Capacity planning: Concept, Types

Capacity planning refers to determining what kind of labor and equipment capacities are required and when they are required. Capacity is usually planned on the basis of labor or machine hours available within the plant. Thus, capacity planning is planning for quantity or scale of output.

There are four major considerations in capacity planning:

1. Level of demand
2. Cost of production
3. Availability of funds
4. Management policy.

Production has no meaning unless its products can be sold at a remunerative price. Generally, the capacity of plant is limited by the level of current demand. Stable demand makes the task of capacity planning simple while fluctuations in demand create problems concerning the acquisition of resources and matching them up with demand levels. Estimation of demand is, therefore, the first step in capacity planning. Size of the market depends upon the sales potential rather than on the geographical areas.

Importance of Capacity Planning

Capacity planning is important due to the following reasons:

1. Capacity limits the rate of output. Therefore, capacity planning determines the ability of an enterprise to meet future demand for its products and services.
2. Capacity influences the operating costs. Capacity is determined on the basis of estimated demand. Actual demand is often different from estimated demand. As a result, there arises excess capacity or under capacity. Excess or idle capacity increases the cost per unit of output. Whereas under capacity results in the loss of sales.
3. Capacity decisions leave a direct impact on the amount of fixed investment made initially.
4. Capacity decisions result in long-term commitment of funds. Such long-term decisions cannot be reversed except at major costs.

The following concepts of capacity are involved in capacity planning:

1. **Design Capacity**: It refers to the maximum output that can possibly be produced in a given period of time. It is the ideal situation.
2. **Effective Capacity**: Refers to the maximum possible output, given the changes in product mix, machine maintenance, schedulingand operating problems, labour problems, etc. It is usually less than the design capacity.

3. **Actual Output**: It is the rate of output actually achieved. It cannot exceed effective capacity due to machine breakdowns, labour absenteeism, irregular supply of raw materials, unusual delay in supply of equipment, power breakdown, etc.

The effectiveness of a production system (system effectiveness) can be measured in two ways:

1. Efficiency which is the rate of actual output to effective output, and
2. Utilization which implies the rate of actual output to the design capacity.

Capacity Planning Classification

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

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.

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.

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.

Plant capacity

1. Facilities

The design of production facilities is the most important determinant of effective capacity. Design includes the size and also the provision for expansion of the facilities. Design facilities should be such that the employees should feel comfortable at their work place. Location factors such as distance from the market, supply of labour, transport costs, energy sources are also important. Layout of the work area determines how smoothly the work can be performed. Environmental factors such as lighting, ventilation, etc., influence the effectiveness with which employees can perform the assigned work.

2. Products or Services

Design of the company's products or services exerts a significant influence on capacity utilization. When more uniform is the output, greater can be the standardization of materials and methods and greater can be the utilization of capacity. For instance, a restaurant that offers a limited menu, can prepare and serve meals at a faster rate. Product mix should also be considered because different products have different rates of output.

3. Process

Quantity capacity of a process is the obvious determinant of effective capacity. But if quantity of output does not meet the quality standards, the rate of output is reduced due to the need for inspection and rework activities.

4. Human factors

Job design (tasks that comprise a job), nature of the job (variety of activities involved), training and experience required to perform the job, employee motivation, manager's leadership style, rate of absenteeism and labour turnover are the main human factors influencing the rate of output.

5. Operational Factors

Materials management, scheduling, quality assurance, maintenance policies and equipment breakdowns are important determinants of effective capacity. Late delivery and low acceptability of materials will reduce effective capacity. Inventory problems are a major hurdle in a capacity utilization. Similarly, when the alternative equipment have different capabilities there may be scheduling problems.

6. External Factors

Product standards (minimum quality and performance standards), pollution control regulations, safety requirements and trade union attributes exercise tremendous influence on effective capacity. Generally, the external factors act as constraints in capacity utilization.

Capacity Planning Strategies

There are three primary strategies companies use to perform capacity planning. Each comes with its own set of advantages and drawbacks, so you'll need to think carefully about which one is most appropriate for your company:

- **Lead Strategy**: The Lead Strategy is the most aggressive of the three approaches to capacity planning. Here, the company increases its production capacity in advance of anticipated increases in demand. Some companies use the Lead Strategy as a way to lure customers away from competitors, especially if a competitor is vulnerable to inventory shortages when demand skyrockets. The big risk with the Lead Strategy is that the anticipated increase in demand never materializes and you are stuck with excess inventory.
- **Lag Strategy**: The Lag Strategy is much more conservative than the Lead Strategy. Instead of increasing capacity in anticipation of suspected increases in demand, the Lag Strategy responds to actual increases in demand by boosting capacity after the operation is running at full steam. Although you won't accumulate excess inventory, the time it takes to ramp up production can result in the loss of customers to the competition.
- **Match Strategy**: The Match Strategy is the middle road between the Lead and Lag Strategies. Rather than substantially boosting capacity based on expected or actual increases in demand, the Match Strategy emphasizes small, incremental modifications to capacity based on changing conditions in the marketplace. Even though this strategy takes more effort and is harder to accomplish, it is much more risk-averse than other capacity planning options.

