Operations Management
Introduction to Operations Management

Introduction:

In this chapter we will discuss:

- The Historical Evolution of Operations Management
- Systems View of Operations Management
- Communications in Operations Management
- Manufacturing Operations versus Service Operations
Introduction to Operations Management

The business environment for corporate organizations is becoming increasingly challenging. In India, firms have to deal with several bottlenecks such as outdated technology, underdeveloped infrastructure, inappropriate payment systems and ineffective scheduling and control systems, which have hampered their progress. The opening up of the Indian economy to global competition has increased the level of competition that domestic companies have to face. Domestic companies operating in automobiles, steel, electronic and other manufacturing sectors have to overcome the threat to their market share posed by foreign companies. The need for operations managers to reduce manufacturing costs, optimize productivity and improve product quality in order to stay in the market, has become imperative. Many organizations now recognize the importance of automation, optimization of scheduling and a proper inventory management system, and are incorporating total quality management and total quality control in their operations. Table 1.1 lists some of the decisions and activities of a typical operations manager.

Today the ordinary customer has become more sophisticated and demanding, and expects more variety, lower costs and better quality. Customers therefore drive demand and the industry has to meet this demand. Inter-firm rivalry and competition have also increased manifold. In line with these changes, organizations are replacing production-driven systems involving mass production, by market-driven systems to enable them to corner market share. This scenario has increased the importance of operations management in an organization, as it is directly responsible for the final product. As a result, operations
management is gaining more significance and has become a key discipline in management science. Until recently, the field of operations management was considered relevant only to the manufacturing sector. But with the increasing influence of service industries, the scope of operations management has widened. This chapter presents an overview of operations management.

Operations management can be defined as the management of direct resources (machine, material, and manpower), which are required to produce goods and services. It involves planning, organizing, controlling, directing, and coordinating all the activities of production systems, which convert resource inputs into products or services. Operations management, as a whole, deals with the design of products and processes, acquisition of resources, transformation of resource inputs into outputs, and distribution of goods and services.

Table 1.1.1: Decisions and Activities of Operations Managers

<table>
<thead>
<tr>
<th>Planning</th>
<th>Organizing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Plan product and service mix</td>
<td>• Centralize or decentralize operations</td>
</tr>
<tr>
<td>• Location and capacity planning</td>
<td>• Decide upon functions, products, or hybrid organization structure</td>
</tr>
<tr>
<td>• Decide upon production methods to use for each item</td>
<td>• Establish work center assignments</td>
</tr>
<tr>
<td>• Plan acquisitions of equipment</td>
<td>• Assign responsibility for every activity</td>
</tr>
<tr>
<td>• Decide on the number of shifts and work hours</td>
<td>• Arrange supplier and subcontractor networks</td>
</tr>
<tr>
<td>• Generate a master schedule of what products to make and when</td>
<td>• Establish maintenance policies</td>
</tr>
<tr>
<td>• Organize changes by incorporating new processes and procedures</td>
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<table>
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<tr>
<th>Controlling</th>
<th>Directing</th>
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<tr>
<td>• Encourage pride in performing as expected</td>
<td>• Establish provisions of union contracts</td>
</tr>
<tr>
<td>• Compare costs to budget</td>
<td>• Establish personnel policies</td>
</tr>
<tr>
<td>• Compare actual labor hours to standards</td>
<td>• Establish employment contracts</td>
</tr>
<tr>
<td>• Inspect the quality levels</td>
<td>• Issue job assignments and instructions</td>
</tr>
<tr>
<td>• Compare work progress to schedule</td>
<td></td>
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<tr>
<td>• Compare inventory level to targets</td>
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<tr>
<th>Motivating</th>
<th>Coordinating</th>
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<tr>
<td>• Provide challenges through leadership examples, specific objectives, and goals</td>
<td>• Coordinate through use of common forecasts and master schedules</td>
</tr>
<tr>
<td>• Encourage through praise, recognition, and other intangibles</td>
<td>• Observe actual performance and recommend needed improvement</td>
</tr>
<tr>
<td>• Motivate through tangible reward system</td>
<td>• Report, inform and communicate</td>
</tr>
<tr>
<td>• Motivate employees by job enrichment and giving challenging assignments</td>
<td>• Co-ordinate purchases, deliveries, design changes, and maintenance activities</td>
</tr>
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<tr>
<th>Training and Developing Personnel</th>
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</thead>
<tbody>
<tr>
<td>• Guide by informing correct work methods</td>
<td>• Respond to customer inquiries about status of orders</td>
</tr>
<tr>
<td>• Encourage employees to seek perfection in their tasks</td>
<td></td>
</tr>
<tr>
<td>• Give more challenging job assignments</td>
<td></td>
</tr>
<tr>
<td>• Support employees in training programs</td>
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THE HISTORICAL EVOLUTION OF OPERATIONS MANAGEMENT

The evolution of modern operations management can be traced back to the beginning of the eighteenth century when Adam Smith recognized the importance of division of labor. In his book *The Wealth of Nations*, he advocated the division of jobs into sub-tasks, and the assigning of workers to tasks based on their individual skills and capabilities, in order to improve productivity. This concept was adopted by Frederick W. Taylor in his book *The Principles of Scientific Management*, a landmark in the field of operations management. Some of the milestones in the field of operations management are listed in Table 1.1.2.

Till the early 1970's, the term “Production Management” was used, but the enlargement of the field, with the inclusion of purchasing, despatch and other allied activities, and the growing influence of the service sector, advocated the need for a more general title. As a result, “Production Management” was replaced by a more general term “Operations Management”, which incorporated both production and service-related concepts and procedures.

**Scientific Management**

F. W. Taylor, in his book *The Principles of Scientific Management*, introduced the concept of scientific management. According to this concept, scientific rules governed the productivity of a worker, and it is the prerogative of the management to study and apply these rules in their operations. Taylor proposed a systematic approach called the “shop system” and implemented it in Midvale Steel Works to improve labor efficiency. A few key concepts are listed below:

1. Each worker should be assigned a task based on his skill, strength, and ability to learn.
2. Standard output time is set for each task, using stopwatch studies. This should be used to plan and schedule future tasks.
3. Instruction cards, routing sequences, and material specifications are used for coordinating the activities in a shop, and work methods and work flow should be standardized.
4. Proper supervision by carefully selected and trained supervisors.
5. Incentive pay systems to motivate workers.

**Moving Assembly Line**

In 1911, Henry Ford applied the principles of scientific management to a moving assembly line for the manufacture of the Model T Ford automobile by employing standardized product designs, mechanized assembly lines, specialized labor and interchangeable parts in production units. Ford was thus able to reduce the production time for a car chassis from twelve-and-a-half hours to only ninety minutes. This was the first instance of the successful implementation of scientific management principles. This application of principles of scientific management increased the popularity across the globe.

**Hawthorne Studies**

Until the late 1920s, the developments in operations management only emphasized planning and control of materials and machines, and not on human dimensions. In 1927, a research team from the Harvard Business School under the supervision of Elton Mayo, undertook a study at Western Electric's Hawthorne plant in Chicago. The initial illumination studies tried to examine the relationship between light intensity on the shop floor and employee productivity. It was found that there was an increase in productivity whenever the intensity of light was increased. But to the team’s surprise, the same thing happened when they reduced the intensity of light. These observations led the team to assume that it was not the light or other physical conditions, but the attention and
importance the workers received during the study, which was responsible for their increased productivity.

This study initiated wide-ranging research into the behavior of the worker in the work environment. The result was a sea change in the way managements treated their workforce. From then on, managements, irrespective of their field of operation, found ways to motivate employees with monetary or other intangible benefits like recognition, etc.

**Operations Research**

During the World War II, many countries faced complex problems in logistics control and weapon systems design and manufacture. The massive deployment of manpower, supplies, planes, ships and other resources created the need to find the most efficient way to utilize these resources. For this purpose, the United States and many European nations formed operations research teams in most of their military branches. These teams developed mathematical techniques to assist in taking appropriate decisions over complex logistical situations.

At the end of the World War II, the successful operations research techniques were incorporated into the decision making processes of many business organizations.

**A SYSTEMS VIEW OF OPERATIONS**

An operation system is responsible for the conversion of resource inputs into desired products and services. The system consists of five basic sub-elements namely resource inputs, transformation, output, control subsystem and feedback. In each phase, value is added to the raw material, and when the value addition is optimum, the final product emerges. In order for the product to be competitive, it should be better than the competitor’s product in terms of quality and cost, and should be delivered on time.

A systems view allows operations managers to see the complete process from concept design to final product output. An operations management system contains resource input, transformation process, output, control subsystem and feedback. Table 1.1.3 provides examples of a manufacturing system (television) and a service system (bank). Figure 1.1.1 illustrates the different subsystems and their relationships.

**Resource Input**

This refers to any physical or nonphysical resource coming into an organization. Physical resources include labor, materials, equipment, etc and non physical resources include information, human knowledge, skills and intelligence.

**Transformation Process**

The conversion or transformation process includes procedures, rules and guidelines employed to convert physical and nonphysical inputs into goods and services through value addition. This conversion can be physical (manufacturing), exchange (retailing), location (transportation), physiological

<table>
<thead>
<tr>
<th>Table 1.1.3: Examples of Manufacturing and Service System</th>
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<tbody>
<tr>
<td><strong>Manufacturing System (e.g. Television)</strong></td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
</tr>
<tr>
<td>Equipment, labor, parts, etc.</td>
</tr>
<tr>
<td><strong>Conversion Process</strong></td>
</tr>
<tr>
<td>Assembling, Producing parts</td>
</tr>
<tr>
<td><strong>Output</strong></td>
</tr>
<tr>
<td>Television set</td>
</tr>
<tr>
<td><strong>Feedback</strong></td>
</tr>
<tr>
<td>Defect rates, Customer response</td>
</tr>
<tr>
<td><strong>Service System (e.g. Banking)</strong></td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
</tr>
<tr>
<td>Clerks, equipment, cash, etc.</td>
</tr>
<tr>
<td><strong>Conversion Process</strong></td>
</tr>
<tr>
<td>Monetary transactions</td>
</tr>
<tr>
<td><strong>Output</strong></td>
</tr>
<tr>
<td>Loans, and deposits</td>
</tr>
<tr>
<td><strong>Feedback</strong></td>
</tr>
<tr>
<td>Interest earned, and deposits received</td>
</tr>
</tbody>
</table>
Output

The output subsystem is the outcome of a conversion process. It could be a tangible product such as a television or an intangible product such as education.

Control Subsystem

The control subsystem is incorporated into the input, transformation and output subsystem to monitor the system. Control subsystems ensure the system's integrity, and prevents it form taking any deviations from planned objectives.

Feedback

Feedback is the communication link between different elements of an operations system. Feedback provides the management with vital information which enables it to take remedial measures in case of any deviation from the desired results. It also allows the management to optimize the total system's operation. Negative feedback provides information about deviations from the plan and helps in control, whereas positive feedback motivates the organization to improve productivity.

COMMUNICATION IN OPERATIONS MANAGEMENT

Proper information flow is the key to any effective management function. The operations manager should always be in a position to interact with other departments for the smooth functioning of the organization. Communication is of two types: internal and external. Internal communication refers to the interaction within the organization. External communication refers to the interaction with individuals outside the organization.

Internal Communications

To run smooth and efficient operations, departments in an organization are dependent on each other. In view of this fact, the operations manager should have open channels of communication with other departmental entities. Proper communication promotes coordination, reduces machine idle time, manpower wastages and minimizes lead time in implementing plans.

Accounting

Proper coordination with the accounting department allows the operations manager to keep a tab on operational expenses. In addition accounting provides many auditing functions that assist in inventory control and purchasing decisions.

Marketing

The marketing department acts as a point of contact with consumers. It provides information regarding customer requirements and preferences, and customer responses to products or services. This information assists the operations manager in deciding the quantity, quality and other specifications of the product or service to be produced.
Finance

The finance department is responsible for investment planning and expenditure. Proper coordination is the key to the timely receipt and approval of funds needed for production. The finance department is also responsible for evaluating and approving technical investment alternatives put forward by the operations manager.

Personnel

Proper communication between the operations and personnel departments ensures the recruitment of competent and skilled manpower.

External Communication

Having communication channels with external entities such as the government, competitors and customers is as important as internal communication. Information gathered from such interaction influences the decision making process.

Customers

Customers are the key to any organization’s well being, and operations managers value the feedback given by customers very highly. This feedback offers many constructive suggestions with regard to the quality, functionality and performance of the product or service.

Competitors

Operations managers get vital clues from information about their competitors’ products and procedures. Based on the acquired information, operation managers can benchmark their products and procedures against their competitors to enhance their company’s productivity.

Suppliers

Suppliers provide the bulk of the inputs into the operations management system and can directly influence many aspects of the product, such as quality and price. In addition, suppliers provide information on new processes, techniques, materials and products.

Government

The government formulates laws, rules and regulations which influence the plans and decisions of operations managers. Operations manager have to be aware of and follow government rules and guidelines e.g. safety guidelines, environmental norms, etc.

MANUFACTURING OPERATIONS VERSUS SERVICE OPERATIONS

Manufacturing and service operations require distinct management skills and tools because of their inherent differences. These differences are summarized below:

Manufacturing operations result in tangible output while service operations result in intangibles like transactions, deeds, performances, experiences, etc. Occasionally this classification may be blurred as in the case of a service organization like a restaurant, where the final product combines elements which are both tangible and intangible.

Briefly, a manufacturing organization can be defined as an organization where the production process involves less labor and more equipment, customer involvement in the conversion process is negligible or nil, and output is a tangible product which is consumed over a period of time. A service organization can be defined as one in which the process of production is more labor intensive, consumer interaction in the conversion process is high, and the output, in general, is an intangible product which is consumed immediately.
Manufacturing organizations, in general, are involved in mass production with few variations, whereas service organizations customize products based on the requirements and preferences of individual customers.

Manufacturing organizations can produce products based on the anticipation of demand which is not feasible for service organizations.

Products of manufacturing organizations face competition in different markets whereas competition in the service organizations is limited to the geographical area in which the service organization is operating.

Manufacturing organizations can measure the quality of the product through inspection and other auditing techniques, whereas the quality of service can only be measured through customer’s response or industry standards.

Question 1 of 10
Which company first adopted the concept of scientific management in the assembly line production system?

A. General Electric
B. Ford Motors
C. General Motors
D. Westing House
Section 2

Case Study: Crisis at Strocem RMC: Significance of Operations

This case study was written by Syed Abdul Samad under the guidance of Dr. V. Srinivas, IBSCDC. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was prepared from generalised experiences.

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It was 10.30 AM when Rajesh Pawar reached the Civil Engineering Society, IIT Delhi – the venue for a seminar on ‘Corrosion of Reinforcement in HV FA Concrete’. After the seminar, when the participants were discussing in groups, he spotted Deepak Kumar among the participants. Rajesh and Deepak had been classmates in the engineering college. Later both of them did their M.Tech in different universities and had joined the industry. Deepak had joined a well known construction company as a structural engineer, while Rajesh took up an additional 6 month diploma course in operations management before joining the industry. He joined a Ready-Mix Concrete (RMC) manufacturing company as an operations manager. Rajesh’s company was an industry leader with many manufacturing plants in various locations all over the country. Deepak had worked for the construction company for 2 years and then sensing the boom in the construction industry and the rising demand for RMC by the builders in the city he established a RMC plant located on the outskirts of the city. However, Deepak was currently going through a bad phase in his business.

After the initial greetings, they decided to catch up at the coffee shop after the day’s activities. Later in the evening they met at the coffee shop.

Suggested Questions for Discussion

1. What is Operations Management (OM)? Explain the purpose and significance of OM in an organisation. Referring to the case study, bring out the differences between the production systems and operations of products and services.

2. What is the difference between OM, Operations Research and Management Science (OR/MS) and Industrial Engineering (IE)? Rajesh lists out the tasks of an operations manager in a manufacturing firm. Similarly list out the tasks of an operations manager in an airline industry? How can services form an important part of operations in any firm?

3. How can an operations manager help Strocem RMC in the short- and long-run? Referring to the case study, discuss the historical developments in the field of OM. List the current issues that an operations manager needs to take care of apart from those mentioned in the case study?
Strategy in Operations Management

Introduction:

In this chapter we will discuss:

- Operations Strategy as a Competitive Weapon
- Strategic Planning for Production and Operations
- Process and Content of Operations Strategy
- Strategic Planning Models
- Productivity and Quality
- International Challenges in Production and Operations Management
- Financial and Economic Analysis in Operations
An organization that wants to succeed in a competitive business environment needs a sound strategy. A strategy is a broad, long-term plan, conceived in order to achieve business objectives. Strategies are developed at three levels: the corporate level, the business level and the functional level. In this chapter, we look at functional strategies, and, in particular, strategic decisions concerning the operations function. Many operations decisions are developed in compliance with business objectives, and with the functional objectives of the marketing, finance and human resources departments. Operations strategies such as the choice of operating structure are influenced by the nature of the goods or services to be produced and the markets to be served.

In the early 1990s, following the liberalization of the Indian economy, many companies from Japan, Europe, North America and Korea started operations in India. Most Indian companies were not in a position to compete against them as their products were either costlier or of lower quality. At this point, many Indian companies realized that they had to improve their operations strategies in order to improve productivity. Today, operations strategies form an integral part of the strategic planning process of most companies. They deal with the development of operational plans for the manufacturing facilities of an organization.

OPERATIONS STRATEGY AS A COMPETITIVE WEAPON

One of the key objectives of any business organization is to reach a position where it is able to attract more customers than its competitors. In order to gain such a competitive advantage, organizations try to identify their distinct competencies. The characteristics of a company’s operations function are important in determining its choice of products and markets, and the elements of its competitive strength. The following examples show how operational strengths can be used effectively as competitive weapons:

Product/Process Expertise: An organization can employ its strengths in certain areas of product functionalities and process capabilities to gain a competitive advantage over its competitors. For instance, Intel Corporation, USA, has superior computer chip design due to its technological expertise in producing microchips.

Quick Delivery: An organization with flexible capacity and an adaptive production process can produce a product and satisfy customer needs quickly. One-hour eyeglass
manufacturing, one-hour photo developing services and ‘same-day’ dry-cleaning and shoe repair services are some examples.

**Shorter Product Cycle**

The first company that enters a market usually gains a significant market share over subsequent entrants. The speed of product introduction is dependent on the flexibility and adaptability of the production system. A company, which is more adaptable than its competitors, can introduce a product into the market relatively quickly and will gain the advantage of untapped market demand and as a result will be able to corner a significant market share.

**Production Flexibility**

Some organizations specialize in having a highly flexible and responsive operations environment. Celestica, Inc, a Canadian computer component manufacturer, uses equipments that are not fixed to the floor. This enables production lines to be reconfigured within hours or days to make new and different products. This flexibility has allowed Celestica to expand from manufacturing a few products for a single customer (IBM) to making hundreds of products for over 40 different companies.

**Low-cost Process**

An organization with an efficient production system or access to low-cost resources can make standard products at costs lower than its competitors. For example, steel companies such as Nucor in the United States, have competed successfully with larger integrated steel producers like Nippon and US Steel by using mini-mills (a smaller version of a steel refining mill that can process scrap). The mini-mill production process allowed Nucor to gain a substantial price advantage over competitors by reprocessing scrap steel rather than producing primary steel from iron ore.

**Convenience and Location**

Facility location can provide substantial competitive advantage. For example, local courier and parcel company, Desk To Desk Couriers (DTDC), is a strong competitor to foreign multinationals like DHL and FedEx in India, as it has deep penetration and covers a larger number of Indian towns and cities.

**Product Variety and Facility Size**

In some industries, the variety of products offered and the size of operations can provide competitive advantage. Increasingly grocery stores and supermarket retailers compete by having larger stores that allow them to display a greater variety of products and to benefit from economies of scale.

**Quality**

An organization that produces a product of higher quality than its competitors can increase its sales volume even while commanding a higher price. Such an example is found in Sundaram Fasteners of the Sundaram Clayton Group. Their radiator caps are standard equipment in major automobile companies like DaimlerChrysler and General Motors.

