Module – 3 (Part-II & III)
Facility Location
Facility Layout
Capacity Planning

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(As per Syllabus of MBA (SCM), MBA(HRM) Semester – II)

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Part – II of III

Facility Layout - Introduction

For an organization to have an effective and efficient manufacturing unit, it is important that special attention is given to facility layout. Facility layout is an arrangement of different aspects of manufacturing in an appropriate manner as to achieve desired production results. Facility layout considers available space, final product, safety of users and facility and convenience of operations. An effective facility layout ensures that there is a smooth and steady flow of production material, equipment and manpower at minimum cost. Facility layout looks at physical allocation of space for economic activity in the plant. Therefore, main objective of the facility layout planning is to design effective workflow as to make equipment and workers more productive.

Facility Layout Objective

A model facility layout should be able to provide an ideal relationship between raw material, equipment, manpower and final product at minimal cost under safe and comfortable environment. An efficient and effective facility layout can cover following objectives:

- To provide optimum space to organize equipment and facilitate movement of goods and to create safe and comfortable work environment.
- To promote order in production towards a single objective
- To reduce movement of workers, raw material and equipment
- To promote safety of plant as well as its workers
- To facilitate extension or change in the layout to accommodate new product line or technology upgradation
- To increase production capacity of the organization

An organization can achieve the above-mentioned objective by ensuring the following:

- Better training of the workers and supervisors.
- Creating awareness about of health hazard and safety standards
- Optimum utilization of workforce and equipment
- Encouraging empowerment and reducing administrative and other indirect work

Factors affecting Facility Layout

Facility layout designing and implementation is influenced by various factors. These factors vary from industry to industry but influence facility layout. These factors are as follows:

- The design of the facility layout should consider overall objectives set by the organization.
- Optimum space needs to be allocated for process and technology.
- A proper safety measure as to avoid mishaps.
- Overall management policies and future direction of the organization

Design of Facility Layout

Principles which drive design of the facility layout need to take into the consideration objective of facility layout, factors influencing facility layout and constraints of facility layout. These principles are as follows:

- **Flexibility:** Facility layout should provide flexibility for expansion or modification.
- **Space Utilization:** Optimum space utilization reduces the time in material and people movement and promotes safety.
- **Capital:** Capital investment should be minimal when finalizing different models of facility layout.

Design Layout Techniques
There are three techniques of design layout, and they are as follows:

1. **Two or Three Dimensional Templates:** This technique utilizes development of a scaled-down model based on approved drawings.
2. **Sequence Analysis:** This technique utilizes computer technology in designing the facility layout by sequencing out all activities and then arranging them in circular or in a straight line.
3. **Line Balancing:** This kind of technique is used for assembly line.

Types of Facility Layout
There are six types of facility layout, and they are as follows:

- Process / Functional Layout
- Product / Line Layout
- Fixed Position Layout
- Combined Layout
- Group / Cellular Technology Layout, and
- Other Layouts

Process / Functional Layout
Process layouts are found primarily in job shops, or firms that produce customized, low-volume products that may require different processing requirements and sequences of operations. Process layouts are facility configurations in which operations of a similar nature or function are grouped together. As such, they occasionally are referred to as functional layouts. Their purpose is to process goods or provide services that involve a variety of processing requirements. A manufacturing example would be a machine shop. A machine shop generally has separate departments where general-purpose machines are grouped together by function (e.g., milling, grinding, drilling, hydraulic presses, and lathes). Therefore, facilities that are configured according to individual functions or processes have a process layout. This type of layout gives the firm the flexibility needed to handle a variety of routes and process requirements. Services that utilize process layouts include hospitals, banks, auto repair, libraries, and universities.
Improving process layouts involves the minimization of transportation cost, distance, or time. To accomplish this some firms use what is known as a Muther grid, where subjective information is summarized on a grid displaying various combinations of department, work group, or machine pairs. Each combination (pair), represented by an intersection on the grid, is assigned a letter indicating the importance of the closeness of the two (A = absolutely necessary; E = very important; I = important; O = ordinary importance; U = unimportant; X = undesirable). Importance generally is based on the shared use of facilities, equipment, workers or records, work flow, communication requirements, or safety requirements. The departments and other elements are then assigned to clusters in order of importance.
Advantages of process layouts include:

- *Flexibility.* The firm has the ability to handle a variety of processing requirements.
- *Cost.* Sometimes, the general-purpose equipment utilized may be less costly to purchase and less costly and easier to maintain than specialized equipment.
- *Motivation.* Employees in this type of layout will probably be able to perform a variety of tasks on multiple machines, as opposed to the boredom of performing a repetitive task on an assembly line. A process layout also allows the employer to use some type of individual incentive system.

- *System protection.* Since there are multiple machines available, process layouts are not particularly vulnerable to equipment failures.