Routing Procedure

Routing is the purpose of the pathway of movement of raw materials through various machines and operations from the beginning of the manufacturing process to the completion of product in its finished form. It is laying out the sequence of machines, process, and operations that are the most desirable and efficient. It is determining the exact route or path a product has to follow right from raw material till its completion.

Routing is a systematic process. The routing procedure for a new product or part may consist of the following steps:

1. **Determination of what to make and what to buy**

   An analysis of the product is made to determine whether to manufacture a component in the factory or to purchase it from outside.

2. **Determination of material requirements**

Each item in the product line is divided into its components and parts required for its manufacturing. Routing section prepares a parts list which includes the drawings, specifications, standards of quality, and identification symbols of parts. Its combined with a bill of materials. This will show each part name, quantity required and the kind and amount of material required for each part. From this list, the inventory control section can determine the adequacy of the materials in stock or on order. To determine the material requirements, the " parts short list" is also prepared. It lists only those parts which are short and hence must be obtained to complete the product.

3. Determination of manufacturing operations and their sequence

Routing section now analyses the production standards and estimates together with data on machine capacities and characteristics. From these facts, it establishes the operations necessary to manufacture the article and lists them in their proper sequence on the route sheet. The route sheet indicates for each operation its standard process time, the type of a number of machines used, materials and tools required.

4. Determination of lot sizes

Routing section also determines the number of units to be produced in any one lot. If products are made to customer's order, the lot size is generally equal to it. Where production is done to stock replacing depleted inventories, the lot size to be manufactured will usually be based on the principle of "economic lot quantities". Where production is done on a weekly or monthly schedule, the quantity to be manufactured for the period will be based on the influx or backlog of sales orders subject to any limitations in the manufacturing capacity.

5. **Determination of scrap factors**

In most production processes, it is reasonable to expect some scrap. This happens because of manufacturing defects or wastage these defective pieces are called scraps. Routing section should take this scrap factor into account when determining lot size of various components parts of the final assembly, it is important to know where scrap is most likely to occur- whether it occurs progressively or all at once after a certain operation. Hence, it is necessary to establish a standard scrap factor at every stage of production. The scrap factors can be estimated on the basis of experience or scrap history.

6. **Determination of the cost of the article**

The routing section may also contribute to cost estimating, although it is the prime responsibility of the cost **mange accounting** department. Cost of the component parts and final product largely depend on the materials and manpower required for manufacturing. Direct material and labor costs are computed, and specific and general indirect expenses are allocated to the product to arrive at the cost estimate

7. **Organization of production control forms**

The types of production have much influence upon the forms required by the plant departments. production control is organized around schedule from in case of mass manufacturing. Job order manufacturing requires the use of a number of control forms such as job cards, shop orders, labor cards, for performing the operations. It should be remembered that production control forms in themselves are costly to use. Hence, these should be reduced to minimum consistent with the degree of control desired.

Material flow pattern

"Flow Pattern" means the system to be adopted, for the movement of raw materials, from the beginning and up to the end of manufacturing. The overall-objective of the 'Flow Pattern' is to plan for the economical movement of the raw materials throughout the plant.

The Flow Pattern affects the following:

(i) Materials handling cost.

(ii) Amount of work-in-process.

(iii) Capital and space tied up by work-in-process.

(iv) Length of total production time.

(v) The rate of the performance and coordination of operations.

(vi) Amount of physical and mental strain on the operators.

(vii) Supervision and control mechanisms.

Quite often a plant layout design starts with the flow system around which services and other facilities are added and building design are modified accordingly but sometimes the flow must be adopted to suit existing buildings.

Factors Governing Flow Pattern:

(i) External transport facilities.

(ii) Number of products to be handled.

(iii) Number of operations on each product.

(iv) Number of units to be processed.

(v) Number of sub-assemblies made up ahead of assembly line.

(vi) Size and shape of available land.

(vii) Necessary flow between work areas.

