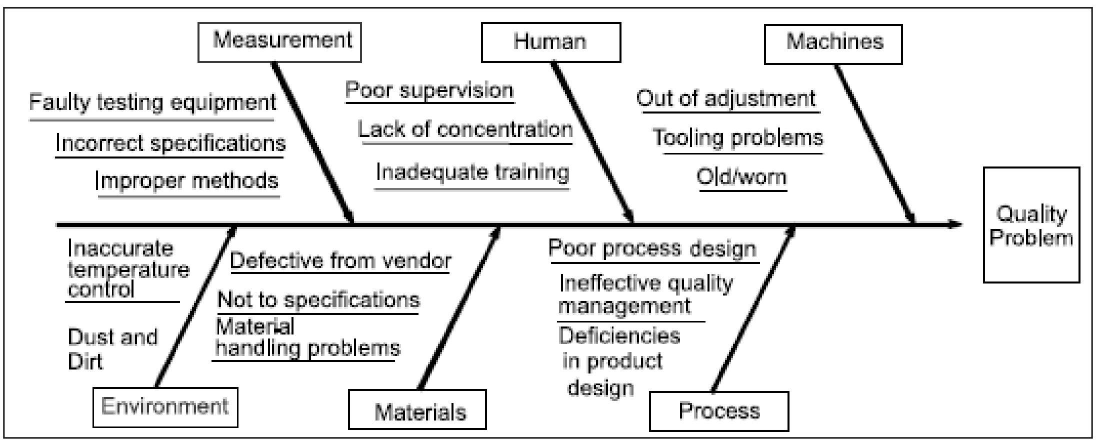
Example: The table is a check sheet for an organization's computer related problems.



Checklist

Cause and Effect Diagram

It is sometimes called as Fish-bone diagram. It is first developed by Kaorv Ishikawa in 1943 and is sometimes called as Ishikawa diagram. The diameter helps the management trace customer complaints directly to the operations involved. The main quality problem is referred to Fish-head; the major categories of potential cause structural bones and the likely specific causes to ribs. It explores possible causes of problems, with the intention being to discover the root causes. This diagram helps identify possible reasons for a process to go out of control as well as possible effects on the process.

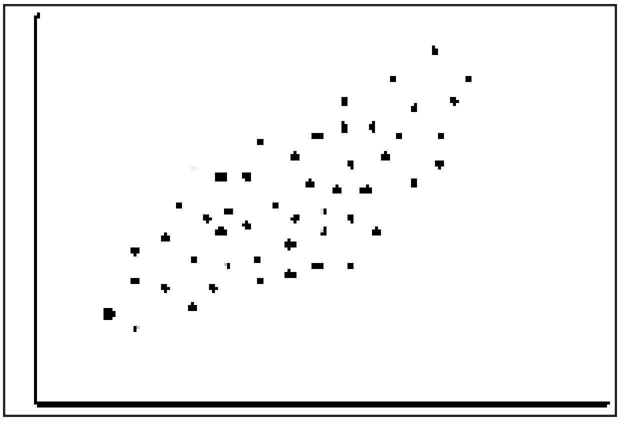


Fishbone diagram

Scatter Diagram (Scatter Plots)

It often indicates the relationship between two variables. They are often used as follow-ups to a cause and effect analysis to determine whether a stated cause truly does impact the quality characteristics.

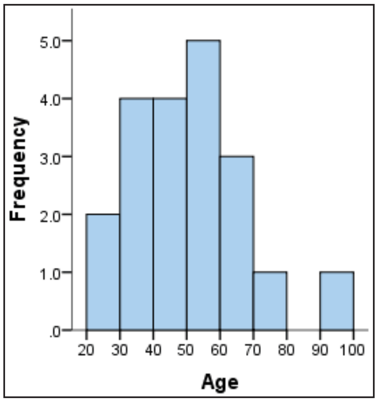
Example: The plots advertising expenditure against company sales and indicates a strong positive relationship between the two variables. As the level of advertising expenditure increases sales tend to increase.



Scatter diagram

Histogram or Bar Charts

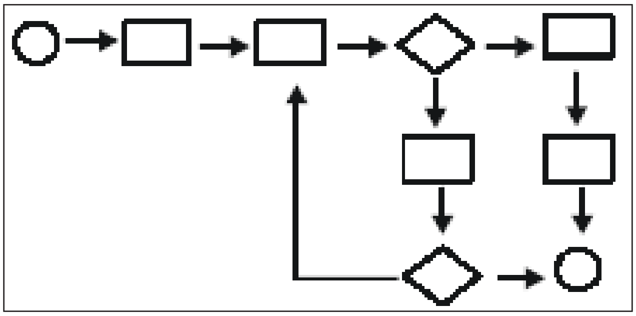
It displays the large amounts of data that are difficult to interpret in their raw form. A histogram summarizes data measured on a continuous scale showing the frequency distribution of some quality characteristics (in statistical terms the central tendency and the dispersion of the data).



Histogram

Often the mean of the data is indicated on the histogram. A bar chart is a series of bare representing the frequency of occurrence of data characteristics, the bar height indicates the number of times a particular quality characteristic was observed.

Flow Charts or Graphs



Flowchart

It shows the sequence of events in a process. They are used for manufacturing and service operations. Flow charts are often used to diagram operational procedures to simplify the system. They can identify bottlenecks, redundant steps and non-value added activities. A realistic flow chart can be constructed by using the knowledge of the person who are directly involved in the particular process. The flow chart can be identifies where delays can occur.

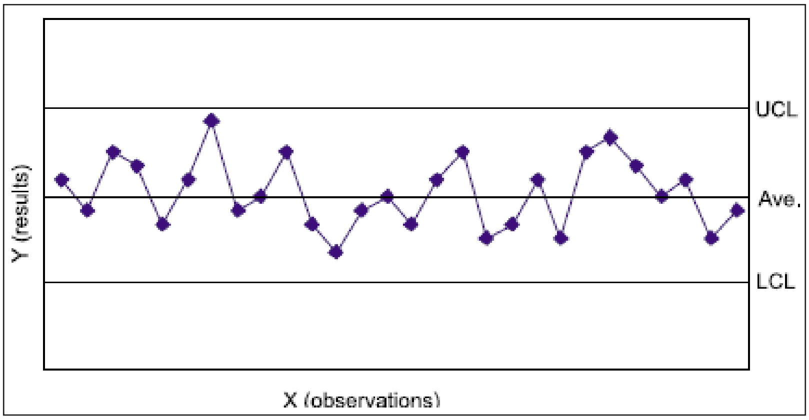
Control Charts

It distinguishes special causes of variations from common causes of variation. They are used to monitor and control process on an on-going basis. A typical control chart plots a selected quality characteristic found from sub-group of observations as a function of sample number.

Characteristics such as sample average, sample range and sample proportion of non-conforming units are plotted. The centre line on a control chart represents the average value of characteristics being plotted. Two limits known as the upper control limit (UCL) and lower control limit (LCL) are also shown on control charts. These limits are constructed so that if the process is operating under a stable system of chance causes, the problem of an observation falling outside these limits is quite small. The following figure shows a generalized representation of a control chart.

Control chart shows the performance of a process from two points of view. *First*, they show a snapshot of the process at the moment the data are collected.

Second, they show the process trend as time progresses. Process trends are important because they help in identifying the out-of-control status if it actually exists. Also, they help to detect variations outside the normal operational limits, and to identify the cause of variations. Fig. shows a generalized representation of a control chart.



Control charts

Causes of Variation in Quality

The variation in the quality of product in any manufacturing process is broadly classified as:

- Chance causes
- Assignable causes

Chance Causes

The chance causes are those causes which are inherit in manufacturing process by virtue of operational and constructional features of the equipments involved in a manufacturing process. This is because of:

1. Machine vibrations,
2. Voltage variations,
3. Composition variation of material, etc.

They are difficult to trace and difficult to control, even under best condition of production. Even though, it is possible to trace out, it is not economical to eliminate. The chance causes results in only a minute amount of variation in process. Variation in chance causes is due to internal factors only the general pattern of variation under chance causes will follow a stable statistical distribution (normal distribution). Variation within the control limits means only random causes are present.

Assignable Causes

These are the causes which creates ordinary variation in the production quality. Assignable cause's variation can always be traced to a specific quality. They occur due to:

1. Lack of skill in operation
2. Wrong maintenance practice
3. New vendors
4. Error in setting jigs and fixtures
5. Raw material defects

Variation due to these causes can be controlled before the defective items are produced. Any one assignable cause can result in a large amount of variation in process. If the assignable causes are present, the system will not follow a stable statistical distribution. When the actual variation exceeds the control limits, it is a signal that assignable causes extend the process and process should be investigated.

Statistic Quality Control

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them. Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

All the tools of SQC are helpful in evaluating the quality of services. SQC uses different tools to analyze quality problem.

1. Descriptive Statistics
2. Statistical Process Control (SPC)
3. Acceptance Sampling

Descriptive Statistics involves describing quality characteristics and relationships. SPC involves inspect random sample of output from process for characteristic. Acceptance Sampling involve batch sampling by inspection.

Objective of Statistical Quality Control

Quality Control is very important for a every company. Quality control includes service quality given to customer, company management leadership, commitment of management, continuous improvement, fast response, actions based on facts, employee participation and a quality driven culture.

The main objectives of the quality control module are to control of material reception, internal rejections, clients, claims, providers and evaluations of the same corrective actions are related to their follow-up. These systems and methods guide all quality activities. The development and use of performance indicators is linked, directly or indirectly, to customer requirements and satisfaction, and to management.