Disadvantages of process layouts include:

- *Utilization.* Equipment utilization rates in process layout are frequently very low, because machine usage is dependent upon a variety of output requirements.
- *Cost.* If batch processing is used, in-process inventory costs could be high. Lower volume means higher per-unit costs. More specialized attention is necessary for both products and customers. Setups are more frequent, hence higher setup costs. Material handling is slower and more inefficient. The span of supervision is small due to job complexities (routing, setups, etc.), so supervisory costs are higher. Additionally, in this type of layout accounting, inventory control, and purchasing usually are highly involved.
- *Confusion.* Constantly changing schedules and routings make juggling process requirements more difficult.

Product / Line Layout

Product layouts are found in flow shops (repetitive assembly and process or continuous flow industries). Flow shops produce high-volume, highly standardized products that require highly standardized, repetitive processes. In a product layout, resources are arranged sequentially, based on the routing of the products. In theory, this sequential layout allows the entire process to be laid out in a straight line, which at times may be totally dedicated to the production of only one product or product version. The flow of the line can then be subdivided so that labor and equipment are utilized smoothly throughout the operation.

Two types of lines are used in product layouts: paced and un-paced. Paced lines can use some sort of conveyor that moves output along at a continuous rate so that workers can perform operations on the product as it goes by. For longer operating times, the worker may have to walk alongside the work as it moves until he or she is finished and can walk back to the workstation to begin working on another part (this essentially is how automobile manufacturing works).

On an un-paced line, workers build up queues between workstations to allow a variable work pace. However, this type of line does not work well with large, bulky products because too much storage space may be required. Also, it is difficult to balance an extreme variety of output rates without significant idle time. A technique known as assembly-line balancing can be used to group the individual tasks performed into workstations so that there will be a reasonable balance of work among the workstations.

Product layout efficiency is often enhanced through the use of line balancing. Line balancing is the assignment of tasks to workstations in such a way that workstations have approximately equal time requirements. This minimizes the amount of time that some workstations are idle, due to waiting on parts from an upstream process or to avoid building up an inventory queue in front of a downstream process.

Advantages of product layouts include:

- *Output.* Product layouts can generate a large volume of products in a short time.
- *Cost.* Unit cost is low as a result of the high volume. Labor specialization results in reduced training time and cost. A wider span of supervision also reduces labor costs. Accounting, purchasing, and inventory control are routine. Because routing is fixed, less attention is required.
- *Utilization.* There is a high degree of labor and equipment utilization.

Disadvantages of product layouts include:

- *Motivation.* The system's inherent division of labor can result in dull, repetitive jobs that can prove to be quite stressful. Also, assembly-line layouts make it very hard to administer individual incentive plans.

- *Flexibility.* Product layouts are inflexible and cannot easily respond to required system changes—especially changes in product or process design.
- *System protection.* The system is at risk from equipment breakdown, absenteeism, and downtime due to preventive maintenance.

Fixed Layout

A fixed-position layout is appropriate for a product that is too large or too heavy to move. For example, battleships are not produced on an assembly line. For services, other reasons may dictate the fixed position (e.g., a hospital operating room where doctors, nurses, and medical equipment are brought to the patient). Other fixed-position layout examples include construction (e.g., buildings, dams, and electric or nuclear power plants), shipbuilding, aircraft, aerospace, farming, drilling for oil, home repair, and automated car washes. In order to make this work, required resources must be portable so that they can be taken to the job for "on the spot" performance.

Due to the nature of the product, the user has little choice in the use of a fixed-position layout. *Disadvantages include:*

- *Space.* For many fixed-position layouts, the work area may be crowded so that little storage space is available. This also can cause material handling problems.
- *Administration.* Oftentimes, the administrative burden is higher for fixed-position layouts. The span of control can be narrow, and coordination difficult.

Combined Layout

Many situations call for a mixture of the three main layout types. These mixtures are commonly called combination or hybrid layouts. For example, one firm may utilize a process layout for the majority of its process along with an assembly in one area. Alternatively, a firm may utilize a fixed-position layout for the assembly of its final product, but use assembly lines to produce the components and subassemblies that make up the final product (e.g., aircraft).

Group / Cellular Layout

Cellular manufacturing is a type of layout where machines are grouped according to the process requirements for a set of similar items (part families) that require similar processing. These groups are called cells. Therefore, a cellular layout is an equipment layout configured to support cellular manufacturing.

Processes are grouped into cells using a technique known as group technology (GT). Group technology involves identifying parts with similar design characteristics (size, shape, and function) and similar process characteristics (type of processing required, available machinery that performs this type of process, and processing sequence).