**STRATEGIC PLANNING FOR PRODUCTION AND OPERATIONS**

Strategic planning is different from operations planning in the scope of its application. Strategic planning is broad-based planning, which involves long-term decisions, whereas operational planning concerns itself with short term, day-to-day planning. Markets are the key to any strategy. Once
markets are analyzed, the strategic task of the operations manager is to develop appropriate processes and designs to achieve the agreed-upon objectives. As mentioned earlier, operations strategy is developed in compliance with business strategy, which, in turn, is derived from corporate objectives. Operations strategy should be flexible enough to support a product or service through its entire life cycle and be able to accommodate future changes in market demand or business objectives. Operational superiority is critical for many manufacturing and service organizations to maintain their competitive position in the market. In addition, operations strategies should be consistent with strategies in other functional areas such as marketing, finance and human resources. The process of strategy development process is depicted in Figure 2.1.

### Elements of Operations Strategy

An operations strategy is a high-level integrated plan for business effectiveness or competitiveness. Key components of operations strategy are described below:

- Designing the production system
- Product/service design and development
- Technology selection and process development
- Allocation of resources to strategic alternatives
- Facility planning

#### Designing the production system

Designing the production system is one of the key responsibilities of any operations manager. It involves selecting the product design, the production system, and the inventory policy for finished goods for each product line.

#### Product design

Product design is primarily of two types:

- Customized product design
- Standard product design

Customized product design is the choice of operations managers when the level of customization is high and the quantity to be produced is low. Products are designed to satisfy individual customer needs. The emphasis in this type of product design is on the quality and on on-time delivery,
rather than on cost. Industrial products like boilers and turbines are examples of customized products.

Standardized product design is employed when an organization is involved in the production of limited variety of products, which are produced in large batch sizes. In such systems, importance is given to cost-control and quality rather than on the flexibility of the system. Consumer durables like coolers, fans, and televisions are examples of standardized products.

**Production system**

The production system can be broadly classified into two major categories:

- **Product-focused systems**
- **Process-focused systems**

Product-focused systems are generally employed in mass production organizations where there are groups of machines, tools and workers arranged according to their respective tasks in order to put together a product. These systems are suitable for producing standardized products like cars, televisions, computer systems, etc.

Process-focused systems are designed to support production departments that perform a single task like painting or packing. These systems are highly flexible and can easily be modified to support other product designs. Hence they are used in the production of customized products.

**Finished Goods Inventory Policy**

There are two types of policies relating to finished goods inventory:

- **Produce-to-stock policy**
- **Produce-to-order policy**

In a produce-to-stock policy, products are produced well in advance and are stored in warehouses, from where they are dispatched as per customer orders. This policy is suitable for organizations manufacturing products, parts or components, which have seasonal demand (like refrigerators and air-coolers) or those, which have general applications (like bolts and nuts).

A produce-to-order policy allows production to start only after the company receives customer orders and halts production until another order is received. This policy is suitable for organizations that produce products, parts or components of high value (like spares of an aircraft engine) or those that are meant exclusively for specific purposes (like dyes, castings, etc.).

**Product/service design and development**

An operations manager in conjunction with the marketing department is responsible for product design and development. The stages involved in product or service development are: creation of the product idea, market definition, definition of the product function, product specification, design analysis, test marketing, introduction in the market, and finally, evaluation of product performance in the market.

**Technology selection and process development**

Once the design of the product is finalized, managers concentrate on determining how the product will be produced. This involves thorough analysis and planning of the production processes and facilities. Every step in the process of production is planned in detail. The technology to be used in the production process is selected from a range of options.

**Allocation of resources to strategic alternatives**

Production companies have to continuously deal with the problem of scarce resources like capital, machines and materials and so on. As these resource inputs are vital to
production activities, their shortages can influence production performance significantly. Hence operations managers have to plan the optimal use of resources, both in terms of minimizing wastage, and in terms of their allocation to the best strategic use. Chapter 7 deals with the allocation of resources to strategic alternatives in greater detail.

**Facility planning**

The location of the production facilities is one of the key decisions an operation manager has to make since it is critical to the competitiveness of the organization.

Setting up production facilities with adequate capacity involves massive initial investment. Therefore, strategically right options should be carefully weighed against all available alternatives. These decisions also influence the future decisions on probable capacity expansions plans. Managers have to take into account factors like the availability of raw materials and access to the market when making their decisions. Operations managers also make layout decisions, i.e. decisions on the internal arrangement of workers and departments within the facility. All these decisions are crucial for the success of the organization and are dealt with in greater detail in Chapter 5.

**PROCESS AND CONTENT OF OPERATIONS STRATEGY**

The ‘process and content’ approach is one of the key approaches to strategic management. The content of a strategy relates to what the organization is planning to achieve, and the process of the strategy relates to how those objectives will be achieved. In other words, content and process can be referred to as the formulation and implementation of strategies, respectively. We can try and understand these concepts by applying them to the working of an insurance company. ‘Content’ in an insurance company represents the information needed to successfully complete a transaction e.g. claims submitted by customers, medical records, processing manuals used by the staff, etc. ‘Process’, on the other hand, represents the actions, activities and other procedures involved in the completion of a transaction e.g. telephone calls made, verifying eligibility, reimbursement, etc. So the content that is acquired from customers, agents and brokers provide the relevant information needed for the implementation of the requisite process. The proper content and relevant processes allow an organization to satisfy customers’ requirements.

**STRATEGIC PLANNING MODELS**

An operations manager has to evaluate a large number of variables that go into a typical decision making process. A strategic planning model helps operations managers in developing strategies to gain competitive advantage and enables them to manage resources optimally.

**TOWS**

Threats, Opportunities, Weaknesses and Strengths (TOWS) analysis developed by Boston Consulting Group is one of the methods, which helps organizations in making strategic decisions. It helps an organization in identifying opportunities and threats in the external environment and weaknesses and strengths within the organization. The difference between SWOT analysis and TOWS analysis lies in the fact that TOWS analysis first looks at the external threats and internal weaknesses and then aims to provide strategies which use external opportunities and internal strengths to counter external threats and eradicate internal weaknesses.

The TOWS matrix, seen in Figure 2.2, illustrates four different strategies that an organization can adopt to handle different situations, internally and externally. The four strategies are described below:

1) **WT Strategy (mini-mini)**: The purpose of the WT strategy is to minimize both weaknesses and threats. This strategy may
involve retrenchment, cutting back on operations, mergers or even liquidation.

2) WO Strategy (mini-maxi): The WO strategy tries to minimize weaknesses and maximize gains from opportunities. If due to an internal weakness, an organization is not able to make full use of the opportunities provided by the markets, the organization tries to tide over such weakness by acquiring necessary technology, imparting training to employees, etc. This enables the organization to take full advantage of the opportunity provided by the markets.

3) ST Strategy (maxi-mini): In this strategy, an organization tries to counter the effects of external threats by using internal strengths. For example, an organization can use its technological, financial, or marketing strengths to respond to a threat posed by the launch of a new product by a competitor.

4) SO Strategy (maxi-maxi): The optimum position an organization can find itself in is one where the organization, using its own strengths, can cash in on the opportunities provided by the market.

**Critical Success Factor Scoring Method**

This is a strategic planning model, which combines critical success factors and a scoring method to analyze the threats from competitors. Critical Success Factor (CSF) analysis developed at MIT’s Sloan School of Management by John Rockart, assists in evaluating factors that are critical to a firm’s competitive position. An organization’s competitive performance depends on its performance with regard to these factors, which indicates the competitive position of an organization with respect to its competitors. The factors include economic factors (product price, cost factors, profitability), social factors (management-employee union relationship, customer perception, supplier relationship) and operations-related factors (procedural advantage, location, technology).

Identification and evaluation of critical success factors, brings forth the factors in which the organization has a competitive advantage and those in which the competitor holds the advantage. To analyze the competitor’s threat, the management uses a rating score. A rating score is a number on continuous scale from 1 to 5 indicating the level of threat a competitor poses.
poses. A score of 1 indicates a high level of threat and 5 indicates a low level or negligible threat. An organization needs to concentrate on those factors in which the competitor holds an advantage and improve those in which the organization is ahead, in order to negate any future threats.

**PRODUCTIVITY AND QUALITY**

The prosperity of nations and organizations alike is considered to be dependent on their comparative productivity. Productivity provides a good measure of performance at national, industry or individual business level. What is productivity? Productivity can be described as the relationship between output from the system and inputs used to produce the output (products and services). In mathematical terms, it is the ratio of output to input.

\[
\text{Productivity} = \frac{\text{Output}}{\text{Input}}
\]

It is incorrect to equate higher production with increased productivity. An increase in output itself is not an indication of an increase in productivity unless there is a less than proportionate increase in inputs. As an example, consider a firm, which produces 10 chairs and employs 10 employees. If tomorrow, the firm starts producing 12 chairs by employing 2 more employees, this increase in output cannot be termed as an increase in productivity. However, if the increase in output was achieved by the 10 employees initially employed, it would be seen as an increase in the productivity of the employees.

Productivity can be measured in relation to a single factor, a combination of factors (multifactor productivity) or all the factors taken together (total productivity). An example of single factor measurement of productivity is labor productivity, which typically measures output per unit of labor. Multifactor productivity takes into consideration more than one factor of production such as labor and materials. Total factor productivity includes all the factors of production (labor, materials, process, energy and other inputs).

Output may be in terms of the number of customers served in a restaurant, the number or volume of products produced in a factory, the number of customer requests processed in a bank. Input may be the number of employees, quantity of raw materials, capital invested, etc.

**Productivity in a Service Organization**

Measuring productivity in a service organization is difficult due the intangible nature of the product. Service companies base productivity on the number of tasks performed, or the number of customers served in any given time period. Other measures include a comparison of the service provided with company, industry or customer quality standards.

In the service industry, it is often difficult to establish a standard time for a task; usually, only a probable time for a task can be established. Service industries, in general, customize products based on each customer’s specific requirements. For example, the time taken to approve a loan in a bank varies with each customer.

In order to measure productivity, service professionals maintain time-sheets to indicate the amount of time spent on a given task. In cases where the task is routine and involves minimal customization, the quantity of work, for example, the number of service calls made per day, the number of queries handled, or the number of customers served, is used as a measure.

**Quality and Productivity**

Quality like productivity is key to the well being of an organization. Quality is complementary to productivity. Quality
should not be compromised when trying to increase productivity. Just by producing more products or serving more customers, an organization cannot expect to increase profits or retain customers. The product or service should be able to satisfy the requirements of the customers. By improving quality of product or service, the organization can improve its competitive position in the market.

Incorporating quality in the operating system can contribute to improved productivity in the following ways:

1) Reducing wastage in production
2) Reducing the rejects
3) Optimizing the process and procedure

The quality of the product or service can ensure that the organization retains its customers and simultaneously are able to attract new customers.

With properly designed operating systems and procedures, an operations manager can improve the quality of the products and the productivity of the factors of production. As opposed to this, inefficient design leads to a decline in quality and productivity, resulting in overall inefficiency and sub-optimal performance.

INTERNATIONAL CHALLENGES IN PRODUCTION AND OPERATIONS MANAGEMENT

International operations management decisions such as those of resource allocation and acquisition, location and logistics are complex. The complexity is due to the fact that the firms have to deal with suppliers from different countries, different government regulations, heterogeneous markets, transportation bottlenecks, etc. In addition, decisions involving location of the facility, exchange rates, tax laws, resource availability, and the political and economic situation in the host country, make international operations management complex and challenging. Few key points organizations have to concern with before formulating international operations are:

1) Resources: where and how to obtain resources
2) Location: where and how to build and operate facilities
3) Logistics: modes of transport and inventory control

First, decision involving the acquisition of resources, an operations manager has to decide on the process and steps an organization uses to acquire the necessary resources. Second, the manager has to decide on how much of vertical integration required to bring home the advantages of economies of scale, and to reduce dependence on local suppliers. Third, the ‘make or buy’ decision has to be taken. Here the operations manager has to decide, based on the risk, investment and flexibility of the production process, whether to make or buy sub-parts needed in production. By making its own components, the firm can have control over quality, quantity, delivery, design alteration, etc. and in addition, this shields the organization from the vagaries of external markets. Buying sub-parts, on the other hand, gives the company the flexibility to change suppliers in event of any change in the production structure, without incurring the huge costs involved in facility re-engineering.

When it comes to choosing a location, the operations manager has to look into country-related factors -- the political and economic situation, and product-related and organizational factors. International location decisions are based on the availability of resources, infrastructure, the ‘country of origin’ effect (for example, US company won’t be welcomed in countries like Iran or Iraq), the cost of labor and raw materials,
etc. Political and economic conditions like political stability, trade policies of the host country, and economic environment have considerable influence on the operational decisions. Product-related factors that influence decisions are market potential, competitors, customer preferences, etc.

Finally, complex decisions regarding logistics have to be worked out as international logistics differ from domestic logistics in many ways; the distance involved, inventory levels, warehousing and distribution, modes of transport, and packaging, vary widely from country to country.

Exhibits 2.1 and 2.2 illustrates the strategy adoption decision based on a company's capabilities, needs, market opportunities and customer requirements.

International Service Operations

Services are intangible, cannot be created or stored in anticipation of demand, and require customer participation. These attributes of services provide different challenges to the services organizations, which are very different from those faced by manufacturing organizations operating in international markets. Service organizations work under standards set in the host country as local governments regulate many service operations and provide guidelines, which may not entirely be applicable for the organization. Industries in service sectors like banking, airlines and insurance have to operate under extensive regulations of the host country. Issues before international service operations include capacity planning, location planning, facility design and layout, customization of services, etc.

FINANCIAL AND ECONOMIC ANALYSIS IN OPERATIONS

Operations managers have to take both financial and economic decisions. Economic and financial analysis is used to evaluate the costs of operation and profit potential of an investment.

Exhibit 2.1

Platform Development at Whirlpool

To what extent should a business customize a product to suit the requirements of various markets? On the one hand, customization allows an organization to satisfy the specific requirements of a market but on the other hand, customization is expensive, because the firm has to forgo the advantages of a standardized production process. Modern manufacturing methods allow firms to customize products without experiencing a steep increase in costs. In platform development, for example, firms use a basic framework that is common to all versions of a product. Attributes and features can be added and deleted to a product based on the specific requirements of different markets. Whirlpool applied this concept to its washing machine manufacturing process.

Whirlpool planned to make a "world washer" which could be sold in any part of the world. Such a washing machine would have to suit both American and European preferences. The Americans preferred top loading washing machines while the Europeans preferred front loading machines. The front-loaders were more efficient and environment friendly machines than the top loading machines since they used less energy, less water, less soap. Americans however preferred top-loaders since they had more capacity. Even then front loaders slowly increased their market share from zero to five percent in US markets within a decade. Whirlpool wanted to be a significant player in this growing market.

So, Whirlpool formed a project team to develop a front-loader that would appeal to both European and American consumers. The 65-member team that was formed included German, Italian, and the US engineers, designers and marketing and production specialists. The outcome of this effort was "Duet", a front-loader with capacity that was 10-15 percent larger than the top-loaders sold in the US. It was introduced in the US in fall 2001. The European version, sub-branded "Dreamspace", with different size, styling, and spin and wash cycles, was launched in the summer of 2002. The same basic machine will be sold in Asia also.

Operations managers should be familiar with conditions and factors affecting costs and the methods of measuring and controlling costs.

Operations costs are divided into direct costs and indirect costs. Direct costs or prime costs are those cost components, which
can be identified individually for each product or service produced, e.g. the cost of direct material, the cost of direct labor etc. Indirect costs or operations overhead are those which cannot be tied to specific product or service e.g. administrative costs, maintenance costs. In addition, an operations manager should be aware of the fixed and variable components of the costs. Fixed costs are those which do not change with a minor change in scale of production e.g. rent on premises, depreciation on equipment, insurance etc. Variable costs denote direct costs like wages of workers, and direct material cost which vary with the change in the scale of production.

Operation managers have many methods at their disposal to evaluate the cost effectiveness of an investment. Two of the most commonly used techniques are the payback method and net present value (NPV) method.

**Payback Method**

One of the basic methods used to compare investment alternatives is by calculating the payback period for each investment alternative. The payback period is the time taken (usually in years) to recover the initial investment. The payback takes into consideration the initial investment and the resulting annual cash flow. Mathematically the payback period is denoted by:

\[
\text{Payback period} = \frac{\text{Net investment}}{\text{Net annual income from investment}}
\]

Where,

Payback period = Time taken to recover initial investment (usually in years)
Net Investment = purchase and installation costs minus its anticipated future salvage value
Net Annual income = Anticipated annual revenue minus expenses

In spite of its popularity, the payback method has a few inherent drawbacks - it ignores cash flow beyond the payback period, and does not take into account the time value of money. These deficiencies are overcome in the net present value method.

Problem 1
Payback period for a project with an initial investment of Rs 10 lakh that is expected to generate an income Rs 2 lakh per annum is calculated as which gives 5 years as the payback period or the time taken to recover the initial investment. Similarly, the payback period for different investment alternatives is calculated. The alternative with the shortest payback period is preferred.

Payback = \frac{10 \text{ lakh (Net Investment)}}{2 \text{ lakh (expected annual income)}}

Net Present Value (NPV) Method
The NPV method is used to calculate present value of future returns, discounted at the marginal cost of capital, minus the present value of the cost of the investment. The net present value method takes into account the time value of money. It is employed for ranking and comparing the profitability of project alternatives. NPV for a project can be determined by using the equation:

\[ \text{NPV} = \sum_{i=1}^{t} \frac{\text{CF}_i}{(1-r)^i} - I \]

Where,
- \( \text{CF}_i \) = the cash flow at time \( i \)
- \( r \) = discount rate
- \( t \) = time horizon
- \( I \) = Initial investment

If the net present value of an investment is greater than zero then the project is acceptable. If the net present value is less than zero, the project is rejected. The greater the NPV value of the project the better is its profitability. In case, where multiple projects are compared the project alternative with the largest NPV is selected. Suppose the net present value of a project is calculated as Rs 1 lakh, this implies that undertaking the project is expected to increase the value of the firm by Rs 1 lakh. NPV is a useful method for comparing investment alternatives, with comparable initial investments.
Question 1 of 20
Which of the following are among the key objectives of an operations manager?

i. Maximizing customer satisfaction
ii. Minimizing inventory
iii. Maximizing resource utilization

A. i & ii
B. ii & iii
C. i & iii
D. i, ii & iii
Case Study: Operations Management at Southwest Airlines

This case was written by R.Muthu Kumar, under the direction of A.V. Vedpuriswar, IBS Center for Management Research. It was compiled from published sources, and is intended to be used as a basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation.
It’s easy to offer great service at high cost. It’s easy to offer lousy service at low cost. What’s tough is offering great service at low cost, and that’s what our goal is. To do it, we have to watch every penny. I personally approve all expenditures over $1,000, not so much because I don’t trust our people, because I know that if they know I’m watching, they’ll be just that much more careful.

--Herb Kelleher, the Chairman of Southwest Airlines

Introduction

In 2003, Southwest Airlines (Southwest) was the fourth largest US airline in terms of domestic customers carried. The airline’s major short haul, low-fare, high frequency, and point-to-point carrier in the US covered 60 cities (59 airports) in 30 states. It was the first airline to introduce a homepage on the Internet. Southwest had enjoyed 30 straight profitable years. Southwest had the best customer complaint record of any US airline for the last 12 years. In 2003, Southwest was named by Fortune as one of the most admired companies in US. In November 2003, Southwest achieved a 9.4% increase in traffic due to Thanksgiving Day. It also recorded 3.76 million revenue passenger miles up from 3.44 million for the same period in the previous year. Its load factor was 63.7% up from 60.5% in November 2002.