Methodology and Tools of Statistical Quality Control

Statistical Quality Control (SQC) is the term used to describe the set of statistical tools used by quality professionals. SQC is used to analyze the quality problems and solve them. Statistical quality control refers to the use of statistical methods in the monitoring and maintaining of the quality of products and services.

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1. Descriptive Statistics
2. Statistical Process Control (SPC)
3. Acceptance Sampling

Descriptive Statistics involves describing quality characteristics and relationships. SPC involves inspect random sample of output from process for characteristic. Acceptance Sampling involve batch sampling by inspection.

The seven major tools used for Statistical Process Control are:

1. Histogram
2. Pareto Chart
3. Cause and Effect Diagram
4. Defect Concentration Diagram

5. Control Chart
6. Scatter Diagram
7. Check Sheet

Benefits of Statistical Quality Control

1. It provides a means of detecting error at inspection.
2. It leads to more uniform quality of production.
3. It improves the relationship with the customer.
4. It reduces inspection costs.
5. It reduces the number of rejects and saves the cost of material.
6. It provides a basis for attainable specifications.
7. It points out the bottlenecks and trouble spots.
8. It provides a means of determining the capability of the manufacturing process.
9. It promotes the understanding and appreciation of quality control.

Tools of Descriptive Statistics

Descriptive statistics can be useful for two purposes: 1) to provide basic information about variables in a dataset and 2) to highlight potential relationships between variables. The three most common descriptive statistics can be displayed graphically or pictorially and are measures of:

- Graphical/Pictorial Methods
- Measures of Central Tendency
- Measures of Dispersion
- Measures of Association

Graphical or Pictorial Methods

There are several graphical and pictorial methods that enhance researchers' understanding of individual variables and the relationships between variables. Graphical and pictorial methods provide a visual representation of the data. Some of these methods include:

- Histograms
- Scatter plots
- Geographical Information Systems (GIS)
- Sociograms

Histograms

- Visually represent the frequencies with which values of variables occur.
- Each value of a variable is displayed along the bottom of a histogram, and a bar is drawn for each value.
- The height of the bar corresponds to the frequency with which that value occurs.

Scatter Plots

- Display the relationship between two quantitative or numeric variables by plotting one variable against the value of another variable.
- For example, one axis of a scatter plot could represent height and the other could represent weight. Each person in the data would receive one data point on the scatter plot that corresponds to his or her height and weight.

Geographic Information Systems (GIS)

- A GIS is a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location.
- Using a GIS program, a researcher can create a map to represent data relationships visually.

Sociograms

- Display networks of relationships among variables, enabling researchers to identify the nature of relationships that would otherwise be too complex to conceptualize.

Measures of Central Tendency

Measures of central tendency are the most basic and, often, the most informative description of a population's characteristics. They describe the "average" member of the population of interest. There are three measures of central tendency:

- Mean - the sum of a variable's values divided by the total number of values.
- Median - the middle value of a variable.
- Mode - the value that occurs most often.

Example: The incomes of five randomly selected people in the United States are $10,000, $10,000, $45,000, $60,000, and $1,000,000.

- Mean Income = (10,000 + 10,000 + 45,000 + 60,000 + 1,000,000) / 5 = $225,000.
- Median Income = $45,000.
- Modal Income = $10,000.

The mean is the most commonly used measure of central tendency. Medians are generally used when a few values are extremely different from the rest of the values (this is called a skewed distribution). For example, the median income is often the best measure of the average income because, while most individuals earn between $0 and $200,000, a handful of individuals earn millions.

Measures of Dispersion

Measures of dispersion provide information about the spread of a variable's values. There are four key measures of dispersion:

- Range
- Variance
- Standard Deviation
- Skew

Range is simply the difference between the smallest and largest values in the data. The interquartile range is the difference between the values at the 75^{th} percentile and the 25^{th} percentile of the data.

Variance is the most commonly used measure of dispersion. It is calculated by taking the average of the squared differences between each value and the mean.

Standard deviation, another commonly used statistic, is the square root of the variance.

Skew is a measure of whether some values of a variable are extremely different from the majority of the values. For example, income is skewed because most people make between $0 and $200,000, but a handful of people earn millions. A variable is positively skewed if the extreme values are higher than the majority of values. A variable is negatively skewed if the extreme values are lower than the majority of values.

Example: The incomes of five randomly selected people in the United States are $10,000, $10,000, $45,000, $60,000, and $1,000,000:

- Range = 1,000,000 - 10,000 = 990,000
- Variance = [(10,000 - 225,000)2 + (10,000 - 225,000)2 + (45,000 - 225,000)2 + (60,000 - 225,000)2 + (1,000,000 - 225,000)2] / 5 = 150,540,000,000
- Standard Deviation = Square Root (150,540,000,000) = 387,995
- Skew = Income is positively skewed

Measures of Association

Measures of association indicate whether two variables are related. Two measures are commonly used:

- Chi-square
- Correlation

Chi-square

- As a measure of association between variables, chi-square tests are used on nominal data (i.e., data that are put into classes: e.g., gender [male, female] and type of job [unskilled, semi-skilled, skilled]) to determine whether they are associated.
- A chi-square is called significant if there is an association between two variables, and non-significant if there is not an association.

To test for associations, a chi-square is calculated in the following way: Suppose a researcher wants to know whether there is a relationship between gender and two types of jobs, construction worker and administrative assistant. To perform a chi-square test, the researcher counts up the number of female administrative assistants, the number of female construction workers, the number of male administrative assistants, and the number of male construction workers in the data. These counts are compared with the number that would be expected in each category if there were no association between job type and gender (this expected count is based on statistical calculations). If there is a large difference between the observed values and the expected values, the chi-square test is significant, which indicates there is an association between the two variables.

The chi-square test can also be used as a measure of goodness of fit, to test if data from a sample come from a population with a specific distribution, as an alternative to Anderson-Darling and Kolmogorov-Smirnov goodness-of-fit tests. As such, the chi square test is not restricted to nominal data; with non-binned data, however, the results depend on how the bins or classes are created and the size of the sample.

Correlation

- A correlation coefficient is used to measure the strength of the relationship between numeric variables (e.g., weight and height).
- The most common correlation coefficient is Pearson's r, which can range from -1 to +1.
- If the coefficient is between 0 and 1, as one variable increases, the other also increases. This is called a positive correlation. For example, height and weight are positively correlated because taller people usually weigh more.
- If the correlation coefficient is between -1 and 0, as one variable increases the other decreases. This is called a negative correlation. For example, age and hours slept per night are negatively correlated because older people usually sleep fewer hours per night.

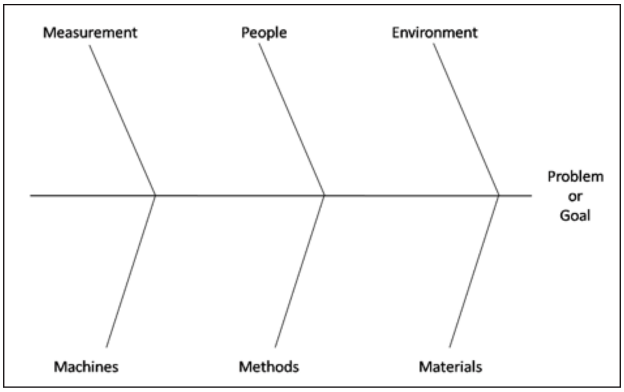
Tools of Statistical Process Control

Statistical Process Control tools help to identify the source of process problems, define a process's capability to meet a customer requirement, and assist with other insights.

The Tools

Cause-and-Effect Diagrams

One analysis tool is the Cause-and-Effect (or Fishbone) diagram. These are also called Ishikawa diagrams because Kaoru Ishikawa developed them in 1943. They are called fishbone diagrams since they resemble one with the long spine and various connecting branches.



The fishbone chart organizes and displays the relationships between different causes for the effect that is being examined. This chart helps organize the brainstorming process. The major categories of causes are put on major branches connecting to the backbone, and various sub-causes are attached to the branches. A tree-like structure results, showing the many facets of the problem.

The method for using this chart is to put the problem to be solved at the head, then fill in the major branches. People, procedures, equipment and materials are commonly identified causes.

This is another tool that can be used in focused brainstorming sessions to determine possible reasons for the target problem. The brainstorming team should be diverse and have experience in the problem area. A lot of good information can be discovered and displayed using this tool.

Control Charts and other Charts

Whether making mom's recipe for spaghetti sauce or admitting patients to an emergency room, the outcome of a process is never exactly the same every time. Fluctuation or variability is an inevitable component of all systems and is expected, arising naturally from the effects of miscellaneous chance events. However, variation outside a stable pattern may be an indication that the process is not acting in a consistent manner. Events which fall beyond expected variability or events forming a pattern that is not random, indicate that the process is out of control.

From a quality control perspective, an out-of-control service or production system is trouble. It is probably not meeting customer specifications or achieving business goals, and there is no way of predicting if it will or can.

There are two general ways of detecting that a process is out of control. The first test for an out-of-control process asks, "Is any point falling above or below the control limits on its control chart". This particular test is very easy to perform by viewing the control chart. The second form of rule violations is based upon patterns of points on the control chart and can be difficult to detect.

Some SPC software programs can quickly and accurately perform such tests on process data using the Western Electric Rules, which are defined in AT&T's Statistical Quality Control Handbook, the definitive source for rule violation standards.

Statistical Process Control charts graphically represent the variability in a process over time. When used to monitor the process, control charts can uncover inconsistencies and unnatural fluctuations. Consequently, SPC charts are used in many industries to improve quality and reduce costs.

Control charts typically display the limits that statistical variability can explain as normal. If your process is performing within these limits, it is said to be in control; if not, it is out of control.