Types of Flow Pattern:

The flow patterns can be classified into horizontal and vertical. The horizontal flow system is adopted on a shop floor while vertical flow is adopted where material has to move in a multi-storey building.

1. **Horizontal Flow Lines:**

There are five basic types of horizontal flow line:

(i) I-Flow or Line Flow.

(ii) L-Flow.

(iii) U-Flow.

(iv) S-Flow.

(v) O-Flow.

2. **Vertical Flow Lines:**

This type of flow is for multi-storey buildings. In order to have the materials handling systems and control mechanisms to operate effectively, following six basic aspects of vertical flow systems are in use.

(i) Processing downward or upward.

(ii) Centralized or Decentalized elevation.

(iii) Unidirectional or Retractional flow.

(iv) Vertical or Inclined flow.

(v) Single or Multi-flow.

(vi) Flow between buildings.

(i) Processing Downwards or Upwards:

In downward processing, the materials are fed from the top floor and in upward processing the materials are fed from the bottom floor while the finished product is received at the top floor.

In processing downward much gravity handling system such as roller lines, chutes, pipes, buckets, hand operated lifts etc. can be used. These are economical in installation, operation, maintenance etc.

(ii) Centralized or Decentralized Elevation:

In a centralized elevation all the material handling devices are installed at one central place of the building. Therefore, this system is economical in supervision and maintenance. It sometimes reduces installation cost also. This method is usually employed when the flow on each floor is a U-flow.

A decentralized elevation method is more costly in installation, maintenance and space, but by this method handling on each floor can be greatly reduced and more flexibility in design of the flow lines is possible.

(iii) Unidirectional or Retractional Flow:

In retractional type of flow, material has to come back on the floor which had already passed previously. This is done purposely to achieve better utilisation of available space and machines.

(iv) Vertical or Inclined Flow:

This type of flow is more economical and carried on with material handling devices such as elevators, chutes, buckets etc. In addition, inclined flow may also be carried out by conveyor belts as used in coal handling plants and chain system to move boiler grates etc. and similar other tasks.

(v) Single or Multi-flow:

In a single flow, there is only one flow line of materials while in multi-flow, there will be several flow lines and all these feed one assembly line.

(vi) Flow between Buildings:

When one production line is executed in several adjacent buildings, the flow of goods may be achieved either on an elevated floor or a ground floor. Ground floor is cheaper but requires more handling than an elevated floor. Elevated flow frees the ground for traffic and storage purposes.

Scheduling: Production scheduling

Production scheduling has become a must for manufacturing operations that wish to take their production facility to the next level. Production scheduling is the allocation of resources, events, and processes to create goods and services.

A business can adjust its production scheduling based on the availability of resources and client orders. The goal of a production schedule is to adequately balance customer needs with the resources that are available whilst operating in a cost-effective manner.

4 Components of Production Scheduling

The four components of production scheduling include the following:

- **Planning:** The planning component of production scheduling is by far the most important. The planning component pertains to deciding in advance what should be done in the future – which is the most crucial step in production scheduling. Without a plan, production scheduling can not even begin or take place. Preparing a plan through charts, production budgets, or various others visual representations can provide a sound basis for steps down the road pertaining to production.
- **Routing:** Production routing is the process that pertains to determining the route or path that a product must follow. This route entails the path from raw materials until it transform into a finished product. The main objective of this component is to locate and perform the most economical and enhanced sequence of operations in the production process.
- **Scheduling:** Scheduling coincides with the time and date that the operation must be completed. Scheduling is an essential and crucial portion of production scheduling and lays the foundation and groundwork for all of the steps within the production process. There are three types of scheduling that

an operation utilizes, such as master scheduling, manufacturing or operation scheduling, and retail operation scheduling. Overall, scheduling is key for a manufacturing operation to proceed.

- **Dispatching:** Dispatching relates to the process of initiating production with a preconceived production plan. Dispatching is concerned with giving a practical shape to an overall production plan. This will also include issuing any orders and instructions and other important information pertaining to production.

Machine Scheduling

Single-machine scheduling or single-resource scheduling is the process of assigning a group of tasks to a single machine or resource. The tasks are arranged so that one or many performance measures may be optimized.
Performance measures
The performance measures of the tasks in the single machine scheduling problem include:
Tardiness – {\displaystyle max(0,receipt\;date-due\;date)}max(0, receipt\;date – due\;date)
Earliness – {\displaystyle max(0,due\;date-receipt\;date)}max(0, due\;date – receipt\;date)
Lateness – {\displaystyle receipt\;date-due\;date}receipt\;date – due\;date
Flowtime – {\displaystyle end\;date-start\;date}end\;date – start\;date
Solution techniques
Many solution techniques have been applied to solving single machine scheduling problems. Some of them are listed below.
Heuristics
Shortest processing time (SPT)

The SPT schedule is optimal if the objective is to minimize the average flowtime.
SPT-order is an order based on processing time. The sequence of remaining jobs in sorted based on non-decreasing processing time.