Background Note

In 1967, Texas businessman Rollin King and lawyer Herb Kelleher founded Southwest as an intrastate airline, linking Dallas, Houston, and San Antonio. In 1971, Southwest made its first scheduled flight. Operating from Love Field Airport in Dallas, Southwest adopted love as the theme of its early ad campaigns. While other airlines moved to the new Dallas/Fort Worth Airport (DFW) in 1974, Kelleher insisted on staying at Love Field, and gained a virtual monopoly there.

When Lamar Muse, Southwest’s president, resigned in 1978, Kelleher was elected as president and Chief Executive Officer. Thus began the career of one of the America’s most popular business leaders.

In 1979, Southwest started its new service to New Orleans from Dallas, the first city outside Texas. In 1982, Southwest extended its services to San Francisco, Los Angeles, San Diego, Las Vegas, and Phoenix. Southwest launched the "Just Say When" campaign in 1985, which established it as the point-to-point carrier in the nation.

Southwest introduced advance-purchase Fun Fares in 1986, and a frequent-flier program in 1987, which was based on the number of flights taken instead of mileage. Southwest and Sea world of Texas joined to promote Texas as a major tourist place.
In 1986, Southwest was announced as Sea World of Texas’s official airline and the official airline of California.

In 1992, Southwest won the first Triple Crown Award for the month of January and won the annual Triple Crown Award. Southwest managed to receive that award without a break till 1996. Southwest moved into the East Coast with a service to Baltimore in 1993 and bought Salt Lake City-based Morris Air in 1994.


In 2000, Southwest had its first major accident, when a Boeing 737 aircraft overran the end of a runway in Burbank, California, and came to a halt in a busy street. But the accident caused only minor injuries. Southwest introduced SWABIZ, a software tool that assisted company travel managers in booking and tracking trips made through its website. Later that year, Southwest placed its biggest aircraft order ever, calling for delivery of another 94 Boeing 737 aircraft between 2002 and 2007.

In 2001, on its 30th anniversary, Southwest changed its logo and added blue to its traditional color scheme of gold, red, and orange. That same year, Southwest experienced a rare labor dispute, when stalled contract negotiations led to picketing by the airline’s ground crew union. Kelleher stepped down as president and CEO in 2001 and was succeeded by General counsel Jim Parker.

**Figure (ii)**

<table>
<thead>
<tr>
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<th></th>
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<th></th>
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<td>$6,000</td>
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<td></td>
</tr>
<tr>
<td>$0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: www.southwest.com

Despite an industry wide downturn following the September 11, 2001 terrorist attacks, Southwest managed to post a profit for 2001 as well as 2002. In the face of weak demand for air service, most major airlines significantly reduced service, grounded aircraft, and retrenched employees. UAL, the parent of United Airlines, and US Airways sought relief from financial obligations in bankruptcy and other smaller carriers ceased operation entirely. But Southwest maintained a full flight schedule and avoided layoffs.

Southwest also continued to strengthen its presence in the east coast of the US. It took advantage of the cutbacks in services by major carriers, by adding five nonstop transcontinental flights. Its latest eastern expansion project was at the Philadelphia
International Airport, which it planned to serve with 14 daily flights.

The year 2002 was the worst year ever for the airline industry. A sluggish economy, radical changes in airport security, high-energy prices, and tension in the gulf spelled financial disaster for the major airlines. Despite all this, Southwest posted its 30th consecutive annual profit. No other airline had equaled this record of profitability.

**Operations**

Southwest’s business model revolved around providing safe, reliable, and short duration air service at the lowest possible fare. With an average aircraft trip of roughly 400 miles, the company had benchmarked its costs against ground transportation. But Southwest believed that cost leadership should not dilute the quality of service.

According to analysts, who had been tracking Southwest closely, the airline’s approach had a lot in common with the approaches taken by cost leaders in other industries. Southwest pursued a blanketing strategy similar to that of the famous US retailer, Wal-Mart. When Southwest decided to serve a new city, it typically scheduled flights from the new city to two, three or even four destinations at which the company had previously established itself. Southwest did not commence a service between any two cities until it was able to devote the planes and personnel necessary to operate at least five to six flights a day. Like Toyota, which manufactured small batches of cars in a cost effective way, Southwest had developed competencies in turning around aircraft quickly.

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**Exhibit 1**

Southwest Building blocks of operational efficiency

- Limited passenger service.
- Frequent, Reliable Departures.
- Short-haul and Point-to-point Routes.
- Highly Productive Ground and Gate crews.
- Low-ticket fares and secondary or smaller airports.
- High Aircraft Utilization.


---

**Figure (iii)**

Key Operational Parameters of Southwest

<table>
<thead>
<tr>
<th>Year</th>
<th>Fleet Size (at year end)</th>
<th>Aircraft Utilization</th>
<th>Passengers boarded</th>
<th>Revenue Passenger Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>190</td>
<td>67.50%</td>
<td>12,500</td>
<td>2,700</td>
</tr>
<tr>
<td>1999</td>
<td>285</td>
<td>68.10%</td>
<td>2,550</td>
<td>3,574</td>
</tr>
<tr>
<td>2000</td>
<td>380</td>
<td>69.00%</td>
<td>3,574</td>
<td>4,252</td>
</tr>
<tr>
<td>2001</td>
<td>332</td>
<td>68.10%</td>
<td>2,800</td>
<td>3,835</td>
</tr>
<tr>
<td>2002</td>
<td>375</td>
<td>68.10%</td>
<td>2,800</td>
<td>4,335</td>
</tr>
</tbody>
</table>

Note: Passenger Load Factor is the percentage of a plane filled with paying passengers. Aircraft Utilization is the hours and minutes in a day a plane is used. Revenue Passenger Miles = One paying passenger flown one mile. Often referred to as the airlines industry’s measure of traffic.

Source: www.southwest.com
Turnaround

Video 1.1: Southwest Airlines “Day in the Life of A 25 Minute Turn”

Quick turnaround held the key to operational excellence in the airline industry. Southwest attempted to reduce the turnaround time through excellent coordination among various functions – pilots, flight attendants, gate agents, ticketing agents, operation agents, ramp agents, baggage transfer agents, cargo agents, mechanics, fuelers, aircraft cleaners and caterers. This was unlike other airlines, where these different functions typically worked in isolation. In 1972, Southwest had operated its flights with just three planes. The company

Exhibit: II
Southwest: Anatomy of a 15-minute turnaround

<table>
<thead>
<tr>
<th>Time</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7:55</td>
<td>Ground crew chat around gate position</td>
</tr>
<tr>
<td>8:03:30</td>
<td>Ground crew alerted, move to their vehicles</td>
</tr>
<tr>
<td>8:04</td>
<td>Plane begins to pull into gate; crew moves towards gate</td>
</tr>
<tr>
<td>8:04:30</td>
<td>Plane stops; Jet way telescopes out; baggage door opens</td>
</tr>
<tr>
<td>8:06:30</td>
<td>Baggage unloaded; refueling and other servicing underway</td>
</tr>
<tr>
<td>8:07</td>
<td>Passengers off plane</td>
</tr>
<tr>
<td>8:08</td>
<td>Boarding call; baggage loading, refueling complete</td>
</tr>
<tr>
<td>8:10</td>
<td>Boarding complete; most of ground crew leaves</td>
</tr>
<tr>
<td>8:15</td>
<td>Jet way retracts</td>
</tr>
<tr>
<td>8:15:30</td>
<td>Pushback from gate</td>
</tr>
<tr>
<td>8:18</td>
<td>Pushback tractor disengages; plane leaves for runway</td>
</tr>
</tbody>
</table>

Source: *Hit ‘em Hardest with the mostest,* Forbes, 16th September 1991.

Source: http://www.youtube.com/watch?v=IBolz4BuMtA&feature=results_video&playnext=1&list=PL1B73FDFF38CB04F

Figure (iv)
Southwest’s System Map 2002

Source: Southwest.com

limited the turnaround time for each plane to ten minutes or less. Southwest had managed to limit airplanes’ turn time to about 20-25 minutes over the years, even though airport congestion had worsened and security regulations had become stricter.
Routing

After the deregulation of the airline industry in 1978, most airlines established the hub-and-spoke system. The system was characterized by longer wait time for both passengers and airplanes, more planes, extra computer systems, extra salaries to ground staff and additional commissions to travel agents. Airlines also had to pay the rent for the gates, as planes were often kept idle at an airport waiting for the connecting flight. Seeing these disadvantages, Southwest persisted with its point-to-point flights between cities. It gained an advantage over other carriers by utilizing the lost time for an additional flight. Southwest also decided against interlining with other carriers. It was not in favour of keeping its planes waiting for passengers to arrive from connecting flights that were often delayed. Southwest felt that customers did not want to go out of their way and travel to a hub city simply for the convenience of the airline.

Southwest's point-to-point route system, as compared to hub-and-spoke, provided for more direct nonstop routings for customers and, therefore, minimized delays, and total trip time. In 2002, Southwest served 338 nonstop city pairs. As a result, approximately 77% of Southwest's customers flew nonstop.

Use of Smaller Airports

Southwest avoided congested airports wherever possible. Instead, it concentrated on convenient, efficient airports like Dallas Love Field and Houston Hobby and enhanced the company's ability to sustain high employee productivity and reliable on time performance. This dependence on secondary airports in major markets made it difficult for passengers to transfer from other airlines to Southwest flights or vice versa. But it saved an average of 15% to 25% of flight time due to reduced taxi time, fewer gate holds and less waiting in the air. This strategy also enabled the company to achieve high asset utilization.

Ticketing

In 1979, Southwest introduced self-ticketing machines in ten cities to make it faster and more convenient for people to fly. This helped in reducing the time each customer spent in line waiting to be ticketed. In this system, a customer inserted a credit card into the machine, and obtained a one-way or round trip ticket for the chosen destination. The system reduced ticketing time to one minute.

In January 1995, Southwest was the first major airline to introduce a ticket less travel option, eliminating the need to print and then process a paper ticket altogether. Southwest also entered into an arrangement with SABRE, the computer reservation system, to facilitate ticketing and automated booking.
in a very cost-effective manner. This allowed the customers to bypass the existing computer reservation systems completely. Instead, they received a confirmation number from Southwest when they logged on to the company’s website. Southwest eased the airport workload for the employees and customers by allowing for Rapid Rewards14 credits at the time of reservation rather than at the airport. This meant one less step for the employees and greater convenience for the customers. Increased Internet sales forced Southwest to close its call centers in Dallas, Little Rock, and Salt Lake. Nearly 2,000 workers were asked to relocate to another call center or accept a severance package. The customers had the opportunity to receive Rapid Rewards, after purchasing and flying only eight roundtrips. They would earn 16 credits (a one-way ticket equals one credit) in a 12-month period, and receive a roundtrip ticket for travel anywhere within Southwest’s area of service for up to a year. Since there were no restrictions on the number of Rapid Rewards seats, customers could fly virtually anytime to any Southwest destination. Rapid Rewards members could also transfer (but not sell) the award ticket to anyone without any additional paperwork. Rapid Rewards program was simple and by far the most generous in the industry. The tickets bought were nonrefundable but could be used toward future travel on Southwest, without the penalty of a change fee. The awards for Best Customer Service, Best Award Redemption, and Best Bonus Promotion among all frequent flyer programs were earned by Southwest.

**Boarding**

To reduce check in times, Southwest automated various procedures. It implemented computer-generated baggage tags to electronically capture bags checked by customers. It also implemented computer-generated boarding passes from multiple points in the airport. This allowed customer identification by name for boarding purposes and allowed the customer a more convenient check in through standing in fewer lines. Southwest also implemented self-service boarding pass kiosks, or Rapid Check-In.

Southwest did not assign any particular seat number to its customers. They were boarded on a first come first serve basis in a group of 30. Southwest used reusable plastic boarding passes to speed up the boarding process. Earlier, the employee collecting the passes, had to read what was printed on the ticket instead of simply looking at the color of the plastic boarding pass. This slowed down the operation. Also, airline employees could not concentrate on welcoming customers on board.

**In flight services**

Southwest did not offer full cabin service and provided only coach class service to its passengers. Southwest served no meals on board. Instead, the airline offered peanuts and other snacks and put extra seats in the empty space that would otherwise be required for food galleries. Southwest also avoided using bulky food and beverage carts that prevented customers from moving about the cabin.

**Aircraft Standardization**

Southwest concentrated heavily on one type of aircraft - the Boeing 737, to simplify scheduling, maintenance, flight operations, and training activities. It gave extensive training to all its pilots, flight attendants and mechanics on the Boeing 737.
The airline could easily substitute the aircraft, reschedule flight crews or transfer mechanics quickly. With only one type of aircraft, spares inventory management and record keeping became simpler. Exclusive use of the Boeing 737 series helped the company to negotiate better deals with Boeing and fuel efficient and lower capital than the other aircraft in the market. Southwest’s efficient flight dispatch system allowed the airline to minimize weather and operational delays. Southwest also used a young fleet of aircraft (average age of 8.4 years) and an efficient maintenance team to minimize delays and cancellations due to mechanical problems.

**Looking Ahead**

Southwest planned to add two more nonstop flights between Baltimore and Houston by 2004. With the additional flights, Southwest would offer a total of four daily nonstop flights between the two airports. Southwest planned to connect with a new daily nonstop service between Spokane and Las Vegas on January 18, 2004. Southwest also had plans to add one daily nonstop flight between various cities from April 4, 2004. These included Chicago midway and Ft. Lauderdale/Hollywood, Chicago midway and Orlando, Chicago midway and Columbus, Baltimore/Washington and Columbus (A total of 12 flights daily). Southwest confirmed, it would start a new service from Philadelphia on May 2004, with daily nonstop service to Chicago midway, Las Vegas, Orlando, Phoenix, Providence, and Tampa Bay.

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Linear Programming

Introduction:
In this chapter we will discuss:
- Requirements of a linear programming problem
- Assumptions of Linear Programming Models
- Solving Linear Programming model
- Formulating of linear Programming model
Linear Programming

Linear programming is an optimization technique that is useful not only in industry and business but also in non-profit organizations. It can be applied to a variety of problems such as production, refinery operations, advertising, transportation, distribution and investment analysis. The well-known mathematician Kohlar has defined linear programming as “a method of planning and operation involved in the construction of a model of a real situation containing the following elements:

(a) Variables representing the available choices, and
(b) Mathematical expressions

(i) Relating the variables to the controlling conditions,
(ii) Reflecting the criteria to be used in measuring the benefits derivable from each of the several possible plans, and
(iii) Establishing the objective.

The method may be so devised as to ensure the selection of the best of a large number of alternatives.”

It can be explained through an example. Suppose a manager has been given resources for use (i.e. available man-hours, quantity of raw material, machine - time, etc). In other words, the quantity of available resources is known to the manager. The objective of the manager is to determine the resources required or utilization to optimize the goal of the firm which can be profit maximization, sales maximization, cost optimization, etc.

This situation requires a search for the variables that affect the objective and are subject to certain constraints. With the help of decision variables, their constraints, equalities or inequalities can be formed. They will then provide the optimal solution to achieve the objective. In this chapter, we discuss graphical and simplex methods of solving linear programming problems.

**REQUIREMENTS OF A LINEAR PROGRAMMING PROBLEM**

In order to solve his day-to-day problems in decision-making, a manager must possess the skill to recognize the problems for which linear programming solutions are appropriate. In general, linear programming models can
be applied to problems which satisfy the following requirements.

1. The problem must have a well-defined single objective to achieve. Assume the case of a firm that manufactures two types of furniture, chairs and tables. The firm, in order to apply linear programming concepts for its production problems, should have a major objective, say profit maximization.

2. There must be alternative courses of action, one of which will achieve the objective. For instance, the firm in consideration may allocate its production resources like raw materials and manufacturing capabilities to chairs and tables in the ratio of 1:1 or 1:2 or 2:1 or some other ratio.

3. The decision variables must be continuous in nature. That is, the number of chairs and tables to be manufactured, in our case, is flexible enough to take any non-negative values within a range.

4. Resources must be limited in supply and the achievement of the objective function is restricted by these constraints. The furniture plant has a limited manpower and machine hours available. Hence, the more it allocates for chairs, the fewer tables it can make.

5. The objective and the constraints must be linear functions. The manager should be able to express the firm's objectives and its limitations (constraints) in the form of linear mathematical equations or inequalities.

The concept of linear programming can be applied to those problems which satisfy the above requirements. Thus, the general form of a linear programming problem can be stated as below:

Maximize

\[ Z = C_1x_1 + C_2x_2 + \ldots + C_nx_n \]

Subject to the constraints

\[ \begin{align*}
A_{11}x_1 + A_{12}x_2 + \ldots + A_{1n}x_n & \leq b_1 \\
A_{21}x_2 + A_{22}x_2 + \ldots + A_{2n}x_n & \leq b_2 \\
A_{31}x_3 + A_{32}x_2 + \ldots + A_{3n}x_n & \leq b_3 \\
\ldots & \\
A_{m1}x_1 + A_{m2}x_2 + \ldots + A_{mn}x_n & \leq b_m \\
x_1, x_2, x_3, \ldots, x_n & \geq 0
\end{align*} \]

Where \( x_1, x_2, x_3, \ldots, x_n \) are a set of variable whose values are to be determined.

\( C_i, A_{ij} \) and \( b_i \) are the coefficients that are specified by the problem assumptions and \( Z \) is a linear function of variables \( x_i \).

It can be noted that the goal of linear programming model need not always be the maximization of the objective function. It can also be to minimize it.

In case the model is meant to minimize the objective function, the sign \( \leq \) in constraints is replaced by \( \geq \) to obtain a general set of linear programming problem. Also, the constraints need not always be represented by inequalities. They can also be linear equalities.

ASSUMPTIONS OF LINEAR PROGRAMMING MODELS

Like any other programming models, linear programming models are also based on many assumptions. The following are some of the main assumptions that are made in the construction of linear programming models:

- Proportionality
- Additivity
- Divisibility
• Certainty

**Proportionality**
The objective function (Z), as described earlier, is a linear function of the decision variables (x_i). In other words, the value of Z increases by C_j times whenever the value of x_i increases by unity. If the variable x_i represents the number of units of product j produced and C_j is the quantity of material used to produce a unit of the product j, then producing five units of product j consumes five times the raw material quantity C_j that is, the material consumption per unit product remains constant irrespective of the quantities of production and the total consumption is always proportional to the total production.

**Additivity**
A typical linear programming problem has an objective function and several constraints, each with a set of decision variables. The aggregate value of the objective function and each constraint is generally obtained as the sum of individual contributions from each decision variable. That is, the concept of linear programming does not consider any synergistic effects among the decision variables, while calculating their total value for the objective function or the constraints that they are associated with.

**Divisibility**
As described earlier, the decision variables in linear programming models are continuous in nature and can take any non-negative, real, numeric value within the range specified by the constraints. The model assumes that these decision variables are divisible and solves the problems that involve fractional values for the variables in the same way in which the problems without any fractional values are solved. The solutions thus obtained are finally rounded off, without making a significant loss of quality in the solution. However, in cases where fractional values for the variables does not make sense, like the case of number of flights for an airline service, the problem can be formulated and solved as an integer program.

**Certainty**
Finally, the linear programming model assumes that all the constants (C_j, A_ij, and B_j) have certain values. It assumes that the optimal solution exists for the problem, only when the values attributed to the coefficients of variables are constant.

A manager can identify problems to which linear programming models are appropriate by testing whether or not the problems satisfy the above assumptions of linear programming.

**FORMULATING A LINEAR PROGRAMMING MODEL**
Formulating a problem as a linear programming model is the vital and difficult aspect of solving it. Though there is no standard pattern to guide the process, many managers adopt the following procedure to formulate a problem as a linear programming model:

**Identifying Decision Variables**
Managers have to first identify the variables that can be controlled or changed in order to optimally achieve the objective function. These variables have to be defined precisely and completely.

**Defining the Objective Function**
Once the decision variables are identified, the managers have to define the objective of the problem and the relevant criteria for evaluating alternative solutions. The objective function has to be represented by a linear mathematical function, with the objective (minimization or maximization) precisely defined.