It is important to remember what you can conclude about a system that is in control: control does not necessarily mean that a product or service is meeting your needs, it only means that the process is behaving consistently.

Rules Testing

How do you judge when a process is out of control? By plotting a control chart of the output of a process, it is possible to spot special or unnatural causes of variability and indications that the process is drifting. Drifting is defined by the mean or range of the variation changing as the process is running. The most common indication of change is a point falling outside of the control limits, but other tests for process instability are also valuable.

Different rules are appropriate for variable data and attribute data. Consequently, choosing which rules to apply depends on the type of chart being produced.

Zones in Control Charts

Many of the standard rules examine points based on *zones*. The area between each control limit and the centerline is divided into thirds. The third closest to the centerline is referred to as Zone A, the next third is Zone B, and the third closest to the control limits is Zone C. Note that there are two of each of the Zones, one upper and one lower.

Zone A is also referred to as the "3-sigma zone", Zone B is the "2-sigma zone", and Zone C is the "1-sigma zone". These sigma zone terms are appropriate only when 3-sigma is used for the control limits.

Sigma is the Greek letter for s and is used in this context to denote the spread of data.

Standard control limits are located 3 sigma away from the average or centerline of the chart. The centerline is also called the *control line*. These are called 3 sigma limits or 3 sigma zones. The distance from the centerline to the control limits can be divided into 3 equal parts of one sigma each.

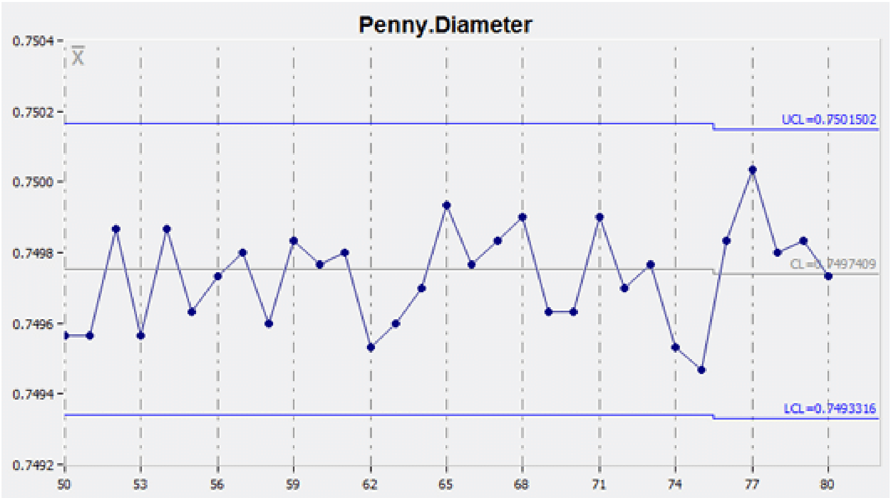
Statistical theory tell us that in normal data dispersion, we can expect the following percentages of data to be included within the sigma:

- 1 sigma – 68.3%
- 2 sigma – 95.5%
- 3 sigma – 99.7%

We can expect 99.7% of the process outcomes to be within the 3-sigma control limits.

Control Limits

Control limits are calculated statistically from your data. They are referred to as the Lower Control Limit (LCL) and the Upper Control Limit (UCL) on a control chart. These are set at 3-sigma by default since this is the most commonly used limit.



Control limits define the zone where the observed data for a stable and consistent process occurs virtually all of the time (99.7%). Any fluctuations within these limits come from common causes inherent to the system, such as choice of equipment, scheduled maintenance or the precision of the operation that results from the design. These normal fluctuations are attributed to statistical variability.

An outcome beyond the control limits results from a *special cause*. Special causes are events external to the ordinary operation of a production or service. Special causes indicate that there have been one or more fundamental changes to the process and the process is out of control. Special causes need to be investigated and eliminated before a control chart can be used as a quality-monitoring tool.

Subgroups

An important factor in preparing for SPC charting is determining if you will measure every product of the process, such as measuring every part, or if you will use subgroups. Subgroups are a sample of data from the total possible data. Subgroups are used when it is impractical or too expensive to collect data on every single product or service in the process. Decisions to use subgroups or not needs to be carefully thought out to ensure they accurately represent the data.

Subgroups need to be homogenous within them so that special causes can be recognized, so problem areas stand out from the normal variation in the subgroup. For example, if you are in charge of analyzing processes in a number of facilities, a separate group should represent each facility, since each facility has different processes for doing the same tasks. Each facility subgroup should probably be broken down even further, for example by work shifts.

Subgroups in Variable Control Charts

All data in a subgroup has something in common, such as a common time of collection, all data for a particular date, a single shift, or a time of day.

Subgroup data can have other factors in common, such as data associated with an operator, or data associated with a particular volume of liquid.

Subgroups in Attribute Control Charts

A subgroup is the group of units that were inspected to obtain the number of defects or the number of rejects. The number of defects is displayed using c charts and u charts. The number of rejects, also called defective items, is displayed using p charts and np charts.

Rejects–Nonconforming Items Data

Nonconforming items are rejects. A reject is tallied when an entire unit fails to meet acceptance standards, regardless of the number of defects in the unit. This includes defective products or unacceptable outcomes.

Defects–Nonconformities Data

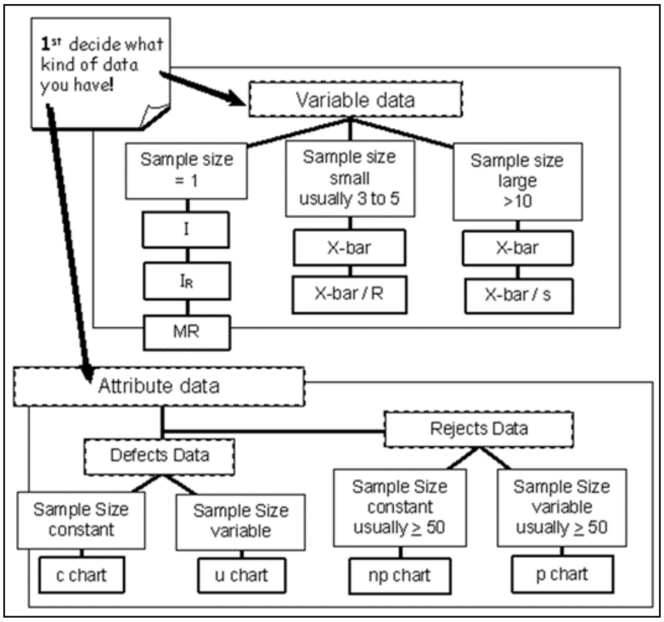
Nonconformities are defects. A non-conformity is any characteristic, which should not be present but is, or a characteristic which needs to be present but is not. A defective item can have multiple nonconformities, for example, errors on insurance forms, incorrect medication, or service complaints.

Using Process Control Charts

OK, enough talk. Let's do some actual control charting. First you need to determine what data you have and select the correct chart for that data. Then make the chart and analyze it to see if the process is in control.

Data Set for Proper Chart Selection

Choosing the correct chart for a given a situation is the first step in every analysis. There are actually just a few charts to choose from, and determining the appropriate one requires following some fairly simple rules based on the underlying data. These rules are described in the flowchart below:



Control charts are divided into two groups:

Variable Charts

Variable charts are based on variable data that can be measured on a continuous scale. For example, weight, volume, temperature, or length of stay. These can be measured to as many decimal places as necessary.

Individual, average, and range charts are used for variable data.

Attribute Charts

Attribute charts are based on data that can be grouped and counted as present or not. Attribute charts are also called count charts and attribute data is also known as discrete data. Attribute data is measured only with whole numbers. Examples include:

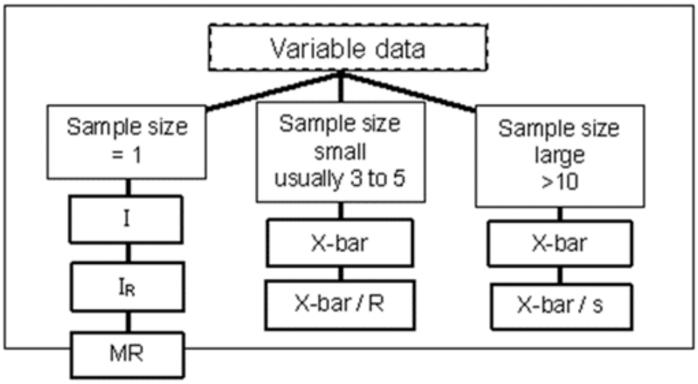
- Acceptable vs. non-acceptable
- Forms completed with errors vs. without errors
- Number of prescriptions with errors vs. without

When constructing attribute control charts, a subgroup is the group of units that were inspected to obtain the number of defects or the number of defective items.

Defect and reject charts are used for attribute data.

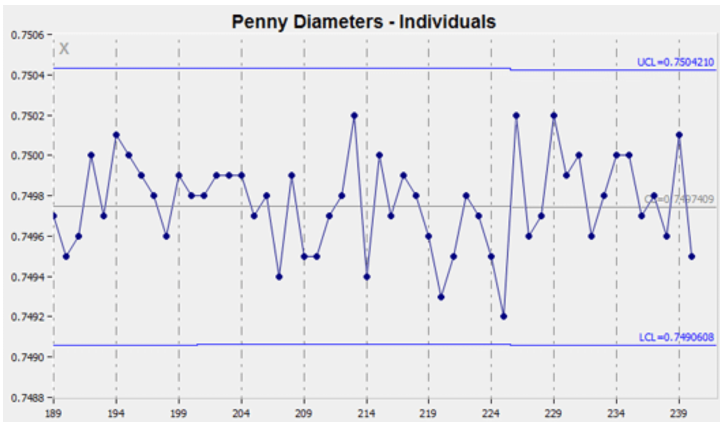
Variable Data Charts – Individual, Average and Range Charts

Variable data requires the use of variable charts. Variable charts are easy to understand and use.