Workers in cellular layouts are cross-trained so that they can operate all the equipment within the cell and take responsibility for its output. Sometimes the cells feed into an assembly line that produces the final product. In some cases a cell is formed by dedicating certain equipment to the production of a family of parts without actually moving the equipment into a physical cell (these are called virtual or nominal cells). In this way, the firm avoids the burden of rearranging its current layout. However, physical cells are more common.

An automated version of cellular manufacturing is the flexible manufacturing system (FMS). With an FMS, a computer controls the transfer of parts to the various processes, enabling manufacturers to achieve some of the benefits of product layouts while maintaining the flexibility of small batch production.

Some of the advantages of cellular manufacturing include:

- *Cost.* Cellular manufacturing provides for faster processing time, less material handling, less work-in-process inventory, and reduced setup time, all of which reduce costs.

- *Flexibility.* Cellular manufacturing allows for the production of small batches, which provides some degree of increased flexibility. This aspect is greatly enhanced with FMSs.
- *Motivation.* Since workers are cross-trained to run every machine in the cell, boredom is less of a factor. Also, since workers are responsible for their cells' output, more autonomy and job ownership is present.

Other Layouts

In addition to the aforementioned layouts, there are others that are more appropriate for use in service organizations.
These include: Warehouse / Storage layouts, Retail layouts and Office layouts.

With Warehouse / Storage layouts, order frequency is a key factor. Items that are ordered frequently should be placed close together near the entrance of the facility, while those ordered less frequently remain in the rear of the facility. Pareto analysis is an excellent method for determining which items to place near the entrance. Since 20 percent of the items typically represent 80 percent of the items ordered, it is not difficult to determine which 20 percent to place in the most convenient location. In this way, order picking is made more efficient.

Retail Layouts: While layout design is much simpler for small retail establishments (shoe repair, dry cleaner, etc.), retail stores, unlike manufacturers, must take into consideration the presence of customers and the accompanying opportunities to influence sales and customer attitudes. For example, supermarkets place dairy products near the rear of the store so that customers who run into the store for a quick gallon of milk must travel through other sections of the store. This increases the chance of the customer seeing an item of interest and making an impulse buy. Additionally, expensive items such as meat are often placed so that the customer will see them frequently (e.g., pass them at the end of each aisle). Retail chains are able to take advantage of standardized layouts, which give the customer more familiarity with the store when shopping in a new location.

Office layouts must be configured so that the physical transfer of information (paperwork) is optimized. Communication also can be enhanced through the use of low-rise partitions and glass walls.

A number of changes taking in place in manufacturing have had a direct effect on facility layout. One apparent manufacturing trend is to build smaller and more compact facilities with more automation and robotics. In these situations, machines need to be placed closer to each other in order to reduce material handling. Another trend is an increase in automated material handling systems, including automated storage and retrieval systems (AS/AR) and automated guided vehicles (AGVs). There also is movement toward the use of U-shaped lines, which allow workers, material handlers, and supervisors to see the entire line easily and travel efficiently between workstations. So that the view is not obstructed, fewer walls and partitions are incorporated into the layout. Finally, thanks to lean manufacturing and just-in-time production, less space is needed for inventory storage throughout the layout.

Pareto Analysis

Pareto analysis is a statistical technique in decision making that is used for selection of a limited number of tasks that produce significant overall effect. It uses the Pareto principle – the idea that by doing 20% of work, 80% of the advantage of doing the entire job can be generated. Or in

terms of quality improvement, a large majority of problems (80%) are produced by a few key causes (20%).
Pareto analysis is a formal technique useful where many possible courses of action are competing for attention. In essence, the problem-solver estimates the benefit delivered by each action, then selects a number of the most effective actions that deliver a total benefit reasonably close to the maximal possible one.
Pareto analysis is a creative way of looking at causes of problems because it helps stimulate thinking and organize thoughts. However, it can be limited by its exclusion of possibly important problems which may be small initially, but which grow with time. It should be combined with other analytical tools such as failure mode and effects analysis and fault tree analysis for example.
This technique helps to identify the top 20% of causes that need to be addressed to resolve the 80% of the problems. Once the top 20% of the causes are identified, then tools like the Ishikawa diagram or Fish-bone Analysis can be used to identify the root causes of the problems.
The application of the Pareto analysis in risk management allows management to focus on the 20% of the risks that have the most impact on the project.