**Identifying the Relevant Constraints**
Once the objective function is clearly stated, the immediate task of the manager is to identify the constraints that hinder the process of meeting the objective.

Once all the constraints have been identified and expressed in the form of linear mathematical (in)equalities, the problem is said to be formulated as a linear programming model. The following example illustrates the process of formulating a real problem into a linear programming model.
SOLVING LINEAR PROGRAMMING PROBLEMS

Linear programming was first developed to solve the problems of facility location. A map of the geographical locations that are under consideration was taken and a string was threaded through a hole over each proposed location. The end of each string was tied with a stone with its weight being proportional to the total cost of the location. All the strings were connected at the top of the map by a sliding knot apparatus. All the weights were dropped simultaneously so that the knot reaches location point that minimizes the total costs.

Though the method was quite effective, it needed more time and effort. Hence, managers prefer to use several other methods like graphical method, and simplex method to solve the problems of linear programming.

Graphical Method

This method involves indicating the constraining factors on the graph and identifying the ‘feasible region.’ This feasible region represents the area containing all the possible solutions to the problem which are ‘feasible,’ i.e. those solutions which satisfy all the constraints of the problem.

While plotting the constraints on the graph, they are assumed to be equations, irrespective of the inequality conditions. Two coordinates for each such constraint are obtained and the line connecting the two coordinates is plotted on the graph. The feasible points are then plotted on the left side for the lesser than or equal to constraint. Similarly, feasible points are plotted on the right hand side for the greater than or equal to constraint. The intersection of points from all the constraints plus the non-negativity conditions forms the feasible region.

The point at which the solution will have optimal value is identified by moving the objective function on the same graph in the feasible region. The objective function is moved slowly away from the origin and parallel to itself until the last point in the feasible region is reached.

However, the optimal point generally occurs at the corner points of the feasible region. Hence it is sufficient to calculate the value of the objective function at these corner points and select the one at which the objective function has an optimal value. Examples 16.2 and 16.3 illustrate the usage of graphical method to solve linear programming problems.

Graphical method involves a simple procedure and is free from complex mathematical calculations. However, the method is not applicable for solving many business problems owing to its inherent disadvantages. The method can be applied to solve only those business problems in which a maximum of two decision variables are involved. Graphs cannot be used to represent a situation with a number of variables. Further, the greater the number of constraints, the more complex is the graph, and harder is the process of identifying the feasible region.

Keynote 3.1.1: Example 1
method fails to solve the problems where the objective function is parallel to one of the constraints. Owing to all these drawbacks, managers prefer to use methods like simplex method for making decisions.

**Simplex Method**
As described earlier, graphical method can solve only those problems which have a maximum of three decision variables. However, it is difficult for solving problems even with three decision variables. Therefore, it is usually used for solving problems two decision variables. The method cannot be used to solve practical problems as many problems contain more than two decision variables. Problems with more than two decision variables can be solved by using a systematic procedure called the simplex method. The method was developed by George Dantzig and involves a systematic and iterative procedure having fixed computational rules that lead to a solution to the problem in a finite number of steps. Simplex method is the effective way of solving large linear programming problems as it allows the managers to evaluate the corner points in such a way that each successive corner point gives at least the same or better solution than the previous one. This search for examining successive corner points continues until no such better solution is found.

Simplex method can be applied to solve any problem formulated in terms of linear objective function subject to a set of linear constraints. It has no restrictions placed on the number of decision variables or constraints in a problem, as it is accompanied by the computational capabilities of a computer.

**Simplex Table**

<table>
<thead>
<tr>
<th>C_0</th>
<th>C_1</th>
<th>C_2</th>
<th>...</th>
<th>C_n</th>
<th>0</th>
<th>0</th>
<th>...</th>
<th>0</th>
<th>Minimum ratio(b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>s_1</td>
<td>b_1</td>
<td>A_{11}A_{12}...A_{1n}</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>s_2</td>
<td>b_2</td>
<td>A_{11}A_{12}...A_{1n}</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>s_3</td>
<td>b_3</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>0</td>
<td>s_m</td>
<td>b_m</td>
<td>A_{n1}A_{n2}...A_{nn}</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Contributi on l oss per unit:
Z = \sum C_bX_b

Net contributio n per unit, C-Z

<table>
<thead>
<tr>
<th>0</th>
<th>0</th>
<th>...</th>
<th>0</th>
<th>0</th>
<th>Z = \sum C_bX_b</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C_1</th>
<th>C_2</th>
<th>...</th>
<th>C_n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C_1</td>
<td>C_2</td>
<td>...</td>
<td>C_n</td>
</tr>
</tbody>
</table>

**Table 3.1**
Solving a linear programming problem by using the simplex method makes use of a simplex table, which can be constructed in many ways. The initial table is formulated by writing out systematically all the coefficients and constraints in the problem.

Consider the general linear programming problem as given below:

Maximize $Z = C_1x_1 + C_2x_2 + \ldots + C_nx_n$
Subject to the constraints

$A_{11}x_1 + A_{12}x_2 + \ldots + A_{1n}x_n \leq b_1$
$A_{21}x_1 + A_{22}x_2 + \ldots + A_{2n}x_n \leq b_2$

...............................................................

$A_{m1}x_1 + A_{m2}x_2 + \ldots + A_{mn}x_n \leq b_m$

And $x_1, x_2, \ldots, x_n \geq 0$

The above problem is first converted into the standard form by introducing slack variables as shown below:

Maximize $Z = C_1x_1 + C_2x_2 + \ldots + C_nx_n + 0s_1 + 0s_2 + \ldots + 0s_m$
Subject to the constraints

$A_{11}x_1 + A_{12}x_2 + \ldots + A_{1n}x_n + s_1 = b_1$
$A_{21}x_1 + A_{22}x_2 + \ldots + A_{2n}x_n + s_2 = b_2$

...............................................................

$A_{m1}x_1 + A_{m2}x_2 + \ldots + A_{mn}x_n + s_m = b_m$

And $x_1, x_2, \ldots, x_n, s_1, s_2, \ldots, s_m \geq 0$

To obtain an initial basic feasible solution
We have to set $x_1 = x_2 = \ldots = x_n = 0$
Thus, we get $s_1 = b_1, s_2 = b_2, \ldots, s_m = b_m$

This solution can be summarized in a tabular form as follows:

The first row of the simplex table (also called objective row) contains the coefficients obtained directly from the objective function. The values of these variables ($C_j$) will remain the same in all the succeeding tables. The second row provides the major column headings for the table and these headings remain unchanged in the succeeding tables of the simplex method.

The first column ($C_B$) is called the objective column and contains the coefficients of the basic variables in the objective function. The second column is known as product mix column and points out the basic variables, which happen to be the slack variables in the initial simplex table. The third column contains information about the resources or the values of the corresponding basic variables.

Each simplex table contains an identity matrix, which represents the coefficients of the slack variables that have been added to the constraints to make them equations. The numbers $A_{ij}$ in the coefficient matrix (the matrix with non-basic variables) can take either positive, zero, or negative values.

The row labeled $Z_j$ contains the sum of the numbers in the $C_B$ column and the corresponding coefficients under each column variable in the table. These values of $Z_j$ under each column variable denote the contribution of each unit of variable brought into the solution through the present iteration.

The last row is called index row and contains the values obtained by subtracting the $Z_j$ value from the corresponding $C_j$ value. Each element of this row represents the net
marginal improvement on the objective function if a unit of each variable (Xj) is included into the solution at the current iteration.
Lastly, the value of the objective function for the current iteration is obtained by adding the products of the numbers in Xb column and the corresponding numbers in the Cb column. This value is represented at the right side bottom end of the table.

Steps in simplex method
Managers have to follow a set of sequential steps in order to obtain solutions for linear programming problems through simplex method. A brief description of these steps is given below:

Step 1: Formulating the linear programming model
This is the first step of converting a real world problem into the standard form of linear programming. The procedure is the same as explained in the previous section.

Step 2: Set up the initial solution
To initiate the solution procedure from the origin the initial basic feasible solution is set by assigning zeroes to all the decision variables.
The solution obtained is summarized and tabulated in the initial simplex table.

Step 3: Test the solution for optimality
The solution thus obtained has to be tested for optimality. This is done by examining the elements in the index row of the simplex table. The solution is optimum if no element in the index row is positive. The presence of a positive element in the index row indicates that the solution can be further improved by removing one basic variable from the basis and replacing it by a non-basic one. The procedure terminates here if the solution is found to be optimal.

Step 4: (a) Determine the variable that has to enter next
Identify the column (and hence the variable) in the index row of the table with the largest positive number as pivot (or key) column.
The value of (Cj - Zj) represents the amount by which the value of the objective function will increase if a unit of xj is introduced into the solution.

(b) Determine the variable to b

Step 5: Identify the key element
The number that lies at the intersection of the key (or pivotal) column and the key (or pivotal) row of the table is called key or pivot element.

Step 6: Evaluate the new solution
The new solution, i.e. the improved version of the old solution is obtained by first evaluating the new values for the elements in the key row. This is done by simply dividing every number in the key row by the key element.

Once the new values for the elements in the key row are calculated, the manager has to compute the new values for each of the remaining rows. This can be accomplished by using the formula:

New row numbers = (Number in old rows) - (Number above or below the key number) \times(number in the row replaced in step 4(a))

= (Old row number) - (Corresponding number in the key row \times corresponding new value in the key row in the same column)

The new entries in the Cb and Xb columns are then entered in the new table.
Step 7 Test the solution

Test this solution for optimality in the same way as we did in step (2). Repeat the process until an optimum solution is obtained.

The procedural steps in the simplex method can be further understood by considering the following example.

ISSUES IN LINEAR PROGRAMMING

The preceding sections discussed only ‘well behaved’ linear programming problems. Each of the problems were having a single objective function and a set of feasible constraints and a unique optimum solution could be obtained.

However, there may exist the solution without a boundary or more than one optimum solutions. The following sections discuss such issues of linear programming.
Infeasible Solutions

Infeasibility is a state that results when there is no solution for a linear programming problem, which can satisfy all the constraints. This can be illustrated by the following example.

Unbounded Solution

A problem may have unbounded solution, i.e., it may have no limit on the constraints. In such cases, there is no solution. Let us consider an example to illustrate the situation.

Redundancy

There may be problems with redundant constraints, i.e. a constraint may be present without any effect on the feasible region set. Let us consider an example to illustrate the case.

Multiple Solutions

Some linear programming problems may have more than one optimal solutions. This happens when objective function is parallel to one of the constraints. Let us illustrate an example.
Duality
For every linear programming (LP) formulation there exists another unique linear programming formulation called the ‘dual’ (the original formulation is called the ‘primal’). The dual formulation can be derived from the same data from which the primal was formulated. The dual formulated can be solved in the same manner in which the primal is solved since the dual is also a LP formulation.

The dual can be considered as the ‘inverse’ of the primal in every respect. The column coefficients in the primal constraints become the row co-efficients in the dual constraints. The coefficients in the primal objective function become the right hand side constraints in the dual constraints. The column of constants on the right hand side of the primal constraints becomes the row of coefficients of the dual objective function. The direction of the inequalities are reversed. If the primal objective function is a ‘maximization’ function then the dual objective function is a ‘minimization’ function and vice versa.

Question 1 of 5
Which of the following is true?

A. Binomial logistic regression is the same as multiple regression
B. Binomial logistic regression can only be used with scores
C. Binomial logistic regression is not at all like multiple regression
D. Binomial logistic regression is analogous to multiple regression.
Section 2

Case Study: Alexander Machine Company

This case study was written by under the guidance of IBSCDC. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was prepared from generalised experiences.
On 6th January 2004, Alexander Machine Company’s (AMC) monthly planning meeting was going on. The company’s General Manager, S.Vimal was worried about the company’s financial performance during the past six months. As he remarked to his colleagues, “We are doing well only in some of our production lines. We have to do something to improve our financial position. We are not generating profit on our Model I printing presses. Why don’t we just stop producing it?

Instead we can purchase gears from an outside supplier, to resolve the capacity problem in our gear-cutting department. Why don’t you get together, consider the various options, and arrive at an optimum solution?”

Gear Cutting could be done through various processes like gear hobbing, gear milling\(^1\), and gear shaping\(^2\). AMC used gear hobbing to produce the gears.

Gear hobbing was a highly customized and flexible manufacturing process for cutting external gears. Gear teeth were generally formed on the gear blank (raw material) by hobbing. Gear was cut on the gear blank using a cutter called hob. The hob had grooves, which could form cutting edges. The hob traversed slowly across the face of the blank as it rotated.

In the printing press, the paper and plate passed under a large metal roller that applied pressure, transferring the image from the plate to the paper. In the roller polishing lathe, the roller was polished to reduce the circumference of printing rollers to specifications and remove defects, such as turning and polishing lines, high spots, and scratches. The roller was mounted on mandrel of lathe. The circumference of the roller was measured at several points to locate irregular spots, using girth tape while the surface of the roller was examined for defects. Polishing of the roller was done by a polishing stone, which moved back and forth across the length of the roller, changing from coarse to finer grades of stone to impart acceptably smooth finish. Again, the polished roller was examined for rough spots, pinholes, and scratches and verified for size. The roller was cleaned before and after polishing, using cloth, water, and detergents or cleaning solution. In the assembly shop, the gears and rollers were assembled and finally checked for quality.

AMC’s gear cutting capacity was adequate to cut gears for either 2000 Model I printing presses per month or 1000 Model II

\(^1\) Hobbing

\(^2\) Shaping
printing presses per month, if committed fully to either model. AMC could also cut gears for both models: for example, it could produce 1000 Model I printing presses and 500 Model II printing presses. The machine-hour requirements for each printing press Model and the monthly machine-hour availability in the departments are shown in Exhibit I. The company believed it could sell as many printing presses as it could produce.

AMC’s production schedule for the last six months of 2003 had resulted in a monthly output of 1000 Model I printing presses and 500 Model II printing presses. At this level of production, Model II assembly and gear cutting were operating at capacity. However, roller polishing and Model I assembly were operating only at 50% capacity. See Exhibit II for details of costs.

The finance manager, sales manager, and production manager discussed the problem in detail in their conference room.

“I have been observing the cost data for the two Models,” the sales manager began. “Why don’t we just stop production of Model I printing presses? We are not generating any profit on Model I printing presses. As we know, the selling prices for Model I are Rs.4,70,000, and for Model II are Rs.4,40,000”.

The finance manager interrupted, “We are trying to absorb the entire fixed overhead of Model I printing presses over only 1000 printing presses. We would be better off increasing production of Model I printing presses, stopping if necessary production of Model II.”
The production manager said, “There is a way to increase Model I production without stopping Model II production. If we purchase gears from an outside supplier, the gear-cutting problem can be solved. We can supply the necessary materials and reimburse the supplier for labor and overhead”. The team wondered how the problem could be resolved.
Facility Location

Introduction:
In this chapter, we will discuss:

- Facility Location
- Importance of Location Decisions
- Factors Affecting the Location Decisions
- General Steps in Location Selection and Location Decision Process
- Location Evaluation Methods
- Locating Service Facilities
Facility Location

The location where firms set up their operations is simply called 'Facility Location.' All the manufacturing and service organizations carefully plan where they should locate their plants and service facilities because location will have a serious affect on the success of an organization. Firms conduct facility location analysis where they evaluate different locations and finally choose an optimum location to start their operations.

The need for selection of facility location may arise under the following circumstances:

- When the business is newly started
- When the expansion to the existing plant is not possible
- When a firm wants to establish new branches
- When the landlord does not renew the lease
- For social or economic reasons like inadequate power supply, government regulations, etc.

Importance of Location Decisions

The selection of a facility location is a strategic decision for any organization and is very important for the following reasons:

- Facility location fixes the production technology to be used and the cost structure.
- Facility location depends on the size and nature of the business.
- Facility location affects the company’s ability to serve its customers quickly and conveniently.

A good facility location helps a firm to score over its competitors since it incurs reduced transportation costs of raw materials and goods and low labour costs, and has easy access to the markets. Therefore, the finance, personnel, marketing, and other departments have to be equally involved in planning the facility locations as the operations managers who run the facilities.

Factors Affecting the Location Decisions

Location decisions are influenced by a number of factors which are broadly classified as market related factors like market proximity, tangible or cost factors like transportation availability, and intangible or qualitative factors like environmental aspects. Following are the factors affecting the location decisions:

- Market proximity
Integration with other parts of the organization
Availability of labour and skills
Site cost
Availability of amenities
Availability of transportation facilities
Availability of inputs
Availability of services
Suitability of land and climate
Regional regulations
Room for expansion
Safety requirements
Political, cultural, and economic situation
Regional taxes, special grants and import/export barriers

General Steps in Location Selection and Location Decision Process

Location decisions are affected by a number of factors and therefore developing a formal and generic location model is very difficult. It is expensive and time consuming to study and evaluate different sites to find out the optimal one. Location decisions are long-range and have a lot of scope for approximation and inference. Therefore, satisfactory decisions are developed rather than optimal decisions. The location decision process varies with the size and scope of the firm’s operations. Following are the steps involved in the location decision process:

- Define the location objectives and associated constraints
- Identify the relevant decision criteria
- Relate the objectives to the criteria using appropriate models
- Do field research to collect relevant data and use the models to evaluate the alternative locations
- Select the location that best satisfies the criteria

Location Evaluation Methods

Before selecting a location or locations, a company should consider certain factors that affect their cost or profit. Each possible decision will have advantages as well as disadvantages. The company should select a location that best suits the products it offers, the location of its customers and materials, and other criteria that are specific to the company.

Video 4.1.1: Mathematical Models for Facility Location (Tutorial)

Source: http://www.youtube.com/watch?v=xk7hS8zCHgA
Several models and techniques are available that help managers make appropriate location decisions. The following models are discussed in detail.

- Factor or Point Rating Method
- Center of Gravity or Centroid Method
- Cost-Profit-Volume or Break-Even Analysis
- The Transportation Method

Example of facility location evaluation methods

1. Factor or Point Rating Method

Companies have several objectives of various importance levels while selecting a site or location. Companies assign weightage to these objectives in the form of points. The potential sites are evaluated with respect to every factor a company is looking for and points are allotted accordingly to each factor. The superior site is the one that ends up with more points. However, the drawback of this method is that a high score in any factor can overcome a low score in any other factor.

The significance of point rating method is the relative importance of tangible cost factors when compared to intangible cost factors. Only intangible factors are assigned points.

A manufacturer decided to compare two potential sites A & B, which are approximately equal when evaluation was done based on cost. Therefore, the manufacturer wants to evaluate the two sites considering intangible factors using point rating method. Comparative ratings for major intangible locations factors and the points assigned to them are given in the table below. From the data, it is clear that location A has an advantage over location B.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Maximum Possible Points</th>
<th>Points Assigned to Location - A</th>
<th>Points Assigned to Location - B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Availability of fuel in future</td>
<td>600</td>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>Availability of labor</td>
<td>500</td>
<td>440</td>
<td>400</td>
</tr>
<tr>
<td>Water supply</td>
<td>200</td>
<td>160</td>
<td>140</td>
</tr>
<tr>
<td>Transportation facility</td>
<td>300</td>
<td>250</td>
<td>150</td>
</tr>
<tr>
<td>Topography of the site</td>
<td>100</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>Living conditions</td>
<td>400</td>
<td>300</td>
<td>310</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1630</strong></td>
<td><strong>1590</strong></td>
<td></td>
</tr>
</tbody>
</table>

2. Center of Gravity or Centroid Method

The center of gravity method is used to find the optimal location for a distribution center that minimizes total transportation costs. This method takes into account factors such as markets, cost of goods, and cost of transportation. The center of gravity method aims at minimizing the total shipping cost, i.e. cost incurred for shipping from the distribution center to the different shipping points.

If the shipping quantities for all destination points are equal, the location at which the transportation cost will be minimum can be
identified by taking the arithmetic averages of the X and Y coordinates of the destination. But if the shipping quantities are unequal, the location can be found using a weighted average approach (the quantities to be shipped are taken as weights).