Individual Charts – I Chart

The I chart is also referred to as an individual, item, i, or X chart. The X refers to a variable X.



Individual charts plot the process results varying over time. Individual observations are plotted on the I chart, averages are not plotted on this type of chart. Individual charts are used to plot variable data collected chronologically from a process, such as a part's measurement over time.

These charts are especially useful for identifying shifts in the process average. When monitoring a system, it is expected that equal numbers of points will fall above and below the average that is represented by the centerline. Shifts or trends can indicate a change that needs to be investigated.

The individual control chart is reserved for situations in which only one measurement is performed each time the data is collected, where it is impractical or impossible to collect a sample of observations. When there are not enough data points to calculate valid control limits, an individual chart functions as a simple run chart.

Average Charts – X-bar Chart

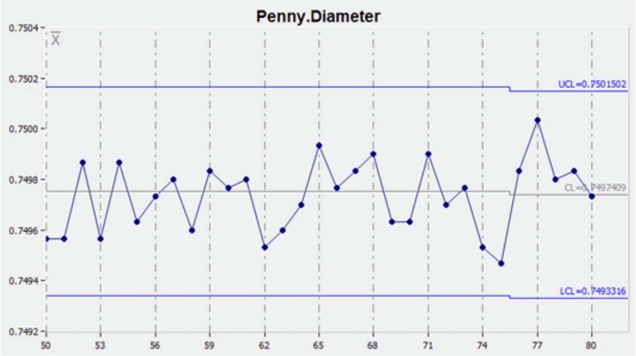
Average charts are made by plotting averages of individual measurements on the chart. The average chart is called the X-bar chart because, in statistical notation, a bar or line over the variable (X) symbolizes the average of X. "X-bar" is a shorthand way of saying "the average of X".

An X-bar chart is a variable control chart that displays the changes in the average output of a process. The chart reflects either changes over time or changes associated with a categorical data variable. The chart shows how consistent and predictable a process is at achieving the mean.

X-bar charts measure variation between subgroups. They are often paired with either Standard Deviation (S) or Range (R) charts, which measure variation within subgroups.

Variable Data Subgroups

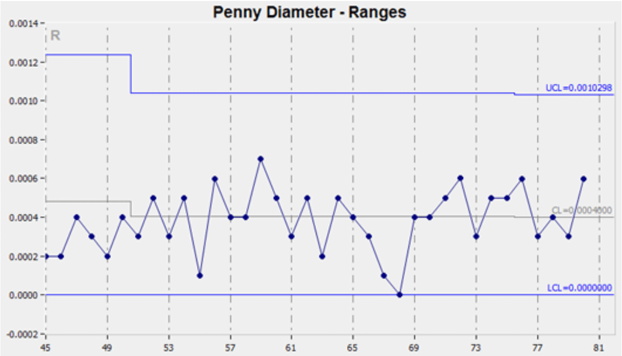
Subgroup data has something in common, such as data associated with a particular operator, or data associated with a particular volume of liquid.



Range Chart – R Chart

The Range chart can be combined with I charts and X-bar charts. The chart names combine the corresponding chart initials.

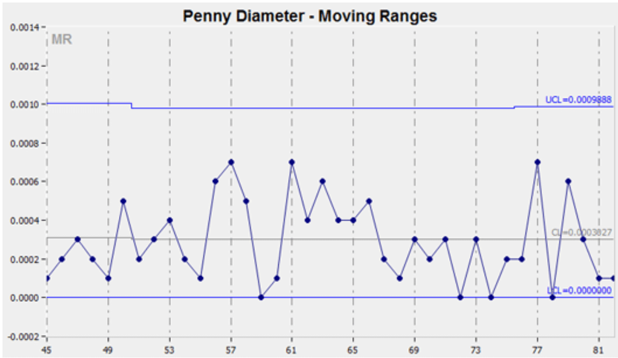
Range charts measure the variation in the data. An example is the weather report in the newspaper that gives the high and low temperatures each day. The difference between the high and the low is the range for that day.



Moving Range Chart – MR Chart

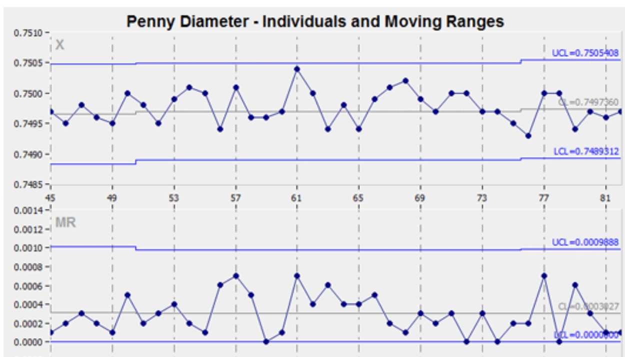
This type of chart displays the moving range of successive observations. A moving range chart can be used when it is impossible or impractical to collect more than a single data point for each subgroup.

This chart can be paired with an individual chart, which is then called an Individual Moving Range (IR) chart. An individual chart is used to highlight the changes in a variable from a central value, the mean. The moving range chart displays variability among measurements based on the difference between one data point and the next.

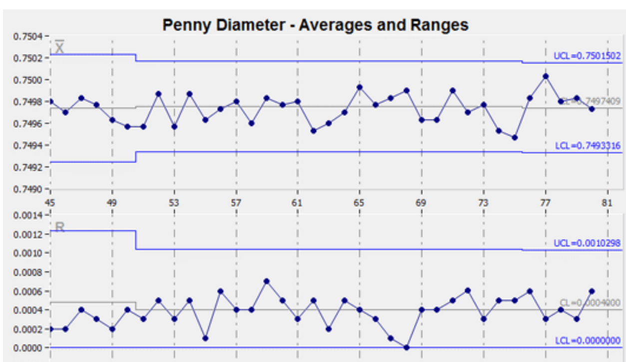


Individual and Range Charts – IR Charts

This pair of variable control charts is often offered together for quality control analysis. The Individual chart, the upper chart in the figure below, displays changes to the process output over time in relation to the center line which represents the mean. The Moving Range chart, the lower chart in the figure below, analyzes the variation between consecutive observations, which is a measure of process variability.



Average and Range Charts – X-Bar and R Charts



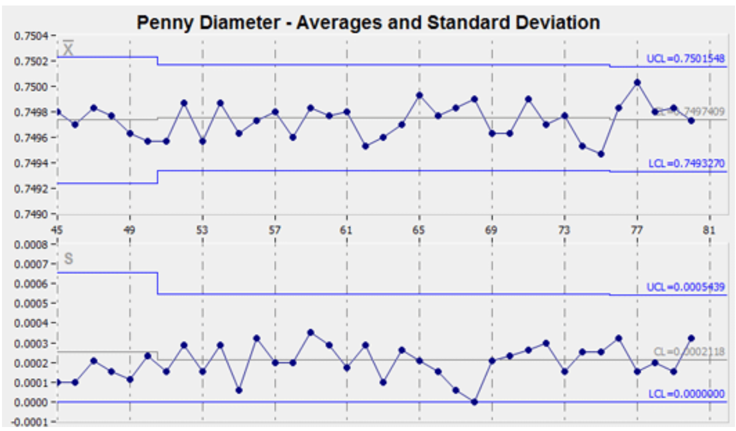
Variable and Range control charts are often displayed together for quality control analysis. The X-bar chart, the upper chart in the figure below, is a graphic representation of the variation among the subgroup averages, the R chart, the lower chart in the figure, looks at variability within these subgroups.

The variation within subgroups is represented by the range (R). The range of values for each subgroup is plotted on the Y-axis of the R chart. The centerline is the average or mean of the range.

X-Bar Standard Deviation Charts – X-Bar And S Charts

This pair of variable control charts is often displayed together for quality control analysis. The X-bar chart, the upper chart in the figure below, displays the variation in the means between the subgroups. The s chart, the lower chart in the figure below, looks at variability within these subgroups.

In this pair of charts, the variation within subgroups is represented by the standard deviation. The standard deviation is plotted on the y-axis, and is a measure of the spread of values for each subgroup. The centerline is the average or mean of these sub-group standard deviations.



You can choose to use a standard deviation chart, i.e. an s-chart, instead of the Moving Range chart. The Range chart is often used because the standard deviation is a more accurate and therefore more difficult measurement. Now that computers are automatically calculating the standard deviation, the s-chart can be used in all situations. This is called the X-bar S chart.

A standard deviation formula is used to calculate the differences in the data. This calculation can be used in cases where the subgroup sample size is large and sampling methods support the modeling of the data as normal distribution.

Process Capability Chart – CP Chart

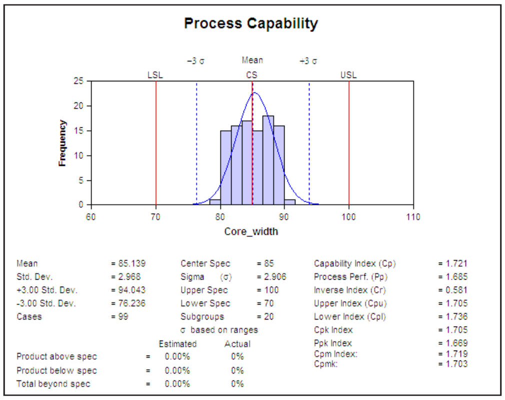
Process capability analysis is used to adjust the process until virtually all of the product output meets the specifications. Once the process is operating in control, capability analysis attempts to answer the question: Is the output meeting specifications, or is the process capable? If it is not, can the process be adjusted to make it capable.