Steps to identify the important causes using Pareto analysis

- Step 1: Form an explicit table listing the causes and their frequency as a percentage.
- Step 2: Arrange the rows in the decreasing order of importance of the causes (i.e., the most important cause first)
- Step 3: Add a cumulative percentage column to the table
- Step 4: Plot with causes on *x*- and cumulative percentage on *y*-axis
- Step 5: Join the above points to form a curve
- Step 6: Plot (on the same graph) a bar graph with causes on *x*- and percent frequency on *y*-axis
- Step 7: Draw line at 80% on *y*-axis parallel to *x*-axis. Then drop the line at the point of intersection with the curve on *x*-axis. This point on the *x*-axis separates the important causes (on the left) and trivial causes (on the right)
- Step 8: Explicitly Review the chart to ensure that at least 80% of the causes are captured

Concept of Line Balancing

In production, line balancing is useful tool. Line-balancing strategy is to make production lines stretchy enough to absorb external and internal indiscretion. This strategy involves setting a planned rate of production for necessary materials to be fabricated within a particular time frame. Additionally, successful line balancing requires assuring that every line segment's production quota can be met within the time frame using the available production capacity. This is an efficient device to develop the throughput of assembly lines and work cells while decreasing manpower requirements and expenses. Line-balancing is slightly different from assembly line balancing. Assembly line balancing involved the action of assemble different parts together. It involves many production lines while normal Line-balancing may only involve one production line. Assembly Line Balancing is the problem of assigning operations to workstations along an assembly line, in such a way that the assignment be best in some sense. Since introduction of assembly lines by Henry Ford, Line-balancing has been an optimization problem of important industrial importance. The efficiency difference between an optimal and a sub-optimal assignment can yield economies reaching huge amount per year. Line balancing technique was used normally in assembly line of the automotive industry which is called ALB. Most of the Small and Medium Industries do not use line balancing method in the production line.

There are two types of line balancing that include Static Balance and Dynamic Balance. Static Balance denotes long-term differences in capacity over a period of several hours or longer. Static imbalance results in underutilization of workstations, machines and people. Dynamic Balance refers to short-term differences in capacity such as over a period of minutes, hours at most. Dynamic imbalance occurs from product mix changes and difference in work time dissimilar to product mix.

The intent of Line balancing is to match the output rate to the production plan. This will help organization to make sure on-time delivery and avoids build-up of surplus inventory. Johnson articulates the problem of line balancing as "a set of non-divisible tasks to be performed, each task has a known deterministic performance time. A partial ordering of tasks by precedence constraints is specified. The problem is to assign these tasks to assembly stations, so that the necessary number of station is minimized." Line balancing is usual practice to resolve problems occurred in assembly line. It is a technique to reduce imbalance between workers and workloads in order to accomplish required run rate (H.Jay and R.Barry, 2006). This can be performed by equalizing the amount of work in each station and assign the smallest number of workers in the particular workstation. Here the job is divided into small portion called "job element". The objective is to uphold production at an equal rate (G. Andrew, 2006).

Line balancing operates under two circumstances:

1. **Precedence Constraint:** Products cannot progress to other station if it doesn't complete necessary task at that station. It should not across other station because certain part needs to be performed before other activities.
2. **Cycle time Restriction:** Cycle time is maximum time for products spend in every workstation. Different workstation has different cycle time.

Objective of Line Balancing

Following are major objectives of Line balancing procedure. It is used to:

i. Manage the workloads among assemblers.
ii. Recognize the location of bottleneck.
iii. Decide number of workstation.
iv. Decrease production cost.
v. Assigning task to each work station in such a way that there is little idle time.

Terms in Line Balancing Technique

There is range of terms used in assembly line balancing system. Each of them has their meaning and purposes.

I. **Cycle Time:** Maximum amount of time allowed at each station. This can be found by dividing required units to production time available per day. This is the time expressed in minutes between two simultaneous products coming of the end of production line. Gaither and Fraizer (2001) described that cycle time demonstrates how often the production line can generate the product with current resources and staffing. It is a precise indicator to signify how the line is currently set up to run. The calculation of cycle time takes into consideration of the entire production quantities. If multiple lines are producing the same product, then the composite cycle time is less than the actual lapse time of any individual line.
II. **Lead Time:** Summation of production times along the assembly line.
III. **Bottleneck:** Delay in transmission that slow down the production rate. This can be overcome by balancing the line.

IV. **Task Precedence:** It is the sequence by which tasks are carried out. It can be represented by nodes or graph. In assembly line the products have to obey this rule. The product cannot be moved to the next station if it doesn't complete at the previous station.

V. **Idle time:** A period when system is not in used but is available.

VI. **Productivity:** Defined as ratio of output over input. Productivity depends on several factors such as workers skills, jobs method and machine used.

VII. **Takt times:** The time needed by competent worker or unattended machine to perform a task. This is usually expressed in minutes. Heizer and Render (2010) stated that takt time is pre-requisite procedure in doing line balancing task. Takt time is the swiftness of production that aligns production with client demand. It shows how fast the need to manufacture product in order to fill the customer orders (Vome lean Briefs, 2006). Producing faster than takt time results in overproduction which is a type of waste whereas producing slower than takt time results in bottlenecks where the customer orders may not be fulfilled in time. There are numerous benefits of using takt time (Heizer and Render, 2010). These include,

  i. Achieve a steady and continuous flow of production.
  ii. Eliminate the waste of overproduction by producing actual customer demand.
  iii. Improves accuracy of planning.
  iv. Encourage the development of standardize work instructions, promoting quality and efficiency.
  v. Set real time targets for production that shows operators exactly where their work output should be at any given point of time.
  vi. Establish what-if scenario for customer demand based on flexible manning.