The center of gravity of a geographical location can be identified by calculating the X and Y coordinate values of the location that would minimize transportation costs.

The coordinates of the center of gravity can be identified by

\[
X_c = \frac{\sum (x_i v_i)}{\sum v_i} \\
Y_c = \frac{\sum (y_i v_i)}{\sum v_i}
\]

Where,

\(X_c\) = X coordinate of the center of gravity
\(Y_c\) = Y coordinate of the center of gravity
\(v_i\) = Volume of items transported to and from location \(i\)
\(x_i\) = X coordinate of location \(i\)
\(y_i\) = Y coordinate of the location \(i\)

3. Cost-Profit-Volume or Break-Even Analysis

Break-even analysis is a graphical and algebraic representation of the relationships among volume of output, costs and revenues. Costs can be classified into two types: fixed costs and variable costs. Fixed costs are the costs such as administration expenses, rents of the buildings, lighting, etc. And they do not vary with the volume of the output. Variable costs are the costs such as raw material cost, labour cost, etc. And they vary with the volume of the output. The sum of the fixed and variable costs at a specific volume of output becomes the total cost at that volume of output.

Break-even analysis is one of the tools used for selection of a location. Since each and every location will have a different cost structure and sales volume, break-even analysis helps the manager identify the location where the profits are high. Figure 4.1 shows the relationship of cost and volume in two different locations A and B.

Figure 4.1.1: Cost Volume Relationships of Two Locations

Here, we assume that the revenues and costs are the linear functions of output volume. We also assume that the revenues for the two locations are the same, as there will not be much difference in the demand if the price of the product remains the same irrespective of the location it was produced at.
4. The Transportation Method
Transportation models deal with the determination of a minimum-cost plan for transporting a consignment from a given sources to a potential destinations.

For example, a motor-bike production company produces motor-bikes at the units situated at various manufacturing units (called sources) and distributes them to various destinations. Here the availability as well as requirements of the various intermediaries are finite and constitute the limited resources. This type of problem is known as transportation problem in which the key idea is to minimize the cost of transportation.

The problem can be solved by the following approach:
Solve the transportation problems by

- North-West corner rule; or
- Lowest cost entry method; or
- Vogel’s approximation method

Test the optimality of the solution

For more details click here.

**Locating Service Facilities**

The capital investment required for setting up a new service facility is much less than that required for setting up a manufacturing facility. As a result, there has been phenomenal growth in new service facilities during the last decade. Despite this growth, in some cases the growth in services facilities did not match population growth.

Services cannot be stored, therefore they have to be developed and delivered in close contact with customers. Therefore, location decisions are dependent on the choice of target markets. The target market also influences the number, size, and other characteristics of locations. While manufacturing location decisions focus on minimizing cost, service facility location decisions focus on the maximization of profit potential.

Decisions regarding the number of locations in a geographical area and the location of service facilities in the area are complex and critical for the long-term profitability of a service organization. These decisions become even more complex if several locations in different geographical areas with multiple locations under each are available. In other words, finding the best option for locating a service facility can be very time consuming.
Section 2

Case Study: Locating and Laying Out the Fast Food Business

This case study was written by Siva V. Gabbita, Asst. Professor, Department of Decision Sciences, IBS Hyderabad. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was compiled from published sources.

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www.icmrindia.org
McDonald's Vision Statement

McDonald's vision to provide the world's best quick service restaurant experience is implemented through the QSCV philosophy. In their own words "Being the best means providing outstanding quality, service, cleanliness, and value, so that we make every customer in every restaurant smile."

Service Delivery Strategy

McDonald's virtually invented the limited-menu fast-food business, thereby revolutionizing the restaurant industry. Over the years it has also made five major innovations.

1950s  Introduced indoor seating
1970s  Introduced the concept of drive through windows
1980s  Introduced breakfast to the menu
1990s  Introduced play areas for children

The McDonald's Story

Richard and Maurice McDonald opened a burger and fry outlet in 1948 at San Bernardino, California. While keeping things simple they used an assembly line to help sell a lot of milkshakes along with the burgers and fries. Ray Kroc, a sales representative with a company that made a mixer that could make five milkshakes simultaneously, bagged an order from the McDonald brothers who wanted eight mixers. Ray Kroc visited McDonald's in 1954 and liked it so much that in 1955, he opened a McDonald's store in Des Plaines, Illinois. Kroc wanted to open a chain of McDonald's restaurants all over the country, because he could get to sell eight mixers to each such store. By 1961 Ray Kroc had set up 228 McDonald's restaurants and he convinced the McDonald's brothers into selling out for $2.7 million dollars when they were not as excited as he was with the rapid expansion. Hamburgers then sold for 15c.

McDonald's went on to become a company that gave great value to customers and great value to shareholders. Parents loved McDonalds because on road trips with children they knew that they could count on McDonalds for food that their kids would not only eat, but love. There were play areas where kids could burn off some energy before the family got back in the car. And there were clean restrooms everywhere. In 1975 McDonald's did not have any drive-throughs, whereas by 2004 more than 90% of its US restaurants incorporated a drive-through process because 80% of growth in the fast food business came from drive-through outlets. Customers could cut waiting time to a minimum by ordering without getting out of their cars. McDonald's calculated that their sales increased 1% for every 6 seconds saved at a drive-through. McDonald's like its rival Burger King also designed 'combo meals' (burger+fries+cola) to save time in ordering. The gains in productivity that combo meals offered were used to offset inflationary pressures caused by wage increases. Burger King found that restructuring the menu enabled the counter staff to enter orders with a single key stroke in place of multiple key strokes on their Point of Sale machines, which reduced the time to take an order, which in turn resulted in win-win advantages since it cut customer waiting time as well as enabled counter staff to take more orders quickly. This increased productivity, reduced labor requirements, produced higher profits and resulted in greater pay to workers.
In 1965 McDonald’s went public at $22.50 per share. It had split twelve times by the year 2000. In 1967 the company opened its first store outside the United States. In 1968 the Big Mac, their first product beyond basic burgers, was introduced, followed by the introduction of Egg McMuffin and a breakfast menu in 1973. By 1974 Kroc had stepped aside as CEO.

**The Service Assembly line – Here or To Go?**

In the 70s Theodore Levitt wrote an article in the Harvard Business Review, called “Production Approach to Services” where he eulogized the standardization of service that McDonald’s had systematized. As Levitt observed the approach which McDonald’s pioneered treated the delivery of fast food as a manufacturing process rather than as a service process. As a result, it was able to provide cutting-edge, efficient services by minimizing deviation in the service experience from customer to customer.

**Video : What is Poka-yoke ?**

Source : http://www.youtube.com/watch?v=1xYef-3m-N4&feature=related

McDonald’s controlled the Operational Execution within its outlets to address Delivery (Time) Speed along with a focus on high quality by standardizing the operational process with careful planning and a systematic production function that minimized operator error and wastage. McDonald’s did this by careful attention to design and facilities planning so that the production process was built into the system.

Mistake-proofing its production process with the extensive use of ‘Poka-Yokes’ was one way in which it was able to do so. For instance, the McDonald’s french fryer equipment only allowed an
optimum number of french fries to be cooked at a time, which maintained uniformity of taste in the fries produced. The counter staff used a wide-mouthed scoop to pick up the precise amount of french fries for each order size. This provided the additional benefit that no service employee ever touched the product. Storage space was also designed for a predetermined mix of products (Exhibit I).

The other way in which McDonald's controlled the service production process was with the use of Automation. McDonald's introduced a food service automation program called ARCH (Automated Restaurant Crew Helper) which uses robotic equipment such as

1. the fry station, that can be programmed to automatically weigh, cook, time, shake and dump fries into baskets, lower the baskets into the cooking oil, shake them intermittently to remove clumps, and then dump finished fries for bagging without any human assistance and

2. an automated drink machine which uses ARCH robots which substitute for crew members to grab cups, add ice, and operate drink valves, significantly reducing the time it takes to fill an order.

These equipment were custom-designed to blend with existing cooking equipment and had special safety features including a shutdown mechanism that is triggered when the robot arm encounters human resistance.

McDonald's ARCH production system also helps in SALES FORECASTING and PRODUCTION PLANNING, by telling managers how many hamburgers, cheeseburgers, or fries they can expect to sell in the next 10 minutes. It indicates how many packages of BigMac sauce should be stocked for the day using recent sales data. It indicates based on daily demand patterns how many employees might be needed in different time slots, thereby assisting in accurate staff planning.

Customising the Service Experience

In 1979 McDonald's introduced the Happy Meal which many said was the last blockbuster product to hit the menu although Chicken McNuggets, was introduced in 1983. By the time Ray Kroc died in 1984, it had 7500 restaurants all across the world. The nineties were characterized by Globalisation and liberalisation and across the world trade barriers came down and competition intensified. In 1990 a McDonald's opened in Russia and McDonald's became a symbol of what American capitalism could achieve. It also signaled the end of the cold war.

With the shrinking of the Global Village, and opening up of economies, disposable incomes grew and customer spends increased. As customers had more options and greater choices and as competition was relentless, producers tried to differentiate themselves from rivals by providing greater variety in and customising their product and service offerings.

In 1991 McDonalds designed a new product for health conscious consumers called the McLean Deluxe. The company also introduced spaghetti, lasagna, pizza and carrot sticks. All of them were disasters and had to be withdrawn from the menu. In 1996 the company re-labelled the McLean Deluxe calling it the Arch Deluxe – a strange tasting "grownup" burger. It bombed.
This was also the time when McDonald’s opened its first outlet in Delhi, India on October 13, 996. It had taken them five long years from 1991 when McDonald’s got the Foreign Investment Promotion Board (FIPB) clearance for its fast food chain to announce their first restaurant in India. The company said that it took so long because it had stringent quality requirements to be met by local companies from which they would source the right raw materials. McDonald’s in India purchases 98% of its food and paper from local companies.

**Made for You**

As competition heated up in the fast-food business, McDonald’s found that it was losing market share. Therefore in 1997 the company slashed the price of the Big Mac to 55¢ in what they called campaign 55. Nevertheless sales continued to fall over the next quarter and McDonald’s decided to abandon marketing strategies and instead adopt an operational strategy to fix the system in their restaurants.

In 1998 therefore, they introduced “Made for You” to counter rivals Wendy’s and Burger King. Wendy International had introduced a made-to-order system that offered fresh food and a wide variety, while Burger King was promoting the idea of “have it your way”.

“Made for You”, was simply is simply a “make-to-order” system, where cooking began after the orders were received so as to ensure the freshness of our products. Each individual order was communicated from the electronic POS systems at the customer counters to the display panel in the kitchen for individual customised cooking. The advantage with these systems was that it also minimized wastage, which is always a problem with perishable products.

When it was first launched in March 1998, McDonald’s promised that customers could obtain their freshly prepared order within 90 seconds of placing their order. It was not easy for a company that had institutionalized standardization to manage both Delivery Time with Flexibility – these being standard operational trade-offs – and as the company focused on personalisation, its service times began to slip. The Made For You process made people wait and customers who saw value in convenient fast food increasingly began to take their business elsewhere. The ailing burger chain thereafter spent $20 million in research and development and $400 million to implement a transformation to the Made for You, food preparation process.

McDonald’s kitchen was designed to prepare large quantities of burgers in advance of the rush hour. From a customer standpoint rush hours are critical because service is judged during such periods. The emphasis therefore was on speed-getting customers in and out as quickly as possible-not variety.

Changing its kitchen system was seen as key to turning things back around. Robert Marshall, McDonald’s U.S. vice president of operations in charge of originally developing Made for You concept as well as its modification realized that not enough McDonald’s restaurants consistently met the 90-second service benchmark during peak periods, although the switch to the new system cost roughly $25,000 a restaurant, or $400 million. McDonald’s told restaurant operators they’d split with them the cost of replacing old equipment.
In 2001 therefore, McDonald’s completed its fifth major innovation, a new layout to facilitate a mass customisation process (Exhibit III). The corporation radically redesigned its kitchens in its 13,500 North American outlets. Dubbed the “Made for You” kitchen system, sandwiches were now assembled to order and production levels were controlled by computers. The new facility layout strategy was intended to improve the taste of food by ensuring it is always freshly made. Under the new restaurant design, no food was prepared in advance except the meat patty which was stored hot in a cabinet. To shorten total production process time to 45 seconds, some steps were eliminated and some shortened. Innovation in certain cooking equipment such as toasters and steamers significantly facilitated implementation. The company developed a toaster that browns buns in 11 seconds instead of half minute. The company worked closely with its Bread suppliers to change the texture of the buns so they could withstand the additional heat. Workers worked out that they could save 2 seconds if the position of containers was changed to enable workers to apply mustard to sandwiches with a single motion instead of two.

McDonald thus expected to save $100 million per year in food costs, because only the meat, and not the bun or other ingredients, would be discarded if sandwiches did not sell. The company was banking on the new layout, to provide greater efficiency and customer responsiveness.

McDonald’s Supply Chain

- QSCV Philosophy.
- 11,000 restaurants (7,000 in USA, remaining in 50 countries)
- Standardized taste at any McDonald, although food must be secured locally. High service levels maintained with low inventory
Efficient Consumer Response

Efficient Consumer Response (ECR) is a global movement in the consumer goods industry. The ECR Europe Executive Board (1995) expresses the ECR vision as: “working together to fulfil consumer wishes better, faster and at less cost” Efficient Consumer Response (ECR) is the realization of a simple, fast and consumer driven system, in which all links of the logistic chain work together, in order to satisfy consumer needs with the lowest possible cost. Eighteen companies, divided equally between retailers and manufacturers, belong to the ECR Europe Executive Board (ECR Board). All are significant players either globally or in their home countries. The list includes the following retailers: Ahold/Albert Heijn, Metro/Askö, Rewe, Auchan, Promodes, ICA, Tesco, Safeway, La Rinascente and the following manufacturers: Unilever, Sardus, Procter & Gamble, Nestlé, Mars, Kraft Jacobs Suchard, Johnson & Johnson, and Coca-Cola. Many other companies are actively involved in projects initiated by the ECR Board. ECR has a few starting points.

Firstly the definition shows that consumer demand plays an important part. The chain has to ensure continual improvement of consumer satisfaction, products, and quality. Secondly, the definition also shows that maximum efficiency of the total logistic chain is required.

The realization of the two starting points cannot be done without accurate information, which must be available when needed. To keep the costs low, it is preferred that this information and communication is paperless. To accomplish these aspects of ECR, three focus areas can be distinguished according to Coopers and Lybrand

1. Category Management
2. Product Replenishment

Product Replenishment

Of the 3 focus areas most improvements in operational activities can be found in the way a store is replenished. Efficient Product Replenishment deals with efficient delivery of the correct product at the correct time at the correct place in the correct quantities. This process is primarily a logistic oriented strategy, which is activated by consumer demand, which is called ‘PULL’.

Three trajectories can be identified:

i. Trajectory from manufacturer to warehouse,

ii. Trajectory from warehouse to retailer and

iii. Trajectory from retailer to consumer.

The aim of Efficient Replenishment is to integrate these three independent trajectories into the logistic chain in order to create one efficient and effective trajectory throughout the whole chain.

Efficient Consumer Response can be worked through product stock replenishment through logistic methods that can in general be classified as:
Methods which work up the supply chain

The upward methods deal with the stream of goods, which are sent in the direction from consumer to manufacturer. One can think of empty containers, pallets, empty packing, defective products and material, which has to be recycled. For many years this topic received little attention, but the upward stream of goods is becoming more and more a hot item, due to environment policies. As yet many companies do not do on this, because most methods result in an increment in costs and are therefore not considered efficient.

Methods which work down the supply chain

Downward methods focus on the trajectories from manufacturer to consumer. Much attention is paid to these methods, because it affects the main part of the stream of goods.

Exhibit IV depicts how the strategic introduction of warehouses and appropriate site selection and facility location can optimize transportation costs in the supply chain.

Site Selection and Facility Location

When asked about the three most important factors for retailing success, it was Lord Sieff of Marks & Spencer, the UK based retail organisation who is reputed to have said - “Location, Location, Location”

A key difference between services and manufacturing is the number of the company's facilities and the nature of the work they do. Manufacturers tend to have a small number of facilities that usually make different products. Services often have a large number of units, where each unit does nearly the same task.

Selecting a site for service firms is fundamentally a different problem from selecting a site for manufacturing facilities. Selecting a site for a manufacturing plant is done infrequently, and the basis for the decision is often centered on reducing costs usually through tax concessions from local governments or exploiting inexpensive labor.
For service firms however the site selection problem is frequent. It is not unusual for a retailing firm to add several hundred new stores in a year. A new McDonald’s store is said to be created every 10 hours. The location decision is often not based on lowering costs and the vast majority of service outlets are too small for governments to give anything in the way of tax incentives. The decision usually centers on customer proximity so that the location will help generate revenue. For many service firms, site selection poses the most important operational decision faced. Despite the fact that a poor location can doom a facility to failure regardless of how well it is managed many location decisions are made with gut feel and opinion than science and fact.

The Location Decision

Suppose McDonald’s retails through the following outlets in the twin cities which are located according to the following grid which represents coordinate locations for each outlet.

<table>
<thead>
<tr>
<th>Location</th>
<th>Fixed Cost per Year</th>
<th>Variable Cost per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Banjara Hills</td>
<td>2,50,000</td>
<td>100</td>
</tr>
<tr>
<td>B Himayatnagar</td>
<td>1,00,000</td>
<td>300</td>
</tr>
<tr>
<td>C Mehdipatnam</td>
<td>1,50,000</td>
<td>200</td>
</tr>
<tr>
<td>D Secunderabad</td>
<td>2,00,000</td>
<td>400</td>
</tr>
</tbody>
</table>

Compiled by the author

Although McDonald’s is open to any location for its new warehouse, it has tentatively identified Banjara Hills, Himayatnagar, Mehdipatnam and Secunderabad as 4 potential warehouse locations whose fixed costs per year and variable costs per unit are as follows.

McDonald’s also needs assess the attractiveness of potential locations with respect to (after allocating weights that will measure the relative importance of) 4 intangible factors.

<table>
<thead>
<tr>
<th>Potential Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banjara Hills</td>
</tr>
<tr>
<td>Himayatnagar</td>
</tr>
<tr>
<td>Mehdipatnam</td>
</tr>
<tr>
<td>Secunderabad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Environmental Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier proximity</td>
</tr>
<tr>
<td>Retail Outlet proximity</td>
</tr>
<tr>
<td>Transportation costs</td>
</tr>
</tbody>
</table>

Compiled by the author

Retail Outlets in the Twin Cities

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ameerpet (200,000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Himayat Nagar (600,200)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secunderabad (800,000)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compiled by the author
1. Environmental Conditions
2. Proximity to Suppliers
3. Proximity to retail outlets
4. Transportation Costs

The transportation costs to and fro potential warehouse locations and the existing retail outlets, as well as the total demands and supplies were computed as shown in the grid below.
Questions for Discussion

1. Using the service-system design matrix (Exhibit II) where would you categorise McDonald’s service design?
2. What is the best location in Hyderabad for a new warehouse/temporary storage facility for storing McDonald’s corrugated cardboard used in the form of shipping containers for hot cups, coffee stirrers, and ice cream cones?

APPENDIX

Facility Location Models

Centre of Gravity Method

The centre of gravity method is used to find the optimal location for a distribution centre (more generally any facility) in such a way as to minimize the total transportation costs. The method treats distribution costs as a linear function of the distance and the quantity shipped. The quantity to be shipped to each destination is assumed to be fixed (i.e., it will not change over time). An acceptable variation is that quantities are allowed to change, as long as their relative amounts remain the same (for example due to seasonal variations).

The method includes the use of a map that shows the locations of destinations. The map must be accurate and drawn to scale. A coordinate system is overlaid on the map to determine relative locations. The location of the 0,0 point of the coordinate system and its scale, is unimportant. Once the coordinate system is in place, the coordinates of each destination can be determined.