The process capability chart contains a normal curve superimposed over a histogram of the data, followed by several statistics. A process is said to be capable if its output falls within the specifications virtually 100% of the time.

Specification Limits are the boundaries, or tolerances, set by management, engineers or customers which are based on product requirements or service objectives. Specification Limits are NOT established by the process itself, and may not even be possible within the given process.

One goal of Statistical Process Control is to determine if specifications are in fact possible in the current process. If the following statements are true, a process capability chart can be an appropriate tool for measuring the inherent reproducibility of the process and monitoring the degree to which it can meet specifications:

- The process is stable and in control.
- The data are normally distributed.
- Specification limits fall on either side of the centerline.
- You are investigating whether your process is capable of meeting specifications.



Attribute Data Charts

Again, attribute data represents particular characteristics of a product or system that can be counted, not product measurements. They are characteristics that are present or not present. This is known as discrete data, and is measured only with whole numbers. Examples include:

- Acceptable vs. non-acceptable
- Forms completed with errors vs. without errors
- Number of prescriptions with errors vs. without

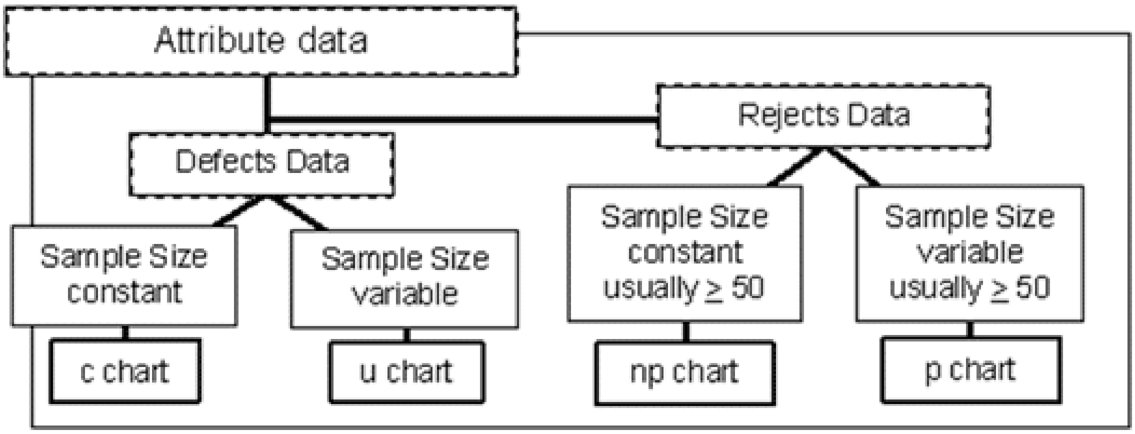
Attribute data has another distinctive characteristic. In quality control analysis, this countable data falls into one of two categories:

- Defects data is the number of nonconformities within an item. There is no limit to the number of possible defects. *Defects charts* count the number of defects in the inspection unit.
- Rejects data where the entire item is judged to conform to product specifications or not. *Rejects charts* count the number of rejects in a subgroup.

One way to determine what type of data you have is to ask, “Can I count both the occurrences AND non-occurrences of the defective data?” For example, you can count how many forms have errors and how many do not, however you cannot count how many errors were NOT made on the form. If you can count both occurrences and non-occurrences, you have rejects data. If the non-occurrences cannot be determined, then you have defects data.

For example: If you are counting the number of errors made on an insurance form, you have an example of the defects per form. There is no limit to the number of defects that can be counted on each form.

If you are counting the total number of forms that had one or more errors, then you have a count of the rejected units. This is either one or zero rejects per unit.



Defects vs. Rejects Data

Subgroup Size – Constant or Changing

Subgroup size is another important data characteristic to consider in selecting the right type of chart. When constructing attribute control charts, a subgroup is the group of units that were inspected to obtain the number of defects or the number of rejects. To choose the correct chart, you need to determine if the subgroup size is constant or not. If constant, for example 300 forms are processed every day, and then you can look at a straight count of the defective occurrences. If the subgroup size changes, you need to look at the percentage or fraction of defective occurrences.

For example: An organization may have a day in which 500 insurance forms are processed and 50 have errors vs. another day in which only 150 are processed and 20 have errors. If we only look at the count of errors, 50 vs. 20, we would assume the 50 error day was worse. But when considering the total size of the subgroup, 500 vs. 150, we determine that, on the first day, 10% had errors while, the other day, 13.3% had errors.

The different types of attribute data, let's move on to the specific charts for analyzing them. There are four different types of attribute charts. For each type of attribute data, defects, and rejects, there is a chart for subgroups of constant size and one for subgroups of varying size.

Rejects Charts count the number of rejected units in a subgroup.

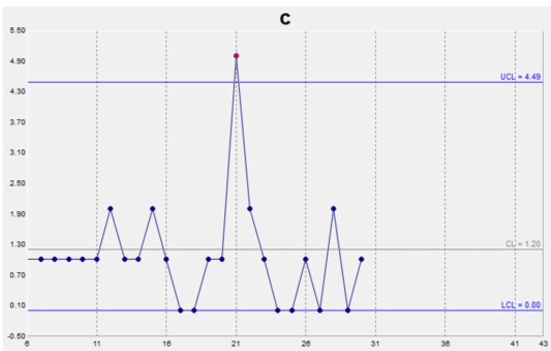
Defects Charts

The two defects charts are the c chart and the u chart. The c refers to count of defects in a subgroup of constant size. The u is a per unit count within a variable size subgroup.

c Chart – Constant Subgroup Size

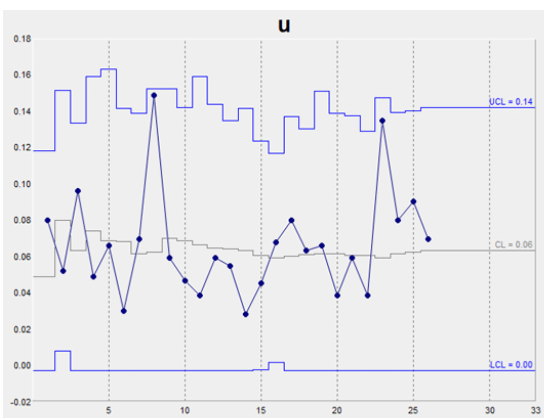
A c chart, or Count chart, is an attribute control chart that displays how the number of defects, or nonconformities, for a process or system is changing over time. The number of defects is collected for the *area of opportunity* in each subgroup. The area of opportunity can be either a group of units or just one individual unit on which defect counts are performed. The c chart is an indicator of the consistency and predictability of the level of defects in the process.

When constructing a c chart, it is important that the area of opportunity for a defect be constant from subgroup to subgroup since the chart shows the total number of defects. When the number of items tested within a subgroup changes, then a u chart should be used, since it shows the number of defects per unit rather than total defects.



u Chart – Varying Subgroup Size

A u chart (u is for Unit) is an attribute control chart that displays how the frequency of defects, or nonconformities, is changing over time for a process or system. The number of defects is collected for the area of opportunity in each subgroup. The area of opportunity can be either a group of items or just one individual item on which defect counts are performed. The u chart is an indicator of the consistency and predictability of the level of defects in the process.



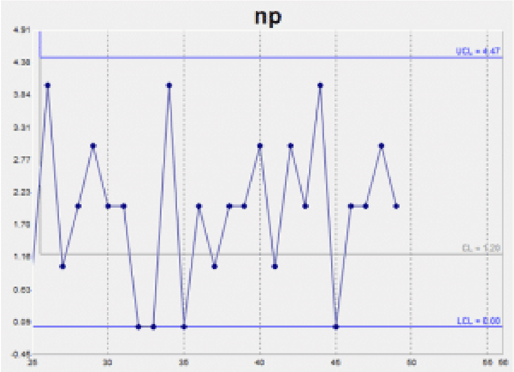
A u chart is appropriate when the area of opportunity for a defect varies from subgroup to subgroup. This can be seen in the shifting UCL and LCL lines that depend on the size of the subgroup. This chart shows the number of defects per unit. When the number of items tested remains the same among all the subgroups, then a c chart should be used since a c chart analyzes total defects rather than the number of defects per unit.

Rejects Charts

The two types of Rejects charts are the p chart and the np chart. The name of the p chart stands for the *P*ercentage of rejects in a subgroup. The name of the np chart stands for the *N*umber of rejects within a p-type chart. You can also remember it as “not percentage” or “not proportional”.

A mnemonic to remember that the p chart and its partner, the np chart, represent Rejects data is to think of P as a “pea” and a canning plant that is rejecting cans of peas if they are not 100% acceptable. As p and np are a team, you should be able to recall this with the same story.

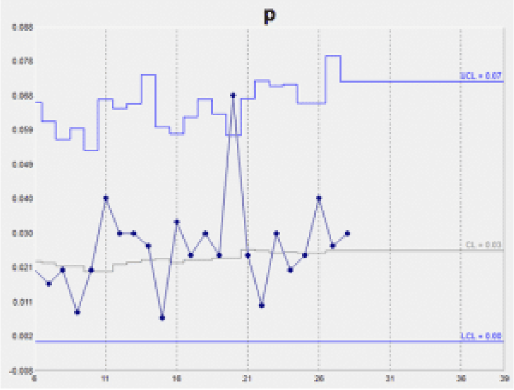
np Chart – Number of Rejects Chart for Constant Subgroup Size



An np chart is an attribute control chart that displays changes in the number of defective products, rejects or unacceptable outcomes. It is an indicator of the consistency and predictability of the level of defects in the process.