VIII. **Work station:** A physical area where a worker with tools / one or more machines or unattended machines such as robot perform specific task in a production line (Gaither and Fraizer, 2001).

IX. **Downtime:** Downtime explained as the time that is non value added (Chase, et al. 2000). It is often associated with the seven wastes as under:

  a. Defects: Defect is direct costs of a company.
  b. Overproduction: One of the severe wastes discourages a smooth flow of goods and services, which may lead to unnecessary lead and storage time. It will lead to the defects which cannot be detected earlier and then the products may deteriorate. It will also lead to excess work-in-progress stocks.
  c. Waiting: It occur when the goods are not moving or being worked on. It affects both goods and workforce where the waiting time should be used for some value added activities such as training and maintenance.
  d. Transportation: Any movement in factory can be considered as waste. Double handling and excessive movements are likely to cause damage and deterioration with the distance of communication between processes proportional to time taken. It takes to feedback reports of poor quality and needs corrective action.
  e. Unnecessary inventory: There is a problem with extra inventory. Inventory will increase the lead time, preventing quick identification of problems and increasing space. Significant storage costs are wasted which absolutely lower the competitiveness of the organization of value stream.
  f. Unnecessary motion: Involve the ergonomics of production where operation might have to stretch, bend and pick up when these actions actually could be avoided. It not only tires the workers but also leads to poor productivity.

g. Inappropriate processing: Over-complexity of a process discourages ownership and encourages the employees to over produce to recover the large investment in the complex machines. It encourages poor quality and takes corrective action.

Steps in Solving Line Balancing

There are four steps in solving line balancing described by G. Andrew (2006).

I. Drawing Precedence Diagram: Precedence diagram needs to be drawn to demonstrate a relationship between workstations. Certain process begins when previous process was done.

II. Determining Cycle Time: Cycle time is longest time allowed at each station. This can be expressed by this formula:

$$\textbf{Cycle time} = \frac{\textbf{Available time}}{\textbf{Desired output}}$$

This means the products needs to leave the workstations before it reaches its cycle time.

III. Assigning tasks to workstation: The tasks distributions should be taken after completing a time cycle. It's good to allocate tasks to workstation in the order of longest task times.

$$\textbf{Number of work Stations} = \frac{\sum \textbf{ Task Time}}{\textbf{Desired Actual Time}}$$

IV. Calculating an Efficiency Line: This is done to find effectiveness of the line. The formula is given by:

$$\textbf{Line Efficiency} = \frac{\textbf{Sum of task times}}{\textbf{Number of workstation X Desired cycle time}}$$

Computerized Line Balancing

Line balancing manually becomes unwieldy as the problem grows in size. There are software packages that will balance large line rapidly. They use various heuristic to balance the line at an acceptable level of efficiency. There are two types of line balancing heuristics which include incremental utilization heuristic and longest task time heuristic. In incremental utilization heuristic, tasks are added to each work station in order of task precedence one at a time until utilization is hundred percent. Longest task time heuristic adds tasks to work station one at a time in the order of task precedence. If there is choice of multiple tasks, longest task is added. It can only be used when each and every task time is less than or equal to the cycle time. There can be no duplicate work stations.

To summarize, a line balance is the modification of the capacity of a line ladder to a particular model mix. The capacity of the line hierarchy is established by the number of tasks and the number of individual capacities in the line segments. The model mix is determined by a number of materials, the rate of the materials and the rate routings, according to which the materials are produced. It is described by experts that line balancing is levelling of the workload across all operations in a line to eliminate blockage and surplus capacity.

Concept of Assembly Line Balancing – Introduction

An assembly line is a type of industrial production in which prefabricated, interchangeable parts are used to assemble a finished product. The most basic assembly system consists of a simple conveyor belt which carries the product, such as a toy, through a series of work stations until it is finished. More complex lines include feeder belts to carry parts to work stations along the line, used for building cars and other complex equipment. The development of the assembly line revolutionized manufacturing, and contributed to the substantial fortunes of several major players in the Industrial Revolution.

Before the advent of the assembly line, when a commercial good was manufactured, it was usually created by hand, from individually fabricated parts. Factory production was limited by available floor-space, as only so many products could be made at once, and workers tended to see a project through from beginning to end. By the mid-nineteenth century, many companies in the food industry had begun to set up something resembling an assembly line to make the process more efficient, but it was not entirely streamlined. Goods like the early automobile and steam engines were still made by hand.