Earliest due date (EDD)

The EDD schedule is optimal if the objective is to minimize the maximum tardiness.
EDD-order is an order based on due date. The sequence of remaining jobs in sorted based on non-decreasing due date.
Note: “Lateness” is any deviation from the due date. Positive lateness is “tardiness,” negative lateness is “earliness”

Hodgson’s algorithm

Hodgson’s algorithm gives an optimal solution if the objective is to minimize the number of jobs with tardiness greater than zero.

Computational
• Genetic algorithms
• Neural networks
• Simulated annealing

• Ant colony optimization
• Tabu search

Line Balancing

"Line Balancing" in a layout means arrangement of machine capacity to secure relatively uniform flow at capacity operation.

It can also be said as **"a layout which has equal operating times at the successive operations in the process as a whole".** Product layout requires line balancing and if any production line remains unbalanced, machinery utilization may be poor.

Let us assume that there is a production line with work stations x, y and z. Also assume that each machine at x, y and z can produce 200 items, 100 items, and 50 items per hour respectively. If each machine were to produce only 50 items per hour then each hour the machines at x and y would be idle for 45 and 30 minutes respectively. Such a layout will be unbalanced one and the production line needs balancing.

As an another example, a bakery would not be in balance, if the oven continuously baked loaves at the rate of 600 per hour and wrapping machine could only wrap 400 loaves per hour Hence the production line requires balancing.

Methods of Line Balancing:

(i) The one possibility in the right direction, as far as balancing the line is concerned, would be to increase the output.

(ii) The second possibility is that another product may be sent close to the first one so that some idle machines may be used jointly.

(iii) The third possibility may be to estimate the output of the last work station. This can be taken as the minimum output of all the intermediate work stations.

A balanced layout eliminates bottleneck operations as well as preventing the unnecessary duplication of equipment capacity. Line balancing is a major consideration in layout because a lack of balance can most easily hinder the production.

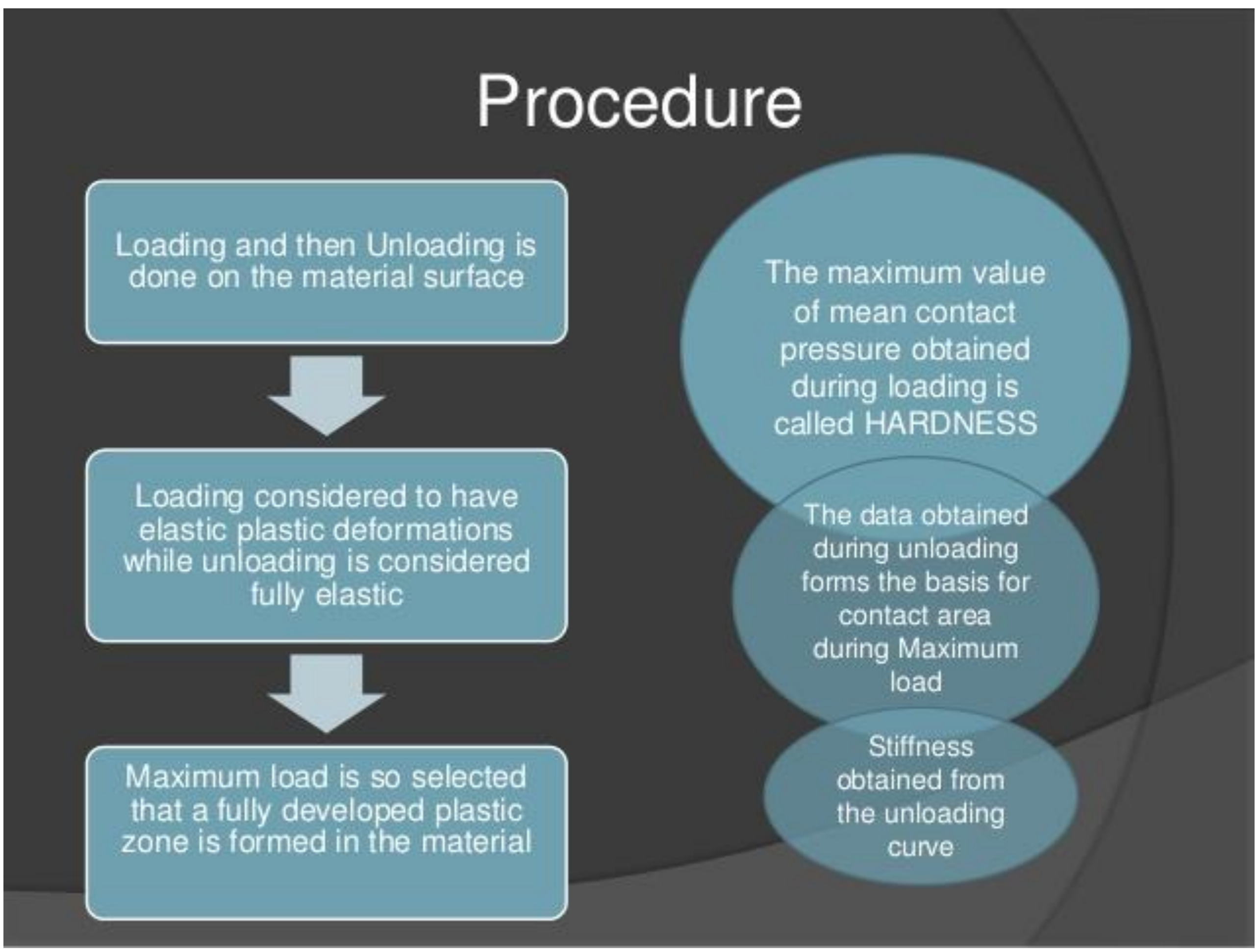
For balancing it is not essential that output of each operation should be same but the essential is to see that output of fastest machine should be multiple of the output of the remaining other machines.