The np chart is only valid as long as your data are collected in subgroups that are the same size. When you have a variable subgroup size, a p chart should be used.

p Chart – Percentage Chart for Varying Subgroup Size



A p chart is an attribute control chart that displays changes in the proportion of defective products, rejects, or unacceptable outcomes. It is an indicator of the consistency and predictability of the level of defects in the process.

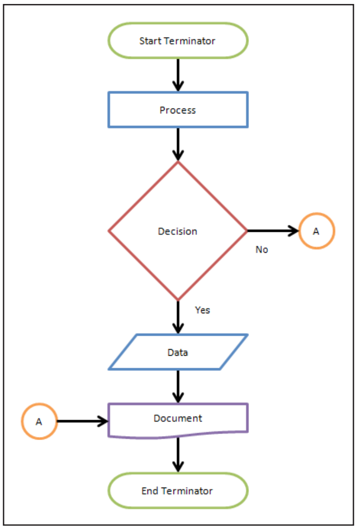
Since a p chart is used when the subgroup size varies, the chart plots the proportion or fraction of items rejected, rather than the number rejected. This is indicated by the shifting UCL and LCL lines that depend on the size of the subgroup. For each subgroup, the proportion rejected is calculated as the number of rejects divided by the number of items inspected. When you have a constant subgroup size, use an np chart instead.

Flow Charts

After a process has been identified for improvement and given high priority, it should then be broken down into specific steps and put on paper in a flowchart. This procedure alone can uncover some of the reasons a process is not working correctly. Other problems and hidden traps are often uncovered when working through this process.

Flowcharting also breaks the process down into its many sub-processes. Analyzing each of these separately minimizes the number of factors that contribute to variation in the process.

After creating the flowchart, you may want to take another look at the fishbone diagram and see if any other factors have been uncovered. If so, you may need to do another Pareto diagram as well. Quality Control is a continual process, in which factors and causes are constantly reviewed and changes made as required.

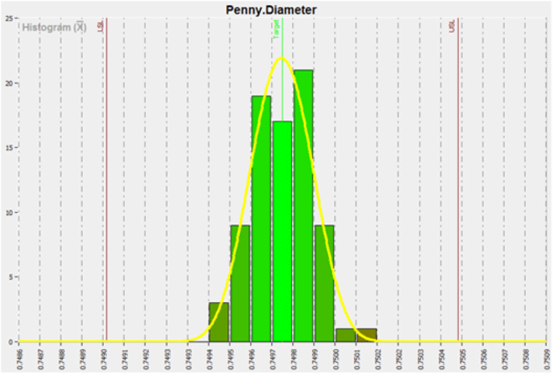


Histograms

Now you can put the data from the check sheets into a histogram. A histogram is a snapshot of the variation of a product or the results of a process. It often forms the bell-shaped curve which is characteristic of a normal process.

The histogram helps you analyze what is going on in the process and helps show the capability of a process, whether the data is falling inside the bell-shaped curve and within specifications.

A histogram displays a frequency distribution of the occurrence of the various measurements. The variable being measured is along the horizontal x-axis, and is grouped into several ranges of measurements. The frequency of occurrence of each measurement is charted along the vertical y-axis.



Histograms depict the central tendency or mean of the data, and its variation or spread. A histogram also shows the range of measurements, which defines the process capability. A histogram can show characteristics of the process being measured, such as:

- Do the results show a normal distribution, a bell curve? If not, why not?
- Does the range of the data indicate that the process is capable of producing what is required by the customer or the specifications?
- How much improvement is necessary to meet specifications? Is this level of improvement possible in the current process?

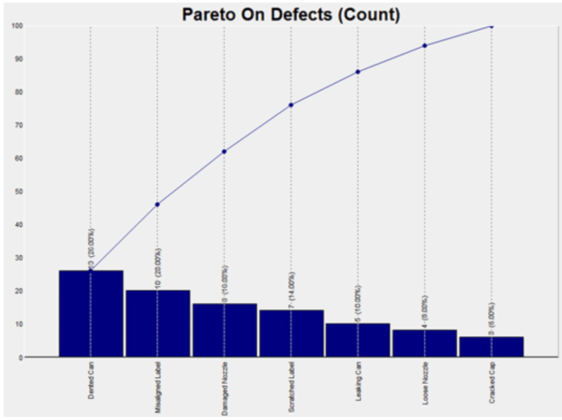
Pareto Charts

The Pareto chart can be used to display categories of problems graphically so they can be properly prioritized. The Pareto chart is named for a 19th century Italian economist who postulated that a small minority (20%) of the people owned a great proportion (80%) of the wealth in the land.

There are often many aspects of a process or system that can be improved, such as the number of defective products, time allocation, or cost savings. Each aspect usually contains many smaller problems, making it difficult to determine how to approach the issue. A Pareto chart or diagram indicates which problem to tackle first by showing the proportion of the total problem that each of the smaller problems comprise. This is based on the Pareto principle: 20% of the sources cause 80% of the problem.

A Count Pareto chart is a vertical bar graph displaying rank in descending order of importance for the categories of problems, defects or opportunities. Generally, you gain more by working on the problem identified by the tallest bar than trying to deal with the smaller bars. However, you should ask yourself what item on the chart has the greatest impact on the goals of your business, because sometimes the most frequent problem as shown by the Pareto chart is not always the most important. SPC is a tool to be used by people with experience and common sense as their guide.

This is a Pareto chart of defect types for whipped cream cans.

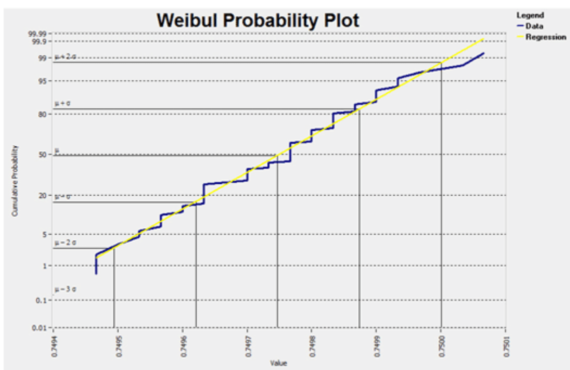


Once a major problem has been selected, it needs to be analyzed for possible causes. Cause-and-effect diagrams, scatter plots and flow charts can be used in this part of the process.

Probability Plots

In order to use Control Charts, the data needs to approximate a normal distribution, to generally form the familiar bell-shaped curve.

The probability plot is a graph of the cumulative relative frequencies of the data, plotted on a normal probability scale. If the data is normal it forms a line that is fairly straight. The purpose of this plot is to show whether the data approximates a normal distribution. This can be an important assumption in many statistical analyses.



Although a probability plot is useful in analyzing data for normality, it is particularly useful for determining how capable a process is when the data is not normally distributed. That is, we are interested in finding the limits within which most of the data fall.

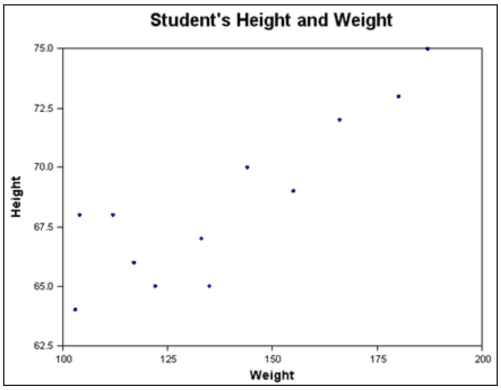
Since the probability plot shows the percent of the data that falls below a given value, we can sketch the curve that best fits the data. We can then read the value that corresponds to 0.001 (0.1%) of the data. This is generally considered the *lower natural limit*. The value corresponding to 0.999 (99.9%) is generally considered the *upper natural limit*.

(To be more consistent with the natural limits for a normal distribution, some people choose 0.00135 and 0.99865 for the natural limits.)

Scatter Diagrams

The Scatter diagram, or plot, is another problem analysis tool. Scatter plots are also called correlation charts.

A Scatter plot is used to uncover possible cause-and-effect relationships. It is constructed by plotting two variables against one another on a pair of axes. A Scatter plot cannot prove that one variable causes another, but it does show how a pair of variables is related and the strength of that relationship. Statistical tests quantify the degree of correlation between the variables.



In this example, there appears to be a relationship between height and weight. As the student gets taller, generally speaking they get heavier.

Six Sigmas

Six Sigma is a quality management methodology used to help businesses improve current processes, products or services by discovering and eliminating defects. The goal is to streamline quality control in manufacturing or business processes so there is little to no variance throughout.

Six Sigma was trademarked by Motorola in 1993, but it references the Greek letter sigma, which is a statistical symbol that represents a standard deviation. Motorola used the term because a Six Sigma process is expected to be defect-free 99.99966 percent of the time — allowing for 3.4 defective features for every million opportunities. Motorola initially set this goal for its own manufacturing operations, but it quickly became a buzzword and widely adopted standard.

Six Sigma is specifically designed to help large organizations with quality management. In 1998, Jack Welch, CEO of GE, helped thrust Six Sigma into the limelight by donating upwards of $1 million as a thank you to the company, recognizing how Six Sigma positively impacted GE's operations and promoting the process for large organizations. After that, Fortune 500 companies followed suit and Six Sigma has been popular with large organizations ever since.

Six Sigma Principles

The goal in any Six Sigma project is to identify and eliminate any defects that are causing variations in quality by defining a sequence of steps around a certain target. The most common examples you'll find use the targets "smaller is better, larger is better or nominal is best."