Concept with Examples

Assembly line balancing can be loosely defined as the process of optimizing an assembly line with regard to certain factors. Configuring an assembly line is a complicated process, and optimizing that system is an important part of many manufacturing business models. Maintaining and operating one is often quite costly, as well. The main focus of balancing is usually to optimize existing or planned assembly lines to minimize costs and maximize gains.

For instance, a car company might want to alter its assembly line layout in order to speed production. The company might consider the number of work stations a manufactured item must pass before it is complete and the time required at each point. Of course, each stage of this process requires a certain length of time, and the allotted time to finish a process, the number of workers, or the resource demand may also be considered, based on the specific manufacturing requirements. The possible results of an assembly line balancing process might be maximized efficiency, minimized time to finish a process, or minimized number of work stations necessary within a certain time frame. Each manufacturing process might be quite different from another, so a company balancing unique workloads must work within the constraints and restrictions affecting its specific assembly line.

To optimize very specific operations, balancing an assembly line might require different methods, some of which include equations and algorithms concerning specific aspects of the manufacturing process. Complex manufacturing processes, such as making automobiles in large quantities, can be broken down into smaller parts, such as individual task times or the resource demands for each machine. This might be especially helpful in manufacturing processes that require the consideration of many variables, such as customized vehicles. Assembly line balancing can also guide decision-making based on the multitude of variables that can affect the manufacturing process.

Many times, this process might be used as support in decision making by offering many different models and types of data. For instance, the manager of a car manufacturer might analyze his or her operation based on the concepts of assembly line balancing using many different variables, and then make a decision based on that analysis. While this might provide the best response to an optimization effort based on one set of variables, the final decision may rest on multiple mathematical perspectives of the same problem.

Part – III of III

Facility Capacity – Introduction

The production system design planning considers input requirements, conversion process and output. After considering the forecast and long-term planning organization should undertake capacity planning.

Capacity Planning – Definition

Capacity is defined as the ability to achieve, store or produce. **For an organization, capacity would be the ability of a given system to produce output within the specific time period**. In operations, management capacity is referred as an amount of the input resources available to produce relative output over period of time.

In general, terms capacity is referred as maximum production capacity, which can be attained within a normal working schedule.

Capacity planning is essential to be determining optimum utilization of resource and plays an important role decision-making process, for example, extension of existing operations, modification to product lines, starting new products, etc.

Strategic Capacity Planning

A technique used to identify and measure overall capacity of production is referred to as strategic capacity planning. Strategic capacity planning is utilized for capital intensive resource like plant, machinery, labor, etc.

Strategic capacity planning is essential as it helps the organization in meeting the future requirements of the organization. Planning ensures that operating cost are maintained at a minimum possible level without affecting the quality. It ensures the organization remain competitive and can achieve the long-term growth plan.

Capacity Planning Classification

Capacity planning based on the timeline is classified into three main categories long range, medium range and short range.

1. **Long Term Capacity:** Long range capacity of an organization is dependent on various other capacities like design capacity, production capacity, sustainable capacity and effective capacity. Design capacity is the maximum output possible as indicated by equipment manufacturer under ideal working condition.

   Production capacity is the maximum output possible from equipment under normal working condition or day.

   Sustainable capacity is the maximum production level achievable in realistic work condition and considering normal machine breakdown, maintenance, etc.

   Effective capacity is the optimum production level under pre-defined job and work-schedules, normal machine breakdown, maintenance, etc.
2. **Medium Term Capacity:** The strategic capacity planning undertaken by organization for 2 to 3 years of a time frame is referred to as medium term capacity planning.
3. **Short Term Capacity:** The strategic planning undertaken by organization for a daily weekly or quarterly time frame is referred to as short term capacity planning.

Goal of Capacity Planning

The ultimate goal of capacity planning is to meet the current and future level of the requirement at a minimal wastage. The three types of capacity planning based on goal are lead capacity planning, lag strategy planning and match strategy planning.

Factors Affecting Capacity Planning

Effective capacity planning is dependent upon factors like production facility (layout, design, and location), product line or matrix, production technology, human capital (job design, compensation), operational structure (scheduling, quality assurance) and external structure (policy, safety regulations)

Forecasting v/s Capacity Planning

There would be a scenario where capacity planning done on a basis of forecasting may not exactly match. For example, there could be a scenario where demand is more than production capacity; in this situation, a company needs to fulfill its requirement by buying from outside. If demand is equal to production capacity; company is in a position to use its production capacity to the fullest. If the demand is less than the production capacity, company can choose to reduce the production or share it output with other manufacturers.