When the quantities to be shipped to every location are equal, one can obtain the coordinates of the centre of gravity (i.e., the
location of the distribution centre) by finding the average of the x coordinates and the average of the y coordinates. This is a special case of the more general situation when the number of units to be shipped are not the same for all destinations in which case the weighted average must be used to determine the coordinates of the centre of gravity, with the weights being the quantities shipped as stated earlier. The formulae for the x and y coordinates are given by

\[ C_x = \frac{\sum d_x V_i}{\sum V_i} \]
\[ C_y = \frac{\sum d_y V_i}{\sum V_i} \]

Where:
- \( C_x \) = X Coordinate of centroid
- \( C_y \) = Y Coordinate of centroid
- \( d_x \) = X Coordinate of the ith location
- \( d_y \) = Y Coordinate of the ith location
- \( V_i \) = Volume goods moved to or from ith location

**Multi-Attribute Models**

In a multi-attribute model (factor-rating, point rating etc.) the key criteria for consideration are listed and subjectively assigned weights, then prospective sites are subjectively assigned values for the key criteria, and the assigned values are combined with the criteria weights to determine an overall score for the site.

The numerical preferences are qualitative in nature and are usually decided in groups depending on the extent to which a particular location provides benefits on a given criterion.

Two mathematically identical ways in which these criteria can be given numerical rankings are presented below.

The first method (Table I) assigns a higher point total to more important criteria. The second method (Table II) allows each factor to be judged on the same scale – a scale of 1-10 –

<table>
<thead>
<tr>
<th>Table I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Land price of neighbourhood</td>
</tr>
<tr>
<td>Proximity to suppliers</td>
</tr>
<tr>
<td>Proximity to retail outlets</td>
</tr>
<tr>
<td>Transportation costs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factor</td>
</tr>
<tr>
<td>Land price of neighbourhood</td>
</tr>
<tr>
<td>Proximity to suppliers</td>
</tr>
<tr>
<td>Proximity to retail outlets</td>
</tr>
<tr>
<td>Transportation costs</td>
</tr>
</tbody>
</table>

Compiled by the author
and then the score is multiplied by a corresponding percentage depending on the importance of the factor.

**The Transportation model**

Managers must often deal with allocation problems that are considerably larger in scope. A beer manufacturer may have 4 or 5 breweries and hundreds even thousands of distributors not to mention retail outlets. An automobile manufacturer may have 2 assembly plants scattered throughout the country, 8-10 warehouses and thousands of dealers that must be supplied with cars. In such cases, the ability to identify the optimal distribution plan makes the transportation model very important.

The shipping points (supply) can be manufacturing factories, warehouses, departments or any other facility from which goods are sent. Destinations can be factories, warehouses, departments or any other facility into which goods are received.

The information needed to use the model consists of the following

a. A list of origins and each one’s capacity or supply quantity per period.

b. A list of destinations and each one’s demand per period

c. The unit cost of shipping items from each origin to each destination

This information is arranged into a transportation table.

The transportation model is one of a class of linear-programming models, so named because of the linear relationships among the variables. In the transportation model, transportation costs are treated as a direct linear function of the number of units shipped.

Use of the transportation model implies that certain assumptions are satisfied.

1. The items to be shipped are homogeneous (ie. They are the same regardless of their origin (source) or destination (sink)

2. Shipping costs per unit is the same regardless of the number of units shipped.

3. There is only one route or mode of transportation being used between each origin and each destination.
Transportation Methods

Introduction:

In this chapter, we will discuss:

- North-West corner method
- Least cost method
- Vogel’s approximation method
- Stepping stone method
Section 1

Transportation Methods

The transportation problem is a special case of linear programming. In its most general form, the transportation problem has a number of origins and a number of destinations. A certain quantity of commodity is produced or manufactured at each origin and it is to be transported to the destinations, each having certain requirements. The objective of the problem is to meet the destination requirements with supply from the origins so that transportation costs are minimal.

This method is applicable in situations involving the physical movement of goods from plants to warehouses, warehouses to wholesalers, wholesalers to retailers and from retailers to customers. These models can also be applied to tasks like production scheduling and inventory control. Moreover, such models reduce the computational effort involved in the simplex method and are hence preferred by many operations managers.

A transportation problem can be either balanced or unbalanced. It is said to be balanced if the quantity of goods produced is equal to the total requirement of all the warehouses. Otherwise, the problem is said to be an unbalanced one. In an unbalanced problem, a dummy warehouse is added if the production capacity is more than the requirement, and a dummy origin is added if production capacity is less than the requirement with desired quantity to make it a balanced problem.

Since the formulation of a transportation problem is a special type of linear programming, it can be formulated as a linear programming problem as shown below.

Suppose \( X_{ij} \) is the quantity transported from the plant \( P_i \) to a warehouse \( W_j \), and \( C_{ij} \) is the unit transportation cost from \( P_i \) to \( W_j \).

Since the objective of a transportation problem is to minimize the total transportation cost, the objective function can be given as,

Minimize, \( Z = \sum C_{ij} X_{ij} \)

Subject to the supply constraints

\[
\sum_{j=1}^{n} X_{ij} = S_i \text{ and } i = 1, 2...m
\]

Demand constraints
\[
\sum_{j=1}^{n} X_{ij} = D_j \text{ and } j = 1, 2, \ldots, n
\]

And \( X_{ij} \geq 0 \) for all \( i \) and \( j \), where:
- \( X_{ij} \) represents the number of units shipped from origin \( i \) to destination \( j \)
- \( C_{ij} \) represents the cost of shipping a unit from origin \( i \) to destination \( j \)
- \( S_i \) represents the supply available at \( i^{th} \) origin
- \( D_j \) represents the quantity demanded at \( j^{th} \) destination

The general layout of the transportation problem in table form is given in table 4.7.

A transportation problem can be solved by using the following procedure:

Step 1: Define the objective function that is to be minimized.

Step 2: Develop a transportation table with rows representing the origins and columns representing the destinations.

Step 3: Determine the initial feasible solution to the problem.

Step 4: Examine whether the initial solution is feasible or not. A solution is feasible, if the number of occupied cells in the solution is \((m+n-1)\), where 'm' is the number of origins and 'n' is the number of destinations.

Step 5: Test the solution obtained for optimality by computing the opportunity costs associated with the unoccupied cells.

Step 6: If the solution is not optimum, modify the allocation such that the transportation cost can be reduced further.

Developing an Initial Feasible Solution

The methods used to determine an initial feasible solution are:
- North-West corner method
- Least cost method
- Vogel’s approximation method

**North-west corner method (NWCM)**

In this method, the allocation of products starts at the north-west corner (or the top left corner) of the transportation table. The method is explained below.

**Table 5.1.1**

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>( O_1 )</td>
<td>( D_1 )</td>
<td>( C_{11} )</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>( D_2 )</td>
<td>( C_{12} )</td>
</tr>
<tr>
<td>( O_n )</td>
<td>( D_n )</td>
<td>( C_{1n} )</td>
</tr>
<tr>
<td>( O_1 )</td>
<td>( D_1 )</td>
<td>( C_{21} )</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>( D_2 )</td>
<td>( C_{22} )</td>
</tr>
<tr>
<td>( O_n )</td>
<td>( D_n )</td>
<td>( C_{2n} )</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>( O_1 )</td>
<td>( D_1 )</td>
<td>( C_{31} )</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>( D_2 )</td>
<td>( C_{32} )</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>( O_1 )</td>
<td>( D_1 )</td>
<td>( C_{n1} )</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>( D_2 )</td>
<td>( C_{n2} )</td>
</tr>
<tr>
<td>( \ldots )</td>
<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
<tr>
<td>( O_1 )</td>
<td>( D_1 )</td>
<td>( C_{mn} )</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>( D_2 )</td>
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<td>( \ldots )</td>
<td>( \ldots )</td>
</tr>
</tbody>
</table>

Step 1: Assign the maximum possible quantity of products to the top left corner cell of the transportation problem.
Step 2: After the allocation, adjust the supply and demand numbers.

Step 3: If the supply in the first row is exhausted, move down to the corresponding cell in second row and assign the possible quantity of products to that cell. If the demand in the column is first satisfied, move horizontally to the next cell in the second column and assign the quantity of products.

Step 4: Continue the same procedure till the entire requirements are met.

Step 5: Check for feasibility of the solution.

**Least cost method (LCM)**

In this method, allocations are made on the basis of unit transportation costs. The method is explained below.

**Step 1:** Select the cell with the least unit transportation cost and allocate as many units as possible to that cell.

**Step 2:** If the minimum cost exists in several cells, select a cell arbitrarily and assign the possible number of goods. Then consider the remaining cells of the same unit transportation cost.

**Step 3:** Select a cell with the next higher unit transportation cost and continue the process till all requirements are met.

**Vogel's approximation method (VAM)**

Vogel's Approximation Method is the most preferred method over the above two methods as it usually results in an optimal or a near optimal solution. The method is explained below.

**Step 1:** Calculate a penalty for each row and column of the transportation table. The penalty for a row/column is the differences between the smallest and the next smallest unit transportation cost in that row or column.
difference between the least cost and the next least cost of that row/column.

Step 2: Identify the row or column with the largest penalty value and assign the possible quantity of products to that cell having the least unit cost in that row or column. In case of a tie,

select the row or column that has minimum cost.

Step 3: Adjust the supply and requirement values after the allocation is made.

Step 4: Delete that row or column where the supply or requirement is zero.

Step 5: Calculate the values of penalty to all the rows and columns for the reduced transportation problem and repeat the same procedure till the entire requirement has been met.

**Stepping stone method**

After computing the initial solution by using any of the three methods explained above, the solution needs to be tested to see whether the solution is optimum or not, by using the stepping stone method. In this method, the decision-maker calculates the net cost change obtained by introducing a unit of quantity in any of the unoccupied cells and checks for the possibility of improving the solution. This method describes the unused cells as ‘water’ and used cells as ‘stones,’ and the transportation refers to walking on a path of stones half submerged in water. The procedure of this method is explained below:

Step 1: Determine the initial basic solution by using any of the three methods: north-west method, least cost method or the Vogel approximation method. Then check the solution for feasibility.

Step 2: Select an unoccupied cell and trace a closed path starting from that cell using the most direct route through at least three occupied cells by making only horizontal or vertical moves.

**Keynote 5.1.3: Example 3**

**Keynote 5.1.4: Example 4**
Step 3: Starting from the selected cell, assign + and – signs alternatively to the corner cells of the closed path.

Step 4: Calculate the 'net cost change' of the selected cell by adding the unit cost values (with the signs assigned) along the closed path.

Step 5: If the 'net cost change' is positive for all the unoccupied cells, we can conclude that optimum solution has been arrived at.

Step 6: If the 'net cost change' of an unoccupied cell is negative, the quantity of products to be assigned to that cell is equal to the minimum quantity of those cells with the minus sign in the closed path.

Step 7: Repeat the same procedure till the optimum solution has been reached.

Keynote 5.1.5: Example 5

Question 1 of 5
Which of the following is true?

A. Binomial logistic regression is the same as multiple regression
B. Binomial logistic regression can only be used with scores
C. Binomial logistic regression is not at all like multiple regression
D. Binomial logistic regression is analogous to multiple regression.
Section 2

Case Study: Utilisation of Transportation Method in Sandino Furniture

This case study was written by RagaSranthi Vemulavada under the direction of R. Muthukumar, IBSCDC. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was prepared from generalised experiences.
When deciding on a furniture store, a consumer generally concentrates on the type of furniture he/she wants to purchase and enquires about the service and quality of furniture at the store. In addition to the above, while choosing a furniture store, consumers also find out details about the store's shipping, delivery and assembling policies. Of late, consumers are also using the internet to read the reviews by other customers on the furniture in the stores and to get information about the sales and deals at certain retailers. By choosing a furniture store with the help of a website, the consumer will have the option of surfing through the store's collections before heading out to the stores. Some of the websites also feature interactive tools wherein one can enter the dimensions of a room and can move the virtual furniture as per one's desire to see how the placement should be done even before the new furniture is brought home.

Although many stores and furniture dealers have samples in a wide range of styles, they are designed in such a way that they can be merged with any kind of furniture. Most of the stores have been offering discounts, clearance sales, and are even trying to entice customers by offering free schemes to customers who have purchased over a certain amount. Nowadays, a good furniture store not only has couches, chairs and tables but also lighting, carpets, blankets, window treatments, beddings, mattresses, pictures, wall hangings and an assortment of other attractive accessories.

One such one-stop destination for all the furniture needs of the customers is Sandino Furniture (Sandino), one of the leading furniture stores located in Sydney, Australia. Sandino is a fully staffed, full service furniture dealer with over 40 years of experience. The company represents over 200 products of fine furniture. Over the years, the company has strived to provide its customers with the best possible products in the market at affordable prices. The company's central location adds to its advantage because it gets to offer better service and delivery to its clients when compared to other stores, which are not very feasible to reach.

Initially, when Sandino was started in 1965, it totally concentrated on selling basic household goods at discount prices. Later, the company got into selling household furniture. Also the company, which at the outset sold furniture produced by local manufacturers, started designing its own furniture. This became the basis for its future growth, led to innovative designs and improved functions at lower prices.

At Sandino, the new product development process is supervised by a product strategy council, which consists of a group of senior managers. They set the priorities in designing products based on consumer trends. The company then establishes the price range for the product. Once the price range is set, the company selects a manufacturer to produce the product. At this stage, the company tries to seek a balance between its product quality standards and cost-efficient labour. Meanwhile, Sandino’s engineers try to determine the materials that could be used to make the product.

In Sandino, products are not available in ready-made form. The customer can select the parts of his choice and get the product assembled. The company also has the facility of delivering the goods. All the parts of a particular product are transported in flat packages. The company ships all its products disassembled. As
per the company, the prices of shipping disassemble products reduced six times when compared to the prices of shipping assembled products.

Sandino’s customers are always delighted for they get a unique product at a more affordable price. Besides, most of its customers also find the Sandino shopping experience immensely appealing. Even though the customers feel that the products are not long lasting and most of the times, the products get destroyed while being shifted from one place to another; they still prefer buying furniture at Sandino.

Sandino’s ambience is made highly attractive to its customers. Once they enter the shop, they get enamoured by the range of fully decorated bedrooms, kitchens, drawing rooms, bathrooms, etc. At Sandino, the transformation that a simple wooden sofa undergoes has to be seen to be believed. Made from teak and sometimes rosewood, the sofas at Sandino enrich the whole experience of seating. The intricate carvings, the straight elegant lines, the finish, the furnishing and last but not the least, its adaptability have made Sandino’s sofas an essential part of every home and office all over Australia. With the passage of time, chairs, tables, sideboards and even wall units beautified the furniture store. The atmosphere is always bright and inviting and the customers are free to laze around the model furniture while making their way through the store.

At Sandino, one can expect to get beds, which are much more comfortable when compared to other stores and also have real solutions for people who seek better rest and comfort. Sandino’s sales executives emphasise on the fact that their bed system is the only one supported by independent medical, scientific and engineering research trials.

Sandino manufactures these kinds of beds at three locations – Sydney, Perth and Melbourne. The firm distributes the beds through warehouses located in Kingston, Darwin and Brisbane (Exhibit I).

<table>
<thead>
<tr>
<th>Capacities</th>
<th>Factories (Sources)</th>
<th>Shipping Routes</th>
<th>Warehouses (Destinations)</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 units</td>
<td>Sydney</td>
<td>Kingston</td>
<td>300 units</td>
<td></td>
</tr>
<tr>
<td>300 units</td>
<td>Perth</td>
<td>Darwin</td>
<td>200 units</td>
<td></td>
</tr>
<tr>
<td>300 units</td>
<td>Melbourne</td>
<td>Brisbane</td>
<td>200 units</td>
<td></td>
</tr>
</tbody>
</table>

Prepared by the author

Suggested Questions for Discussion

1. How should the company select the shipping routes to be used and the number of desks to be shipped on each route to minimise the total transportation cost (Exhibit II)?
Exhibit II
Transportation Costs per bed for Sandino Furniture Ltd.

<table>
<thead>
<tr>
<th>To</th>
<th>From</th>
<th>Kingston</th>
<th>Darwin</th>
<th>Brisbane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>$5</td>
<td>$4</td>
<td>$3</td>
<td></td>
</tr>
<tr>
<td>Perth</td>
<td>$8</td>
<td>$4</td>
<td>$3</td>
<td></td>
</tr>
<tr>
<td>Melbourne</td>
<td>$9</td>
<td>$7</td>
<td>$5</td>
<td></td>
</tr>
</tbody>
</table>

Prepared by the author
Facility Layout

Introduction:
In this chapter, we will discuss:

- Facility Layout
- Criteria for a Good Layout
- Basic Layout Formats
- Developing a Process Layout
- Developing a Product Layout
- Developing a Cellular Manufacturing Layout
- Japanese Approaches and Trends in Manufacturing Layouts
- Service Facility Layouts
Facility Layout

The physical disposition of the facilities of a plant and its various parts for the purpose of achieving quickest and smoothest production is referred to as the layout of the plant. As per the definition of Knowles and Thomson, plant layout involves:

Planning and arranging manufacturing machinery, equipment and services for the first time in completely new plants.

The improvements in layouts already in use in order to introduce new methods and improvements in manufacturing procedures.

Similar to location decisions, layout decisions also have long-term consequences in terms of cost and the company’s ability to serve its customers. While designing a layout, an organization should identify the objectives of its strategy that have to be supported by the layout and many other factors that affect and are affected by the layout. The overall objective of designing a layout is to provide a smooth work flow of material through the factory, or a comfortable traffic pattern, for both customers and workers in an organization.

Some of the major objectives of an ideal layout are given below:

- Providing enough production capacity
- Reducing material handling costs

Video 6.1.1: Typical Plant Layout
Animation

Source: http://www.youtube.com/watch?v=f5wfzqoMJuA
Reducing accidents and hazards to personnel
Reducing congestion and utilizing the space efficiently and effectively
Efficient utilization of labour and increase in employees morale
Easy supervision
Easy maintenance and high machine/equipment utilization
Improve in productivity

Criteria for a Good Layout
The designing of a layout is a creative exercise. The use of work study methods and industrial engineering techniques are helpful in designing the layout. Following are some of the criteria that need to be satisfied by a good layout.

- Maximum flexibility
- Maximum coordination
- Maximum visibility
- Maximum accessibility
- Minimum distance
- Minimum handling
- Minimum discomfort
- Inherent safety
- Efficient process flow
- Identification

Video 6.1.2: Facility Layout (Tutorial)
Source: http://www.youtube.com/watch?v=cTtu2P9dGqE

Basic Layout Formats
The layouts are differentiated by the types of work flow they entail, and the work flow in turn is dictated by the nature of the product. The following are some of the types of layouts:

1. Process Layout

Process layouts, which are also known as functional layouts or job-shop layouts, involve grouping of all the similar equipment or functions (all the lathe machines in one area, all drilling machines in another area, and all assembling works in some other area). They are designed to accommodate variety in product designing and processing.

Process layouts mostly use general purpose machines that can be changed over rapidly to new operations for different product designs. The workers in process layouts must be highly skilled. They also require intensive job instructions and technical supervision. These layouts are able to change and adapt quickly to the multitude of operations to be performed on each unique batch of products.
**Advantages**

- Greater flexibility in production
- Better and more efficient supervision is possible through specialization
- Breakdown of equipment can easily be handled by transferring work to another machine
- The capacity of different production lines can be expanded easily
- Better utilization of men and machines is possible through this layout

**Disadvantages**

- Production requires more time as work-in-progress has to travel from one place to another place in search of machines
- This type of layout requires more floor space and there might be difficulties in production
- There will be accumulation of work at different production units.

**2. Product Layout**

Product layouts, also called flow-shop layouts or straight-line layouts, involve arrangement of equipment or machines according to the progressive steps by which a product is made. Raw materials are moved into the first machine and the finished products come out from the last machine.

These layouts are designed to accommodate only a few, mostly one or two, standardized products and process designs. They allow direct material flow through the facility for attaining large volumes of production. These types of layouts are preferred in the plants that manufacture standardized products on a mass scale such as chemical, paper, rubber, refineries, and cement industries.