- Smaller is Better creates an "upper specification limit," such as having a target of zero for defects or rejected parts.
- Larger is Better involves a "lower specification limit," such as test scores — where the target is 100 percent.
- Nominal is Best looks at the middle ground — a customer service rep needs to spend enough time on the phone to troubleshoot a problem, but not so long that they lose productivity.

The process aims to bring data and statistics into the mesh to help objectively identify errors and defects that will impact quality. It's designed to fit a variety of business goals, allowing organizations to define objectives around specific industry needs.

Six Sigma Methodologies

In practice, Six Sigma follows one of two sub-methodologies: DMAIC and DMADV:

Six Sigma DMAIC

The Six Sigma DMAIC project methodology includes five phases, each represented as a letter in the DMAIC acronym. These include:

- Define the problem, the customer, the project requirements and the ultimate goals and expectations of the customer.
- Measure performance of the current process by establishing a data collection plan to determine defects and gather metrics.
- Analyze the process to establish root cause of variations and defects to identify issues with the current strategy that stand in the way of the end goal.
- Improve the process by eliminating the root causes of defects through innovative solutions.
- Control the new process to avoid falling into old habits and to ensure it stays on track.

Six Sigma DMADV

The Six Sigma DMADV, also known as the Design For Six Sigma (DFSS), includes five stages:

- Define realistic goals that suit the customer's requirements or the business strategy.
- Measure and identify the customer's critical to quality (CTQ) requirements and translate them into clear project goals.
- Analyze multiple options and alternatives for the customer along with the estimated total life cycle of the project.
- Design the process at a high level before moving onto a more detailed version that will become the prototype to identify errors and make modifications.
- Verify that the final iteration of the product or process is approved by all customers and clients — whether internal or external.

DMAIC vs. DMADV

The DMAIC and DMADV methodologies seem similar, but they have different use cases. The DMAIC methodology is designed for existing process or products that aren't meeting customers' needs or performing to standards. When a business needs to develop a product or process that doesn't already exist or when a product has been optimized but still falls short, that's when you want to use DMADV.

Determining a Six Sigma Project

To find projects in your organization that would benefit from Six Sigma they need to fit some criteria:

- Each project needs to have a clear process of inputs and outputs.
- Don't go into the project with a pre-determined solution — that means you already know the fix.
- Focus on reducing "operation variation" to make it easier for untrained operators.
- Project needs to be approached with knowledge of variations in process inputs and how to control and eliminate defects.

iSixSigma offers the example of a "slow cycle time at Station 30" due to defective parts coming from "Station 20." A "non-Six Sigma solution" would attempt to rebalance the assembly line, while re-doing the work, keeping cycle time low and not spending on labor. A Six Sigma solution would be to "investigate and control key inputs that contribute" to defective parts coming from Station 20 to keep it from happening again in the future. In this case, the Six Sigma focus looks at proactively eliminating the defect, while a non-Six Sigma approach simply reacts to the problem without identifying the cause.

Six Sigma Implementation Roles

A key concept in Six Sigma is the idea of establishing clear leadership roles and a hierarchy for quality management. The key roles for Six Sigma implementation include:

- Executive leadership: This includes the CEO and other executive management who are charged with developing the vision for Six Sigma implementation. Leaders should also be responsible for encouraging new ideas and supplying the resources to act on innovation.
- Champions: Typically found in upper management, Champions are the people responsible for acting on executive leadership's vision and acting as mentors to black belts.
- Master Black Belts: These workers spend all their time on Six Sigma methodology, either by guiding Black or Green Belts or helping Champions. They're picked out by Champions and are tasked with ensuring consistency in the Six Sigma strategy.
- Black Belts: Working below Master Black Belts, Black Belts are responsible for executing on the Six Sigma strategy and typically act as leaders for specific tasks.
- Green Belts: Guided by Black Belts, Green Belts are new to the Six Sigma methodology and start learning it while maintaining their other job responsibilities.

You may find other belts — like white, yellow and orange. These are adopted by organizations to represent employees with some Six Sigma training, but aren't involved in the overall project.

Six Sigma Certification and Training

Certification and training are offered directly by businesses, with GE and Motorola paving the way by being the first to develop Six Sigma certification programs to verify proficiency in the Six Sigma methodology. After that, large companies and universities followed suit, offering their own version of a Six Sigma certification program.

However, there isn't much oversight to what qualifies as Six Sigma certification and the criteria for Green Belt and Black Belt certification can vary. Certification programs are offered through businesses, universities, professional associations and for-profit training organizations. Some notable organizations include:

- American Society for Quality
- Dartmouth College
- Boston University
- GE
- Accenture
- IASSC
- Cornell University
- Motorola Solutions
- Purdue University

Some organizations offer Six Sigma accreditation — the IASSC offers Lean Six Sigma credentialing and accredited training providers. The Council for Six Sigma Certification also offers a list of accredited Six Sigma providers. Ultimately, when choosing a Six Sigma certification or training program, it's important to do your research to ensure the organization, university or third-party vendor offers the right training for your needs and has the right qualifications.

Six Sigma Criticisms

Six Sigma is popular with large organizations, but it's not as realistic for businesses with less than 500 employees. While certain aspects of the methodology can certainly apply to small businesses, it's not as relevant. There are also cautions around a growing industry catering to Six Sigma certifications and training. You want to do your research to ensure any third party offering Six Sigma services are highly qualified to do so.

Other cautions point to Six Sigma's focus on improving what already exists, while much of the business world is pivoting to innovating around new technology. So, while it might help uphold legacy systems and current products, it doesn't leave much room for disrupting an industry or developing fresh products and services. Although, iSixSigma counters this claim, pointing out that it can help bring efficiency to process, reducing waste and cost, which allows businesses to find the funds for innovation.

Process Capability

A process has been defined as a sequence of interdependent procedures, operations or steps that consume resources and convert the inputs into outputs. Each operation or step adds to the next to achieve a goal or desired result. In every process, there exists a certain amount of variation. Variation in a process cannot be eliminated, but it can be measured, monitored, reduced and controlled. If we look at a simple example of making a cup of coffee, we can identify the inputs, steps, equipment and output of the process. Some of the inputs are coffee and water. The steps include turning on the coffee maker, measuring and adding the coffee and water and the output is a pot or cup of coffee. The variation can occur in the amount of coffee or water introduced in the process and the performance of the coffee maker itself. Not every cup of coffee is exactly the same but in most cases, if the measurements are controlled and reasonably consistent, it tastes the same. By utilizing process controls, taking measurements and using reliable, well-maintained equipment, variation in a process can have less effect on the quality of the output. The process can be capable of producing acceptable product on a consistent basis. We can maintain Process Capability.

Process Capability (Cp) is a statistical measurement of a process's ability to produce parts within specified limits on a consistent basis. To determine how our process is operating, we can calculate Cp (Process Capability), Cpk (Process Capability Index), or Pp (Preliminary Process Capability) and Ppk (Preliminary Process Capability Index), depending on the state of the process and the method of determining the standard deviation or sigma value. The Cp and Cpk calculations use sample deviation or deviation mean within rational subgroups. The Pp and Ppk calculations use standard deviation based on studied data (whole population). The Cp and Cpk indices are used to evaluate existing, established processes in statistical control. The Pp and Ppk indices are used to evaluate a new process or one that is not in statistical control.

Process capability indices Cp and Cpk evaluate the output of a process in comparison to the specification limits determined by the target value and the tolerance range. Cp tells you if your process is capable of making parts within specifications and Cpk tells you if your process is centered between the specification limits. When engineers are designing parts, they must consider the capability of the machine or process selected to produce the part.

To illustrate, let us use a real world example. Imagine that you are driving your vehicle over a bridge. The width of your vehicle is equivalent to the spread or range of the data. The guardrails on each side of the bridge are your specification limits. You must keep your vehicle on the bridge to reach the other side. The Cp value is equivalent to the distance your vehicle stays away from the guardrails and Cpk represents how well you are driving down the middle of the bridge. Obviously if the spread of your data is narrower (your car width is smaller), the more distance there is between the vehicle and the guardrails and the more likely you are to stay on the bridge.

The Cp index is a fundamental indication of process capability. The Cp value is calculated using the specification limits and the standard deviation of the process. Most companies require that the process Cp = 1.33 or greater.

The Cpk index of process center goes a step further by examining how close a process is performing to the specification limits considering the common process variation. The larger the Cpk value the closer the mean of the data is to the target value. Cpk is calculated using the specification limits, standard deviation or sigma, and the mean value. The Cpk value should be between 1 and 3. If the value is lower than 1 the process is in need of improvement.

The Cp and Cpk indices are only as good as the data used. Accurate process capability studies are dependent upon three basic assumptions regarding the data:

1. There are no special causes of variation in the process and it is in a state of statistical control. Any special causes must be discovered and resolved.
2. The data fits a Normal distribution, exhibiting a bell shaped curve and can be calculated to plus or minus three sigma. There are cases when the data does not fit a normal distribution.
3. The sample data is representative of the population. The data should be randomly collected from a large production run. Many companies require at least 25 to preferably 50 sample measurements be collected.

Reasons to Measure Process Capability

In manufacturing and many other types of businesses, reduction of waste and providing quality products are imperative if they are to survive and thrive in today's marketplace. Waste exists in many forms in a process. When we look at the bigger picture, process capability is more than just measuring Cp and Cpk values. Process capability is just one tool in the Statistical Process Control (SPC) toolbox. Implementing SPC involves collecting and analyzing data to understand the statistical performance of the process and identifying the causes of variation within. Important knowledge is obtained through focusing on the capability of process. Monitoring process capability allows the manufacturing process performance to be evaluated and adjusted as needed to assure products meet the design or customer's requirements. When used effectively this information can reduce scrap, improve product quality and consistency and lower the cost to manufacture and the cost of poor quality.