Concept of Design Capacity, Effective Capacity, Utilization and Efficiency Capacity Planning (CP) and Capacity Requirement Planning (CRP)

Capacity is the throughput or number of units a facility can hold, receive, store, or produce in a period of time. Design capacity is the theoretical maximum output of a system in a given period under ideal conditions. For many companies designing capacity can be straightforward, effective capacity is the capacity a firm expects to achieve given its current operating constraints. It is often lower than design capacity because the facility may have been designed for an earlier version of the product or a different product mix than is currently being produced.

Capacity available is the capacity of a system or resource to produce a quantity of output in a given time period. It is affected by:

(1) product specifications change, the work content (work required to make the product) will change, thus affecting the number of units that can be produced,

(2) product mix where the product has its own work content measured in the time it takes to make the product. If the mix of products being produced changes the total work content (time) the mix will change,

(3) plant and equipment which relates to the methods used to make the product, and

(4) work effort, which relates to the speed or pace at which the work is done; if the workforce changes pace, perhaps producing more in a given time, the capacity will be altered.

To measure capacity we need units of output. If the variety of products produced at a work center or in a plant is not large, it is often possible to use a unit common to all products. We also need standard time which is expressed as the time required for making the product using a given method of manufacturing.

Utilization is the available time that is the maximum hours we can expect from the work center; the percentage of time that the work center is active.

Efficiency is how the work center is used in comparison with standard.

Available time is the number of hours a work center can be used.

Available time = the number of machines x the number of workers x the hours of operations.

The other measures:

1. Utilization = Actual output / Design capacity, this is a percent of design capacity. Also measured as:

   Utilization = (Hours actually worked / available hours) x 100%
2. Efficiency = Actual output / Effective capacity, this is an actual output as a percent of effective capacity. Also measured as:

   Efficiency = (Actual rate of production / Standard rate of production) x 100%

These measures are important for an operations manager, but they often need to know the expected output of a facility or process.
Also referred to as rated capacity:

Rated Capacity = (Available time) x (Utilization) x (Efficiency)

Capacity considerations for a good capacity are:

1. Forecasts demand accurately
2. Understand the technology and capacity increments
3. Find the optimum operating level (volume)
4. Build for change

Even with good forecasting and facilities built in to the forecast, there may be a poor match between the actual demand that occurs and available capacity. There are some options for managing demand:

1. Demand exceeds capacity by raising prices, or scheduling long lead times.
2. Capacity exceeds demand by price reductions or aggressive marketing.
3. Adjusting to seasonal demands or cyclical pattern of demands.
4. Tactics for matching capacity to demand by
   a. Making staffing changes (increasing or decreasing the number of employees or shifts)
   b. Adjusting equipment (purchasing additional machinery or selling or leasing out existing equipment)
   c. Improving processes to increase throughput
   d. Re-designing products to facilitate more throughput
   e. Adding process flexibility to better meet changing pr5oduct preferences
   f. Closing facilities

Capacity Expansion Strategies

There are three basic capacity strategies used by different organizations when they consider increased demand; lead capacity strategy, lag capacity strategy, and the match capacity strategy.

1. Lead Capacity Strategy

As the name suggests, the lead capacity strategy adds capacity before the demand actually occurs. Companies often use this capacity strategy, as it allows a company to ramp up production at a time when the demands on the manufacturing plant are not so great. If any issues occur during the ramp up process, these can be dealt with so that when the demand occurs the manufacturing plant will be ready.
Companies like this approach as it minimizes risk. As customer satisfaction becomes an increasingly important, businesses do not want to fail to meet delivery dates due to lack of capacity. Another advantage of the lead capacity strategy is that it gives companies a competitive advantage. For example, if a toy manufacturer believes a certain item will be a popular seller for the Christmas

period, it will increase capacity prior to the anticipated demand so that it has product in stock while other manufacturers would be playing “catch up.”
However, the lead capacity strategy does have some risk. If the demand does not materialize then the company could quickly find themselves with unwanted inventory as well as the expenditure of ramping up capacity unnecessarily.

2. Lag Capacity Strategy
This is the opposite of the lead capacity strategy. With the lag capacity strategy, the company will ramp up capacity only after the demand has occurred. Although many companies follow this strategy success is not allows guaranteed.
However, there are some advantages of this method. Initially, it reduces a company’s risk. By not investing at a time of lesser demand and delaying any significant capital expenditure, the company will enjoy a more stable relationship with their bank and investors. Secondly, the company will continue to be more profitable than companies who have made the investment with increased capacity. Of course, the downside is that the company would have a period where the product was unavailable until the capacity was finally increased.

3. Match Capacity Strategy
The match capacity strategy is one where a company tries to increase capacity in smaller increments to coincide with the increases in volume. Although this method tries to minimize the over and under capacity of the other two methods, companies also get the worst of the two, where they can find themselves over capacity and under capacity at different periods.
Example: In order to optimize ones supply chain, one needs to be able to supply their customers with what they want, when they want it - and accomplish that by spending as little money as possible. By understanding and taking advantage of ones facility's capacity, one can accomplish that goal.