**Advantages**

- Mechanization of materials is possible and material handling costs can be reduced considerably
- This layout requires less floor area per unit of production
- This layout facilitates better production control and production bottlenecks can be avoided

**Disadvantages**

- Expansion of the production line is difficult
- There is difficulty in supervising
- Breakdown of equipment may disrupt the entire production system

**3. Grouping Technology Layout**

In a grouping technology layout (also called cellular manufacturing layout), dissimilar machines are grouped into cells, and each cell functions like a product layout within a larger job shop or process layout. Each cell in this layout is formed to produce a single part family – a few parts with common characteristics that usually require the same machines and similar machine settings.

These layouts help simplify machine changeovers, reduce materials-handling costs, quicker manufacturing and shipping quickly, reduce the in-process inventory required, and automate the production easily. But the disadvantage of this layout is the reduced manufacturing flexibility.

**4. Fixed Position Layout**
A fixed position layout involves movement of all machines and men to the product that remains stationary. In this layout, a major component of the product is fixed in a particular location and all the requirements are brought to the location. This type of layout is used when the product is bulky, large, heavy or fragile. This layout is followed in construction firms where the product will be in a fixed position and all the workers, materials, machines and sub contractors are brought to the construction location. The examples of such layouts are those production lines designed for ship construction, aircraft assembly, rocket assembly, etc. The advantage of this layout includes less investment on layout, avoidance of transporting bulky materials.

Although hybrid layouts make the identification of layout types fuzzy, it is very important to understand the characteristics, advantages and disadvantages of each type of layout. In plants involving the fabrication of parts and assembly, fabrication is done by the process type of layout, while in the assembly areas, product type of layout is preferred.

**Developing a Process Layout**

Managers can use various models like mathematical models, computer models, and physical models. Mathematical models help managers analyze and conceptualize the problem; computer models provide them a quick approximation of goods layouts; and physical models help them visualize the layout. They are very useful in planning process layout.

1. **Graphic and Schematic Analysis**

Templates, and two-dimensional cutouts of equipment drawn to scale are the most common layout-planning tools. Templates are moved about within a scaled model of the walls and columns of a facility to identify the best layout through trial and error. These templates are also used for developing product and fixed-position layouts.

2. **Computer Models – CRAFT**

A number of computerized layout programs have been developed to devise good process layouts. CRAFT (Computerized Relative Allocation of Facilities Technique) is one such program that works on the criteria similar to the load-distance model. The model finds a layout by evaluating thousands of alternative layouts quickly. CRAFT has the capacity to handle plants comprising up to 40 work centers of different shapes and sizes, and can account for mobile and immobile process centers. The model considers various types of layouts and different materials-handling methods that a firm can use among its work centers.
The initial layout, a matrix identifying the number of loads moved among process centers, and a matrix of the cost of transporting loads among process centers have to be provided to CRAFT. CRAFT then evaluates the effectiveness of the initial layout and exchanges the locations of pairs of process centers. Each exchange is evaluated for its effectiveness and the best exchange is adopted. The process is repeated several times until there is no further reduction in the materials-handling costs. Finally, the last available solution is considered as the final layout.

3. Load Distance Model

A plant having a process layout produces diversified products in variable work flows. Such a plant handles relatively large amounts of material. Since the movement of the material in such a process is more, and huge movement costs are incurred. Since material transportation does not add any value to the product, managers prefer layouts that result in minimum material movement; thereby aim at reducing the unnecessary flows among processing centers.

The load distance model is one of the important models used to minimize the material flow. In this model, the number of loads (standardized amount of material) moved between each pair of process centers over a period of time and the distances between them are considered. These distances depend on the locations fixed by the initial layout. The initial layout is then modified to reduce costs. This process is repeated until there is no scope for further cost minimization.

Developing a Product Layout

The design for developing a product layout is partly established when each part of the product is designed and the different steps required to make it are determined. The volume of production will determine the most economical process, and the process technology will determine the sequence of steps which have to be performed in production. Finally, the equipment and workstations are placed along a line in that sequence. Figure 6.4 shows some of the possible line arrangements.

There might be many possible sequences to arrange workstations and equipment for the same product. Line-balancing, a mathematical model, is used for determining appropriate ways to group the tasks to be performed at each workstation.

1. Line Balancing

Line balancing is a part of the assembly line study that comprises the selection of the appropriate combination of work tasks to be performed at each workstation so that the work is performed in a feasible sequence. The line balancing

Video 6.1.4: Product Layout (Tutorial)

Source: http://www.youtube.com/watch?v=cTtu2P9dGqE

mainly ensures that each workstation gets equal amount of the time approximately.

Line balancing is achieved by breaking the total amount of work to be performed on a line into tasks. These tasks are assigned to workstations that allow the work to be performed in a feasible sequence within an acceptable cycle time. The time between completion of successive items on the line is
termed as cycle time. The cycle time is determined by the maximum time required at any workstation. Work on the line cannot flow faster than it can pass through the slowest-stage, which is referred to as bottleneck. To avoid the bottleneck, some of the work tasks from workstations that deal with more work are assigned to workstations with less work.

**Steps in Assembly Line Balancing**

The following steps are needed to balance an assembly line:

**Step 1:** The sequential relationship among different tasks is specified by using a precedence diagram. The cycle time is determined by using the following formula:

\[
\text{Cycle time} = \frac{\text{Production time per day}}{\text{Required output per day}}
\]

**Step 2:** The theoretical minimum number of workstations required to satisfy the cycle time is determined using the following formula:

\[
N_t = \frac{T}{C}
\]

Where \( N_t \) = Theoretical number of workstations

\( T \) = Sum of task times

\( C \) = Cycle time

**Step 3:** A set of rules is identified to shortlist and select the tasks to be assigned to workstations. A sample set of rules is given below.

a) **Identification of feasible (remaining) tasks for the same station:**

From the unassigned tasks, identify the task(s) which can be assigned next to the same station, subject to two constraints:

- The precedence rules should not be violated.
- The individual time required for each of these feasible (remaining) tasks should be less than the unassigned time for the station, where

Unassigned time for a station = Cycle time – (Sum of the time required for all previous tasks that have been assigned to the station)

**Note:**

- When there is no feasible (remaining) task for the same station, move on to the next station.
- When there is exactly one feasible remaining task for the same station, assign it as the next task for the same station.
- When there are multiple feasible remaining tasks for the same station, use the following tiebreaker rules to shortlist/select the next task for the same station.

b) **Shortlist the tasks with most followers, among the feasible (remaining) tasks for the same station:**

**Video 6.1.5: Ford Assembly Line**

Source: http://www.youtube.com/watch?v=0h5V0pFGrLU
From the feasible (remaining) tasks for the same station, shortlist the task(s) which has (have) the most followers.

c) Select the task with the longest operation time:
From the shortlisted tasks with most followers, select the task which has the longest operation time, and assign it as the next task for the same station.
Sometimes, there may be many such tasks. In this case, one of these tasks with the longest operation time can be (arbitrarily) assigned as the next task for the same station.

Keynote 6.1.1: Problem 1

The efficiency of the balance is calculated by using the following formula.

\[
\text{Efficiency} = \frac{T}{N_a \times C}
\]

Where, 
\( T \) = Sum of task times
\( N_a \) = Actual number of workstations
\( C \) = Cycle time

Step 5: The balance is accepted if the efficiency is satisfactory, otherwise balancing is done using a different decision rule.

2. Mixed-model Line Balancing
So far we assumed that only one product was produced in each assembly line. But, to meet the demand for a variety of products many manufacturers consider mixed-model line balancing. Mixed model lines involve multiple lot sizes, lot sequencing, different setup times for each lot, differing workstation sizes along the line, and task variations that make it very difficult to design. As such, no technique exists to provide the optimum assignment of tasks to workstations in mixed-model lines.

The objectives of a mixed-model line design are to minimize idle time and minimize the inefficiencies caused by changing from model to model. Though many techniques such as integer programming, branch and band techniques, and simulation are used by researchers, they are unable to find the optimal solution for a realistic sized, real-world problem.

Developing a Cellular Manufacturing Layout
Developing a cellular manufacturing layout comprises three steps:
The parts that follow a common sequence of steps are grouped into a family. To do this, computerized parts classifications and a coding system have to be developed and maintained. Since systems are very expensive, many companies have developed short-cut procedures for identifying parts-families.

The dominant flow patterns of parts-families are identified as a basis for location or relocation.

Finally, the machines and processes are physically grouped into cells. The machinery parts that cannot be grouped with any cell or family are placed in a remainder cell.

The major problems in developing a cellular manufacturing layout are developing and classifying a coding scheme for items of different shapes, sizes, materials etc., grouping parts in families to form cell groups on the basis of processing requirements and routings, and creating the physical layout for positioning cells relative to each other.

Japanese Approaches and Trends in Manufacturing Layouts

The business philosophy, objectives, and manufacturing methods of Japanese are somewhat different from those of US firms. These differences are reflected in their facility layout. Since space is at a premium in Japan, the Japanese make the most use of what little space is available. Compared to US manufacturing facilities, Japanese factories are quite compact – almost one-third of their US counterparts. These compact layouts, with smaller pieces of equipment closely placed together, aisles squeezed down, and work centers closely placed together, help them save space. They also use areas and train workers for more than one task.

Due to the compactness of the layout, the materials travel shorter distances and products go through the factory faster, resulting in high production rates, quick processing of customer orders, and reduction in materials handling and inventory costs. It also enables the factories to be more flexible to changes in customer orders, production schedules and production rates. Communication and morale within a group also improve as the workers are stationed close to each other.

In general, US manufacturing layouts are designed for high worker and machine utilization, whereas Japanese layouts are designed for flexibility and adaptability to different product models or to different production rates.

Service Facility Layouts

The fundamental difference between a service facility and a manufacturing facility is that service facilities exist to bring together the customer and the organization’s services. Features like easy entrance to these facilities from freeways and busy thoroughfares, well organized parking lots, well marked entries and exits, powered doors, escalators and lobbies for customers provided by these service facilities are

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Source: http://www.youtube.com/watch?v=A1tKzU1TaW4

Video 6.1.6: Cellular Layout Presentation

---
mainly because of their differences from the manufacturing facilities.

Two extremely different types of layouts of service facilities exist, based on the degrees of customer contact. At one extreme is that layout which is totally designed around the customer receiving service functions, and the other is that layout which is designed around technology, processing of physical materials, and production efficiency. Banks are the

Video 6.1.7: Service Layouts

Source: http://www.youtube.com/watch?v=ws9lQPOgH9A

best examples of layouts designed around customers. Such service facility layouts give importance to customer convenience, but treat the employee work areas for information processing and financial record keeping etc. as secondary.

On the other hand the best examples for service facility layouts that focus more on technology or physical materials processing and production efficiency are hospitals. The hospital layout considers application of medical technologies such as surgery, radiology, laboratory tests, patient rest and recovery, patient feeding and the effective employment of doctors and nurses healing skills as the primary factors as opposed to factors like receiving patients, setting accounts and discharging patients.

Some other service facilities strike a balance between these extremes. The best example of such a service facility is a restaurant where attention is directed both at customer receiving and servicing as well as on processing and preparation of food.
What do you understand by the term ‘facility layout’?

A. A list of facilities provided by the organization to the consumers

B. The physical distribution of various departments for ease in production

C. The location of employees inside the organization

D. Layout of safety equipment in an organization
Section 2

Case Study: Travelsafe Manufacturing Company (TMC)

This case study was written by Sourabh Bhattacharya, Asst. Professor, Department of Decision Sciences, IBS Hyderabad. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was prepared from generalised experiences.

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www.icmrindia.org
Travelsafe Manufacturing Company (TMC) is a manufacturer of leather suitcases in northern India. Along with the leather suitcases, TMC also manufactures leather backpacks, leather briefcases, leather suave backpacks, zippered leather briefcases and leather travel backpacks. However, over the period of time, TMC has acquired latest know-how to manufacture fine leather suitcases. The leather suitcases manufactured at TMC have always been in high demand with fashion houses, leading suitcase brands such as Samsonite, Delsey, American Tourists, VIP, etc.

TMC has earned a reputation of reliable and best quality leather suitcase manufacturer among its clientele. Though happy with this reputation, TMC became concerned about the performance of other products it produced. It's leather briefcases have literally no visibility in the market. The company experts attribute single-tracked focus on suitcase business to the low visibility of the briefcase business. Lately, management of TMC has started contemplating the idea of revamping their briefcase business. After a thorough assessment of its own capabilities TMC figured out that it would be difficult to penetrate new markets or acquire new customers. TMC thought it would be easier to cash on its reputation with the existing clientele and convince them for leather briefcase's orders too.

After efforts of many months TMC could receive an order for 60,000 leather briefcases from one of its European client to be delivered over a period of 300 working days. Because the company has never produced this product before in such a volume, an assembly line had to be planned to produce the order on a basis of one 8-hour shift per day. The company's employees are allowed to take two 15-minute coffee breaks per shift, they take 15 minutes per shift to clean up their immediate work area, and they lose an average of about 20 minutes per shift because of material delivery delays. Suitcase's staff has identified these tasks and their predecessor tasks, and has estimated the time required for each task as shown in the table below. Four production departments will do the work on the cases: metals, woods, leather, and final assembly. The union contract does not allow workers to do work outside their own departments (for example, an individual employee could not do both leather and woodwork), but they are allowed to do any work within their own production departments.
Suggested Questions for Discussion

1. Draw a diagram of the precedence relationships.
2. Compute the cycle time per briefcase in minutes.
3. Compute the minimum number of workstations required.
4. Which tasks are combined into workstations? How many workstations are in each of the work centers?
Materials Requirement Planning

Introduction:
In this chapter we will discuss:

- Fundamentals of Materials Requirement Planning
- Objective of MRP
- Components of an MRP System
- Key Planning Factors and Issues in MRP
- Closed Loop MRP
- Advantages and Disadvantages of MRP
- Problems in Implementing MRP
- Resource Planning for Service Organization
- Manufacturing Resource Planning (MRPII)
Section 1

Materials Requirement Planning

MRP system is the application of computers in operations management. It helps an operations manager find the net requirement of a component after taking into consideration inventory on hand, scheduled receipts, and scheduled order releases.

MRP system generates schedule for material and component supply after considering end product requirements, product structure data (product production hierarchy), and historical lead-time information.

Fundamentals OF MRP

MRP is a backward scheduling process that estimates requirement of materials starting with the date of delivery of products and working backward to estimate date of receipt keeping in view production and waiting time, and estimating date of order, based on delivery lead-time.

An MRP system helps in coordinating orders from external orders referred to as purchase orders and internal sources referred to as jobs. The system studies the future production requirements and disassembles the end product into required amount of raw materials, parts, subassemblies, and assemblies required in each time bucket (time period) of the planning horizon. It then determines the existing level of inventories for each item and the required order quantities. Figure 7.1 illustrates how a typical end product is expressed in terms of

![Figure 7.1: Product Hierarchy](image-url)
assemblies, sub-assemblies, components, etc. Finally, a schedule is generated that specifies the time when the items are required based on the time when each item is needed in production, the lead times available for procuring the items, etc. This ensures the availability of parts and materials exactly when they are required in the production process. MRP is useful for organizations involved in the production of complex products, organizations working with shorter delivery schedules, job-shops and assemble-to-order organizations.

Table 13.1 illustrates the suitability of MRP in different types of industries and the benefits that can be achieved from it.

**OBJECTIVES OF MRP**

MRP helps an organization achieve the following objectives:

- **Improved customer service**: MRP helps organizations in improving customer service by identifying the quantity, timing and availability of components and parts, and by simultaneously placing orders to satisfy the requirements on time.
- **Reduced investment in inventory**: An MRP system assists organizations ordering quantity based on the actual number of components and parts required, hence, reduces investment in inventory.
- **Improved operating efficiency**: MRP system helps organizations in reducing both stock-out and inventory holding costs. It facilitates the timely supply of needed materials which reduces the idle time and improves the overall operating efficiency of organizations.
- **Faster response to market changes**: MRP system enables an organization to respond quickly to market changes. If the market demand necessitates a change in the master production schedule, it can be easily incorporated in the MRP system.

Thus by providing improved customer service, reduced investment in inventories, improved operating efficiency and faster response to market change, MRP contributes to the overall growth and operating efficiency of an organization.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Description</th>
<th>Expected Level of Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assemble-to-stock</td>
<td>Combines multiple component parts into a finished product, which is then stocked in inventory to satisfy customer demand. Examples: Watches, tools, and electrical appliances.</td>
<td>High</td>
</tr>
<tr>
<td>Fabricate-to-stock</td>
<td>Items are manufactured directly by machines rather than assembled by parts, and are stored in stock points to meet the anticipated customer demand. Example: Electrical fuses.</td>
<td>Low</td>
</tr>
<tr>
<td>Assemble-to-order</td>
<td>A final assembly is made according to the customer’s orders. Examples: Motors, weigh feeders, and crushers.</td>
<td>High</td>
</tr>
<tr>
<td>Fabricate-to-order</td>
<td>Items manufactured by machines to customer orders. Examples: Gears, ball bearings and conveyor belts.</td>
<td>Low</td>
</tr>
<tr>
<td>Manufacturer-to-order</td>
<td>Items either fabricated or assembled completely in adherence to customer specifications. Examples: Turbines, packing machines, and heavy machine tools</td>
<td>High</td>
</tr>
<tr>
<td>Process</td>
<td>Industries such as chemicals, foundries, cement, steel, rubber, and plastics</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Table 7.1.1: Expected Benefits from MRP
COMPONENTS OF an MRP SYSTEM

An MRP system translates the demand for end products into raw material and component requirements. The system requires the following information to operate successfully:

- Customer orders and unfinished orders that must be completed in the planned production period.
- Demand forecasts of products demanded and the time period in which these demands are to be met.
- Capacity information that helps in anticipating resource shortages.
- Details of the dependent demand inventory items at different stages of the transformation process and the stages through which these items traverse to make an end product.
- Changes in inventory requirements due to change in product design expected during the planning period.
- Available level of inventories at the beginning of the planning time period.
- Quantities of ordered, purchased, or contracted inventory items that an organization expects to receive during the planning period.

Once all pre-requisite information is received, operations managers convert it into a form acceptable to the MRP system. Three elements common to all available variants of MRP system are:

- Inputs
- Processing
- Outputs

Figure 7.1.2: Materials Requirement Planning System

MRP System Inputs: Inputs of an MRP system include:

- Master production schedule
- Bills of material
- Inventory records file

Master production schedule:
The Master Production Schedule (MPS) file contains information about when and how many units of finished products are required. It also contains information about the available cumulative lead-time for purchasing, receiving, fabricating, and assembling. This information is derived from an aggregate production plan and is based on demand forecasts. Based on this information from MPS, MRP system generates a replenishment plan for items needed in the production of the final product.

The time horizon in the MPS is divided into shorter time buckets such as a day or two to plan short-term requirements, and longer time buckets such as a fortnight or a month to plan long-term requirements.

**Bills of material:**

The Bills of Material (BOM) contain the list of materials and the quantity required to produce one unit of a product. The BOM file shows the hierarchical levels or phases a product goes through during production. It consists of the complete list of all end products, the structure (subassemblies, parts, and raw materials which constitute the product assembly) of the products, and the quantity of each item required for producing each higher-level item in the product hierarchy. It also contains information about whether a particular item was produced internally or purchased from external sources. Figure 13.3 presents a product structure chart for a hypothetical product. In this chart, one unit of a finished product, its eight different component (P₁ to P₈) and different phases or level of production are shown.

In the Figure 13.3, the hypothetical end product is assembled from two component parts, P₁ and P₂. The number “3” next to part P₄ indicates that three units of P₄ are required to make a unit of P₁. In the hierarchy, the component parts at the lower levels are combined to form the inventory item at the next higher level. For instance,
This situation causes some inefficiency in computer processing because MRP program has to consider more than one level where the part is required while processing material requirements. To overcome this problem, managers generally restructure the BOM, so that a common component appears at the same level throughout. This restructuring is called low-level coding as the common component is incorporated at the lowest level at which it appears in the original product structure chart. It is important for the operation managers to revise the BOM file at regular intervals and update it accordingly.