Measurement of Process Capability

The capability indices can be calculated manually, although there are several software packages available that can complete the calculations and provide graphical data illustrating process capability. For the example we will utilize a popular statistical software package. For our example, we will utilize data from randomly collected measurements of a key characteristic of a machined part. To better represent the population values, the sample data must be randomly collected, preferably over time from a large production run. A few things to keep in mind:

- Our data is quantitative and variable,
- Our data consists of 100 measurements,
- The target dimension is 25.4 mm,
- USL (Upper Specification Limit) = 25.527 mm,

- LSL (Lower Specification Limit) = 25.273 mm,
- Range = 0.254 mm.

First, we will examine our data with a simple histogram to determine if it could fit a normal distribution. In addition, we can generate a probability plot evaluating our data's best fit to a line further indicating we are 95% confident that our data fits a normal distribution.

Now let us examine the Process capability report:

- Cp (Process Capability = 1.68
- Cpk (Process Capability Index) = 1.66

Using the graph, we can further evaluate process capability by comparing the spread or range of the product specifications to the spread of the process data, as measured by Six Sigma (process standard deviation units).

Through examination of the reports, we can determine that our example process is in a state of statistical control. All the data points fall well within the specification limits with a normal distribution. A process where almost all the measurements fall inside the specification limits is deemed a capable process. Process capability studies are valuable tools when used properly. As previously mentioned the information gained is generally used to reduce waste and improve product quality. In addition, by knowing your process capabilities, the design team can work with manufacturing to improve product quality, and processes that are "not in control" may be targeted for improvement. During a typical Kaizen event or other quality improvement initiatives, Process Capability is calculated at the start and end of the study to measure the level of improvement achieved. Accurate knowledge of process capability enables management to make decisions regarding where to apply available resources based on data.

Quality Circles

A quality circle is a participatory management technique that enlists the help of employees in solving problems related to their own jobs. Circles are formed of employees working together in an operation who meet at intervals to discuss problems of quality and to devise solutions for improvements. Quality circles have an autonomous character, are usually small, and are led by a supervisor or a senior worker. Employees who participate in quality circles usually receive training in formal problem-solving methods—such as brain-storming, pareto analysis, and cause-and-effect diagrams—and are then encouraged to apply these methods either to specific or general company problems. After completing an analysis, they often present their findings to management and then handle implementation of approved solutions. Pareto analysis, by the way, is named after the Italian economist, Vilfredo Pareto, who observed that 20 percent of Italians received 80 percent of the income—thus the principle that most results are determined by a few causes.

The interest of U.S. manufacturers in quality circles was sparked by dramatic improvements in the quality and economic competitiveness of Japanese goods in the post-World War II years. The emphasis of Japanese quality circles was on preventing defects from arising in the first place rather than through culling during post-production inspection. Japanese quality circles also attempted to minimize the scrap and downtime that resulted from part and product defects. In the United States, the quality circle movement evolved to encompass the broader goals of cost reduction, productivity improvement, employee involvement, and problem-solving activities.

Quality circles were originally associated with Japanese management and manufacturing techniques. The introduction of quality circles in Japan in the postwar years was inspired by the lectures of W. Edwards Deming, a statistician for the U.S. government. Deming based his proposals on the experience of U.S. firms operating under wartime industrial standards. Noting that American management had typically given line managers and engineers about 85 percent of the responsibility for quality control and line workers only about 15 percent, Deming argued that these shares should be reversed. He suggested redesigning production processes to account more fully for quality control, and continuously educating all employees in a firm—from the top down—in quality control techniques and statistical control technologies. Quality circles were the means by which this continuous education was to take place for production workers.

Deming predicted that if Japanese firms adopted the system of quality controls he advocated, nations around the world would be imposing import quotas on Japanese products within five years. His prediction was vindicated. Deming's ideas became very influential in Japan, and he received several prestigious awards for his contributions to the Japanese economy.

The principles of Deming's quality circles simply moved quality control to an earlier position in the production process. Rather than relying upon post-production inspections to catch errors and defects, quality circles attempted to prevent defects from occurring in the first place. As an added bonus, machine downtime and scrap materials that formerly occurred due to product defects were minimized. Deming's idea that improving quality could increase productivity led to the development in Japan of the Total Quality Control (TQC) concept, in which quality and productivity are viewed as two sides of a coin. TQC also required that a manufacturer's suppliers make use of quality circles.

Quality circles in Japan were part of a system of relatively cooperative labor-management relations, involving company unions and lifetime employment guarantees for many full-time permanent employees. Consistent with this decentralized, enterprise-oriented system, quality circles provided a means by which production workers were encouraged to participate in company matters and by which management could benefit from production workers' intimate knowledge of the production process. In 1980 alone, changes resulting from employee suggestions resulted in savings of $10 billion for Japanese firms and bonuses of $4 billion for Japanese employees.

Active American interest in Japanese quality control began in the early 1970s, when the U.S. aerospace manufacturer Lockheed organized a tour of Japanese industrial plants. This trip marked a turning point in the previously established pattern, in which Japanese managers had made educational tours of industrial plants in the United States. Thereafter quality circles spread rapidly here; by 1980, more than one-half of firms in the Fortune 500 had implemented or were planning to implement quality circles. To be sure, these were not installed uniformly everywhere but introduced for experimental purposes and later selectively expanded—and also terminated.

In the early 1990s, the U.S. National Labor Relations Board (NLRB) made several important rulings regarding the legality of certain forms of quality circles. These rulings were based on the 1935 Wagner Act, which prohibited company unions and management-dominated labor organizations. One NLRB ruling found quality programs unlawful that were established by the firm, that featured agendas dominated by the firm, and addressed the conditions of employment within the firm. Another ruling held that a company's labor-management committees were in effect labor organizations used to bypass negotiations with a labor union. As a result of these rulings, a number of employer representatives expressed their concern that quality circles, as well as other kinds of labor-management cooperation programs, would be hindered. However, the NLRB stated that these rulings were not general indictments against quality circles and labor-management cooperation programs, but were aimed specifically at the practices of the companies in question.

Silver Bullets and Marksmanship

In the mid-2000s, quality circles are almost universally consigned to the dustbin of management techniques. James Zimmerman and Jamie Weiss, writing in *Quality*, summed the matter up as follows: "Quality and productivity initiatives have come and gone during the past few decades. The list of 'already rans' includes quality circles, statistical process control, total quality management, Baldrige protocol diagnostics, enterprise wide resource planning and lean manufacturing. Most have been sound in theory but inconsistent in implementation, not always delivering on their promises over the long run."

Nilewide Marketing Review said the same thing in similar words: "Management fads should be the curse of the business world—as inevitably as night follows day, the next fad follows the last. Nothing more typifies the disastrous nature of this following so-called excellence than the example of quality circles. They rose to faddish heights in the late 80s presenting the so-called secret of Japanese companies and how American companies such as Lockheed used them to their advantage. Amid all the new consultancies and management articles, everyone ignored the fact Lockheed had abandoned them in 1978 and less than 12% of the original companies still used them."

Harvey Robbins and Michael Finley, writing in their book, Why The New Teams Don't Work, put it most bluntly: "Now, we know what happened to quality circles nationwide—they failed, because they had no power and no one listened to them." Robbins and Finley cite the case of Honeywell which formed 625 quality circles but then, within 18 months, had abandoned all but 620 of them.

Japanese industry obviously embraced and applied quality circles (the idea of an American thinker) and QC has contributed to Japanese current dominance in many sectors, notably in automobiles. If QC became a fad in the U.S. and failed to deliver, implementation was certainly one important reason—as Zimmerman and Weiss pointed out. U.S. adapters of QC may have seen the practice as a silver bullet and did not bother shooting straight. The reason why a succession of other no doubt sensible management techniques have also, seemingly, failed to get traction may be due to a tendency by modern management to embrace mechanical recipes for success without bothering to understand and to internalize them fully and to absorb their spirit.

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We would like to thank the editorial team for lending their expertise to make the book truly unique. They have played a crucial role in the development of this book. Without their invaluable contributions this book wouldn't have been possible. They have made vital efforts to compile up to date information on the varied aspects of this subject to make this book a valuable addition to the collection of many professionals and students.

This book was conceptualized with the vision of imparting up-to-date and integrated information in this field. To ensure the same, a matchless editorial board was set up. Every individual on the board went through rigorous rounds of assessment to prove their worth. After which they invested a large part of their time researching and compiling the most relevant data for our readers.

The editorial board has been involved in producing this book since its inception. They have spent rigorous hours researching and exploring the diverse topics which have resulted in the successful publishing of this book. They have passed on their knowledge of decades through this book. To expedite this challenging task, the publisher supported the team at every step. A small team of assistant editors was also appointed to further simplify the editing procedure and attain best results for the readers.

Apart from the editorial board, the designing team has also invested a significant amount of their time in understanding the subject and creating the most relevant covers. They scrutinized every image to scout for the most suitable representation of the subject and create an appropriate cover for the book.

The publishing team has been an ardent support to the editorial, designing and production team. Their endless efforts to recruit the best for this project, has resulted in the accomplishment of this book. They are a veteran in the field of academics and their pool of knowledge is as vast as their experience in printing. Their expertise and guidance has proved useful at every step. Their uncompromising quality standards have made this book an exceptional effort. Their encouragement from time to time has been an inspiration for everyone.

The publisher and the editorial board hope that this book will prove to be a valuable piece of knowledge for students, practitioners and scholars across the globe.

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