Capacity Planning Process (Services)
Any manufacturing facility benefits from the financial and logistical capabilities of capacity planning, no matter the size of the business. It is a method of management that features the efficient use of resources through a projection of production needs. Capacity planning can apply to a company’s computer network, storage, workforce maintenance, and product manufacturing.
Planning for capacity breaks down into three steps: determining service level requirements, analyzing current capacity, and planning for the future. To gain a better grasp on how each applies to the planning process, let us take a closer look at each one individually.

Step – 1. Determining Service Level Requirements
In this step, a business breaks down work into categories; it also quantifies users’ expectations for how that work gets done. Within this first step exist three stages: establishing workloads, determining the unit of work, and setting service levels.
Businesses choose to organize workloads by either who is doing the work, the type of work performed, or the work process. They then create a definition of satisfactory service for each load. Whereas a workload measures the resources needed to accomplish the work, a unit of work measures a quantity of work completed.
A "service level agreement" lays out the acceptable parameters between the provider and the consumer.

Step – 2. Analyze Current Capacity

Businesses take an in-depth look at their current production schedule to evaluate capacity. They analyze each workload and system as a whole, following these steps:

- Compare the measurements of any items referenced in service level agreements with their objectives
- Check the usage of the various resources of the system
- Take a look at the resource utilization for each workload and decipher which workloads are the major users of each resource
- Determine where each workload spends its time. This provides insight into which resources take the greatest portion of response time for each workload

Step – 3. Plan for the Future

Finally, after analyzing current capacity, it's time to plan for the future. Base a plan on forecasted processing requirements to prevent overwhelming the system. In order to accomplish this task, you need to know the amount of incoming work expected over the coming quarters. Then, configure the optimal system for satisfying service levels over this period.

These three steps in capacity planning help your organization prepare for future growth. Optimal configuration ensures you meet service level requirements while only purchasing what you need to get the work completed. This process facilitates a manufacturing process' well-being. It offers your company an opportunity to optimize its production process and ready itself for the future.

Service Operations vs. Manufacturing Planning

Both service operations and manufacturing operations are in the business of satisfying customers, and that requires organization and planning. While the mechanisms and inputs for creating customer value are very different, the essence of planning is the same: Put the right things together at the right time to meet customer demand. Planning for manufacturing organizations is typically more complex due to the physical movement and processing of material.

Customer Demand

Both service and manufacturing companies have goals of satisfying customer demand. Maintaining sufficient capacity to meet demand is one of the great challenges of operations management. Demand planning depends on some type of forecast; in some industries, customers will partner with a company to help create a forecast. In most cases, forecasts are generated by analyzing historical demand, plus marketing and sales forecasts based on current and expected future conditions. The goal of a forecast is to prepare to meet the right amount of customer demand. Over-forecasting results in waste, and under-forecasting creates back orders and customer dissatisfaction.

Resource Planning

Everything a customer pays for is the result of a process. Whether you're building cars for sale or cleaning homes for a fee, there is a process required to go from start to finish. Resource planning is the discipline of making sure all the necessary inputs are present at the right time so the process that makes your company money can be completed. A good start for identifying the resources needed is a SIPOC chart. SIPOC (supplier, input, processing, output, customer) spells out exactly what's needed to complete each step of a process, who must supply it, what processing will occur, and who the customer is -- all the way to the end customer.

Manufacturing Operations

Manufacturing organizations must plan to have materials, personnel, facilities and equipment all ready at the right time to produce finished goods for sale. Many manufacturing companies use a version of Manufacturing Resource Planning (MRP-II) software to help schedule all the required resources at the right time. The key difference that tends to make manufacturing planning more complex than service planning is the addition of materials and physical processing. Many physical processes have fixed time and space requirements that can't be compressed.

Service Operations

While a service organization will also require some equipment and supplies, its key planning decisions surround processing times. The primary input to most service processes is labor. Whether it's an auto mechanic tuning an engine or an insurance agent preparing an application for coverage, the constraint is the amount of time it takes to process each task. The constraining or "bottleneck" process is often a department with limited personnel or resources, as opposed to a mechanical process with a fixed time or capacity constraint. As such, it usually requires less investment to add capacity to a service organization to satisfy more customer demand.

Value Stream Map

Value stream mapping is a method of visually representing the flow of a process from beginning to end, and separating the parts of the process that add value from those which do not. Both service and manufacturing companies have value streams, although they look much different. Completing a value stream map analysis of a business -- especially a new business -- is an excellent tool for understanding and improving the flow of its processes and, therefore, to satisfy more customers, faster and with less cost. Read more about Value Stream Mapping in the Resources section.