Loading: Process, Strategies

A load means the quantity of work, and allocating the quantity of work to the processes necessary to manufacture each item is called loading.

It is performed in the **CRP (Capacity Requirements Planning)** of the manufacturing planning. Each item planned in MRP is first explored to the processes necessary to manufacture it, which is usually called process explosion. Next loading is performed for the explored process. In loading, each load is usually piled up by time (hour), by which a setup time and a real operating time are determined. The real operating time may be set by manufacturing lot or by real operating time per item unit. In the former case, the time of hour is piled up as load, while in the latter case, loading is performed after calculating the real operating time per manufacturing unit by multiplying the number of manufacturing items by real operating time.

In addition, the calculated load is piled up for a certain period, which is determined by selecting either the earliest start date or the last start date as a base date. This method enables loading for each process or each period.



Relationship between capacity and Loading

Load is the amount of work that **MUST** be done, amount of work scheduled ahead of a manufacturing facility.

Capacity is the amount of work that **CAN** be done, and measures the highest output of work expressed as a rate with current product specifications, work force, plant, equipment etc.

PPC: Job, Batch, Mass (Assembly) and continuous

Batch Process

Batch process refers to a process that consists of a sequence of one or more steps that should be performed in a defined order. A finite quantity of the product is produced at the end of the sequence, which is repeated in order to produce another product batch.

Generally, batch is a process that results in the production of limited quantities of material through subjecting quantities of raw materials to a set of processing activities over a significant period of time with the use of one of more piece of equipment. Processing of successive batches must wait until the completion of the current batch.

A flexible assembly system is appropriate when:

- A **wide variety of products** and/or parts is to be manufactured on the same equipment
- Products have a **short life cycle.**
- **Environmental uncertainties** are taken into account in order for a firm to accommodate internal changes and external influences.
- **Offshore competition** can produce products at much lower costs than can traditional manufacturing methods.
- Parts can be easily damaged by **over-handling** through manual cells.
- A high degree of **accuracy** and **repeatability** is required.
- Parts are too **intricate** to be assembled efficiently with considerable human intervention.
- Volumes are moderate to high, i.e., cycle time rates are not dependent on the slowest worker.
- **Ergonomics** is a significant factor.
- The assembly task requires less than roughly 10 seconds.

Continuous Process

A continuous process, on the other hand, refers to a processing that involves moving a single work unit at a time between every step of the process without any breaks in time, substance, sequence or extend. As the name suggests, the flow of product or material is continuous. Every machine operates in a steady state and performs a certain processing function.

For majority of applications, continuous flow saves costs, energy and time. When this process is properly implemented, it can reduce waste, improve quality by making it easier to identify and correct errors, increase productivity and adapt to the needs of customers more efficiently than batch processing.