Inventory records file:
The inventory records file is a computerized file with a complete record of each material held in the inventory. It contains all the information about inventory levels at the beginning of the planning horizon and the details of the expected arrivals of inventory during that period. It also contains information about vendors like their names and addresses, and the time required for supplying materials, parts, etc. Inventory records file also contains information of some components and parts as end products that are supplied to customers as replacement parts or spare parts.

MRP System Information Processing: MRP system uses information from product structure file and lead-time information to develop purchase and production schedule for the component, so that the materials are available exactly when they are required in the production process.

The steps in the MRP information processing:
- Explosion
- Netting
- Offsetting

Explosion
The first step in the MRP information processing is that of explosion in which end product is disassembled into components required for its production. It starts with the time when the product is required and then proceeds backward to determine each production or purchasing activity that is necessary to make each higher-level item in the product structure chart. Explosion uses the information from MPS and BOM to generate the sequence followed to produce the end product.

Netting
The next step in MRP information processing is to develop a materials requirement plan for each item in the BOM file for each time bucket. The system first identifies the gross product requirements from the master production schedule. It then calculates the net product requirements by subtracting the available units of item and the quantity on order from gross product requirement.

Net Requirement = Gross Requirement - On hand inventory - Quantity on order

Offsetting
The system then uses the information obtained from explosion and netting process to determine planned order releases, i.e. the quantities to be ordered (either internally through production or from an external supplier) so that the materials arrive just when they are needed. The planned order releases for the finished product or component becomes the gross product requirement for items at the next lower level in the product structure chart. In case of product described in the Figure 13.3, the planned order release of 10 units of product...
P₁ on day 4 means that on day 4, the gross requirements for products P₃ and P₄ are 10 and 30 respectively.

The final step in information processing is the consolidation of material requirements. Production organizations that produce multiple products generally have common material requirements for two or more products. These material requirements are consolidated to form a single master material requirements plan to take advantage of benefits of economies of scale and discounts for bulk purchases.

**MRP System Output**

An MRP system generates many types of reports and planning information as outputs. These outputs include notices, reports, and schedules, which help operations managers in planning and scheduling the dependent demand inventory. The reports can be customized to suit individual organization requirements.

**Primary reports:** Primary reports are the main reports that are used in inventory and production control.

- **Planned orders:** It is a simple report that defines the quantity of inventory required in a specific time bucket. It includes information about all inventory requirements during the planning period.

- **Order releases:** These documents empower the purchase department to procure a specific quantity of inventory items required within a specific period.

- **Changes in due date:** These reports are generated to revise purchase orders if the orders are not completed on time. These reports include revision in delivery periods and order quantities.

- **Cancellation or suspension:** These report are generated when the order is to be canceled or suspended because of changes in the MPS.

**Secondary reports:** These are optional reports that assist operations managers in assessing the performance of the inventory management system.

- **Planning reports:** Planning reports contain information about material (inventory) requirements. Examples of such reports are inventory forecasts, purchase commitment report, and long-range materials requirement planning information.

- **Performance reports:** These reports inform about the performance of the MRP system. At the same time, it helps...
identify the problem areas and verifies whether the system can achieve its planned objectives.

Exception reports: Exception reports contain information about errors, late or overdue orders, or regarding any other deviations from the normal planned objectives. Exception reports are automatically generated whenever actual delivery of parts, sub-assemblies, etc. differs from the planned schedule.

KEY PLANNING FACTORS AND ISSUES IN MRP

The performance of an MRP system depends on certain variables and factors. Some of these have been discussed below:

Lead-Time

Lead-time is the time difference between placing an order and receiving the ordered materials. Proper planning and awareness of lead-time ensures timely receipt of raw materials and components needed in production process. If items are received before they are required, the inventory holding costs increase and if the material arrives late, stock-out costs increase. The accurate estimation of order time is necessary to avoid stock-out costs and control inventory holding costs.

Lot-Sizing Rules

Lot sizing rules assist in identifying time and size of the order. The objective of lot-sizing rules is to minimize the setup, order and holding costs. These rules include economic order quantity, lot for lot (L4L), least total costs (LTC) and least unit costs (LUC).

Economic order quantity

Table 7.1.2: Least Total Cost Run Size for MRP Schedule

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Quantity Ordered</th>
<th>Carrying Cost</th>
<th>Ordering Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>2-3</td>
<td>150</td>
<td>40</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>4</td>
<td>230</td>
<td>90</td>
<td>200</td>
<td>290</td>
</tr>
<tr>
<td>5</td>
<td>310</td>
<td>130</td>
<td>200</td>
<td>330</td>
</tr>
<tr>
<td>6</td>
<td>400</td>
<td>190</td>
<td>200</td>
<td>390 (LTC)</td>
</tr>
<tr>
<td>7</td>
<td>520</td>
<td>280</td>
<td>200</td>
<td>480</td>
</tr>
<tr>
<td>8</td>
<td>600</td>
<td>330</td>
<td>200</td>
<td>530</td>
</tr>
</tbody>
</table>

Table 7.1.3: Least Unit Cost Run Size for MRP Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Net Requirement</th>
<th>Production Quantity</th>
<th>Closing Inventory</th>
<th>Ordering or Set up cost (Rs.)</th>
<th>Holding cost (Rs.)</th>
<th>Total cost (Rs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>400</td>
<td>300</td>
<td>200</td>
<td>50</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>35</td>
<td>285</td>
</tr>
<tr>
<td>3</td>
<td>80</td>
<td>0</td>
<td>170</td>
<td>0</td>
<td>31</td>
<td>316</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>0</td>
<td>90</td>
<td>0</td>
<td>22</td>
<td>338</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>338</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>200</td>
<td>80</td>
<td>200</td>
<td>32</td>
<td>570</td>
</tr>
<tr>
<td>7</td>
<td>80</td>
<td>80</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>570</td>
</tr>
</tbody>
</table>

Economic order quantity is the optimal order quantity where the total cost of acquiring material is the minimum.

Lot for lot (L4L)
Lot for lot is a commonly used technique for lot sizing. In this technique, planned order releases exactly match the net requirement. As no inventory is carried forward for the next week’s production, the carrying cost is minimized. The objective of the rule is to order the quantity that satisfies the exact requirements of the planned time bucket, which is usually one week. Under lot for lot rule, the lot size to be ordered is the difference between the estimated gross requirement for a week and the projected on-hand inventory at the end of the immediately preceding week.

**Least total costs**

In the least total cost lot-sizing technique, the order quantity is determined by comparing the inventory carrying cost and ordering or set-up costs for different lot sizes and selecting the lot where both the costs are equal. The primary objective of this method is to minimize the ordering or setup costs and holding cost of inventory items. Table 13.3 shows the procedure to identify the lot size with the least total cost. In this example the ordering cost is taken as Rs. 200. The carrying cost in the table is an estimate to illustrate the procedure. We can see from the Table 13.3 that for the lot size of 400, the ordering cost is closest to the carrying cost.

**Least unit costs**

The least unit cost method involves summing up of the inventory carrying and ordering costs for various lot sizes and dividing it with the number of units in the lot. The lot size with the lowest unit cost is selected. Table 13.4 shows the procedure to identify the lot size with the least unit cost.

**Safety Stock**

Safety stock refers to the inventory level that is maintained to avoid the risks of stock-out. In case, any delays are encountered in the procurement of requisite items, or if there is any variability in demand, safety stocks can be used to continue the production process. The higher the safety stock level the lower the risk of stockout. But if the safety stock is greater, the inventory carrying costs are also higher.

**Implosion**

Implosion is a bottom up approach wherein one goes upwards in the product structure chart to find the parent end product of every raw material used. By using this procedure, one can find the items, which are required for more than one end-item.

**Combing Requirements**

It refers to the process of obtaining the gross requirements of common items. When a single item is used at different levels of BOM in more than one end product, its requirements should be combined.

**Pegging**

Pegging is one of the techniques associated with combing requirements. It allows planners to identify the source of demand that relates to planned order release. It also helps ascend BOM and identify the item’s end product. Therefore, pegging enables executing an implosion process for common items.

**Cycle Counting**

Cycle counting is the process of keeping MRP records up-to-date. It involves counting predetermined inventory items regularly on a daily, weekly or monthly basis throughout the year. For instance an organization needs to maintain inventories of items A, B, C, and D. Under annual inventory inspection method, the counting is carried out for all the items at the end of a year and discrepancies are noted and adjustments are made. But in cycle counting, the organization may schedule inventory inspection of item A in the first week of a month, items B in the second week of a month and so on. At
the end of one month all the items are counted once. This process is repeated every month and discrepancies are noted. The number of items to count during a cycle period and time period for carrying out the inspections are based on an organization’s specific requirements and resource availability for conducting these inspections. During counting, defective and rejected inventory items are subtracted from the available inventory records. Using this method, production managers can estimate whether the inventory available is more than what is needed. If there is a shortage, they can take decisions accordingly.

**Updating**

As inventory is regularly consumed from the stock, it is necessary to constantly update the MRP. An MRP system responds to any changes in MPS, product structure file, and product design. To update the system any of the two approaches can be used:

**Regenerative Method:** This approach involves the complete regeneration of the MRP system at periodic intervals by reprocessing the entire data and accommodating new information.

**Net Change Method:** This approach involves updating those parts of the MRP system, which are affected by the changes. Whenever there is any change in inventory stock level, it is incorporated in the MRP system. In this system, the program generates new information only on those products that are affected by the change. So, if a change in a component affects the planning of some products, a net change system generates reports on the affected products.

**Time Fence**

Time fences provide stability to the ever-changing MRP system. Time fence is described as the shortest time period in which any kind of modification or rescheduling is not allowed.

During this time period, MPS remains fixed. Changes are incorporated only under extreme circumstances.

**Closed-Loop MRP**

Closed-loop MRP is an extension of MRP that incorporates feedback loops which provides feedback to aggregate production plan, capacity plan, master production schedule, etc. The objective of a closed loop MRP system is to check

**Figure 7.1.4 Closed-Loop MRP**

![Closed-Loop MRP Diagram](source: Vollmann, Berry, and Whybark, Manufacturing Planning and Control Systems (Irwin, 3rd edition) 122.)
whether the available resources are sufficient to meet the requirement of production plan. Any changes in the planning due to variations in lead-time, discrepancies in the quantity ordered and received, change in customer demand etc. would necessitate a change in BOM and inventory status files. Using three planning routines, a closed loop MRP system checks whether the available resources can satisfy the requirements of the production plan. This is shown in Figure 13.6.

**Resource Requirement Plans**

Resource requirement plans are static in nature and involve identifying requirements for large structural parts of operations such as numbers, size and capacity of plants. As they help arrange resources in long-term, they are sometimes called infinite capacity plans.

**Rough-Cut Capacity Plans**

These are short term or medium term plans that check the requirements of MPS with available capacity. If the available capacity is less than required, then the options before the management are to alter the MPS, install additional capacity, etc. These plans are called finite capacity plans because they operate within capacity and other resources constraints.

**Capacity Requirement Plans**

Capacity requirement plans are used to assign loads to different workstations based on the information from MRP system. These are infinite capacity plans wherein the loads assigned to an individual workstation does not consider the capacity constraint of that particular workstation. For instance if an machine has a capacity of producing 100 units in a day then capacity requirement plans assign production of 100 units to that machine, without taking into consideration whether the machine is scheduled for some other operation during that time, or it requires any setup time.

So if the load is characterized by variations, then to avoid any discrepancies between assigned load and available load, additional capacity is added or finite capacity plan is used i.e. load is assigned based on the actual available capacity on a workstation.

**ADVANTAGES AND DISADVANTAGES OF MRP**

**Advantages**

Following are the advantages of an MRP system:

- Reduced per unit cost of production thus enabling an organization to price its products competitively
- Low inventory levels, especially for in-process materials
- Better response to market demand
- Better customer service
- Reduced set-up and tear-down costs
- Comprehensive material tracking and optimized production scheduling
- Improvement in capacity allocation and planning

**Disadvantages**

Following are the disadvantages of an MRP system:

- High costs and technical complexities in implementation. In addition, organizations, which use an MRP system need to spend considerable effort on installing necessary equipment (computers), training personnel, modifying the software to serve their specific needs, validating, testing,
and eliminating possible errors, and maintaining the software.

The time required for planning and implementing an MRP system is generally very long.

Data entry and file maintenance requires considerable inputs in the form of training and education of the personnel.

Dependence on forecast values and estimated lead-time can sometimes be misleading.

PROBLEMS IN IMPLEMENTING MRP SYSTEMS

Though the underlying principle of an MRP system is simple, but many a time the implementation fails due to the following reasons:

- Inadequate employee training and involvement
- Use of inaccurate and obsolete data
- Inappropriate product environment

Inadequate Employee Training and Involvement

Inadequate employee training and involvement is one of the major obstacles in implementing MRP systems. If the employees are not trained properly, they will not be able to understand the system and hence cannot use it properly.

Use of Inaccurate and Obsolete Data

An MRP system cannot yield good results if the data is either inaccurate or obsolete. In other words, the system will not yield the desired results if the BOM records are not updated regularly.

Inappropriate Product Environment

The success of an MRP system usually depends on the product environment. The system is useful only when an organization needs to purchase many items, a majority of which are components and parts. The demand pattern of these items should be dependent in nature and irregular in timing. Moreover, the lead times for purchase of these items should be consistent. If any of these criteria is not satisfied, the functioning of the system may not be economical and satisfactory.

RESOURCE PLANNING FOR SERVICES

Manufacturing organizations are materials driven whereas service organizations are capacity driven. Hence, the dependent demand in service organizations can be defined as the requirements for resources that are dependent on the customer demand for services. So instead of the bills of material, service organizations use the bills of resource. The bills of resource contain information on required materials, equipment time, staff that are used in providing services. The scheduling of staff and allocation of resources is done on the basis of this information. For an airline, the bills of resource include meals, fuel, staff and equipment.

MANUFACTURING RESOURCE PLANNING (MRP II)

The materials requirement planning system, like any other management information system, can be expanded to support other functions like engineering, production, finance, marketing and purchasing. Integrating these functional areas redefines the nature of an MRP system into a full-scale management information system referred to as the Manufacturing Resources Planning (MRP II) system. The MRP II system can be used to analyze complete product cycles, from corporate production plans to finished goods distribution.
Product planning functions: Product planning functions are carried out by managers at the upper-management level. They translate the strategic considerations into corporate business objectives. The output of this function is a production plan. This production plan becomes a point of reference for the production department to manufacture the specified quantities; for the sales department to sell the quantities produced; and for the finance department to manage the necessary financial resources so that manufacturing and sales department can carry out their operations smoothly.

Operations planning functions: Operations planning functions are performed by middle level managers. Many activities in this function are similar to that of MRP, but with additional attention to both short and long-term physical constraints. The activities of this function include purchasing parts and components, executing work orders, monitoring material movements, checking worker performance, reviewing the distribution activities, and so on. All the three functions mentioned above interact with the help of feedback provided by the checkpoints between them. Exhibit 7.1.1 lists the benefits that can be derived from an MRP II system. Exhibit 7.1.2 illustrates the use of MRP II in semiconductor industry.

References:
http://www2.cob.iilstu.edu/achoudh/MQM227/Chap14_MC_Questions&Answers.pdf

Exhibit 7.1.1
Benefits of a Manufacturing Resource Planning System
Through MRP II, organizations can improve their competitive position with regard to pricing, product quality and delivery schedules. The benefits of MRP II system are
1. Effective inventory management and control
   a. Balanced inventories
   b. Reduction in work in process inventories
   c. Reduction in finished goods inventory
2. Improved capacity planning
   a. Improvement in equipment utilization
   b. Easy identification of problem areas in work centers
   c. Improvement in maintenance
3. Better priority
   a. Reduction in production lead time
   b. Rescheduling capabilities
4. Enhanced customer service
   a. Improved costs
   b. Timely delivery
   c. Improvement in quality of products
   d. Reduction in lost sales
5. Improved management
   a. Improved control and management through performance measures
   b. Gives a detailed overview of the manufacturing process
6. Enhanced employee morale
   a. Confidence in system
   b. Enhanced interdepartmental coordination
7. Effective long range planning tool for
   a. Marketing
   b. Production
   c. Personnel
   d. Finance
   f. Purchasing
   g. Top management

Exhibit 7.1.2
MRP II in Semiconductor Industry

The semiconductor equipment and materials industry started as made-to-order business i.e. customers placed the orders and based on them, suppliers provided the raw materials such as wafers, chemicals, etc. This process was effective in the past when the numbers of customers were less, orders were smaller and firms had to deal with less inventory. Now the requirements for semiconductor materials and equipment have increased manifold. Thus the industry has to deal with more number of customer, larger order sizes etc. To deal with such large scale purchasing and delivering requirements, organizations need to improve their supply chain activities. This can be achieved by implementing of MRP II system. MRP II facilitates the integration of different business functions and improves the supply process, leading to greater customer satisfaction. In MRP II, communication between different functional entities is critical. MRP II encompasses the complete supply chain from demand forecasts to planning and production and the delivery of final product. Adoption of MRP II improves the on-time shipment of goods and the accuracy of the inventory records, which is critical in materials supply industry.

Semiconductor materials and equipment industry operates in an ever changing and unpredictable environment. MRPII allows the supply chain activities of semiconductor equipment and materials’ suppliers to operate efficiently in such volatile business environment.

A master production schedule specifies

A. The financial resources required for production
B. What component is to be made, and when
C. What product is to be made, and when
D. The labor hours required for production
Section 2

Case Study: Material Requirements at King’s Furniture

This case study was written by R. Muthukumar, IBSCDC. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was prepared from generalised experiences.

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The King Furniture Pvt. Ltd (King Furniture), founded in 1982, is part of a family enterprise with a combined manufacturing strength across several products that gives it the vital component strength in furniture manufacture. King Furniture's facilities include state-of-the-art plants for manufacturing powder coated and electroplated metal parts and injection moulded items. Injection mould unit manufactures Chair seats and its inners and outers of chair back and other chair components. Thermoforming unit for chair seat and back covers, melamine laminates. It serves all over India and popular for its quality, innovative & aesthetic designs and prompt delivery.

This and a mighty investment in manpower towards design and production of quality furniture have been instrumental in what the company is the leading manufacturer of chairs and components in south India. King Furniture is endowed with a ISO 9001 certificate and is the trusted supplier of leading architects and companies across the country. King Furniture has been a trusted name in the furniture industry for over two decades, and manufacturer furniture for all office applications, covering open office systems, modular furniture, workstations, chairs and tables. It also retails the finest lines of home furniture, imported from across the globe.

The managing director of the company, Narasimha Reddy, says, "On time deliver performances of product shall be ensured. The cost of activities shall be brought down by reducing and rework and optimum utilisation of all resources. Identify and fulfil the training needs for all employees. To enable employees participation in continuous improvement through suggestion scheme and services preventive action and control to avoid customer dissatisfaction. Continuous review of service requirements and achievements to identify opportunities for the organisation's quality improvement."

Although it has tie-ups with many corporate customers, the demand for the company's chairs is not regular. For some weeks there will not be any demand at all, while for some weeks there will be a huge order. Hence, from after onwards the company decided to plan the production for every quarter. The same was intimated to the production manager. Now, the production manager at the company wanted to develop a materials requirements plan for producing chairs over a 12 week period. He estimated that the lead time between releasing an order to the shop floor and producing a finished chair is 2 weeks. The company currently had 300 chairs in stock and no safety stock (safety stock is stock held in reserve to meet customer demand if necessary). The forecast customer demand is for 200 chairs in week 1, 90 in week 3, 225 in week 5, 1,000 in week 7, 75 in week 8, 250 in week 11 and 100 in week 12. He was in sceptical as to how to go about it.

**Suggested Questions for Discussions**

1. What do you mean by Material requirement planning?