3
SYSTEMS DESIGN AND CAPACITY

3.1 INTRODUCTION

Before products can flow into a market, someone must design and invest in the facilities and organisation to produce them. This chapter concerns the planning of the systems needed to produce goods and services. Capacity Planning for manufacturing and service systems are different. Both must be designed with capacity limitations in mind. The approaches for long-term and short-term capacity planning will help the managers to make best use of resources.

3.2 MANUFACTURING AND SERVICE SYSTEMS

Manufacturing and service systems are arrangements of facilities, equipment, and people to produce goods and services under controlled conditions.

Manufacturing systems produce standardized products in large volumes. This plant and machinery have a finite capacity and contribute fixed costs that must be borne by the products produced. Variable costs are added as labour is employed to combine or process the raw materials and other components. Value addition will takes place during the production process for the product. The cost of output relative to the cost of input can be measured, as the actual cost is known i.e. productivity is measurable quantity.

Service systems present more uncertainty with respect to both capacity and costs. Services are produced and consumed in the presence of the customer and there is little or no opportunity to store value, as in a finished goods inventory. As a result capacity of service systems like hospitals, restaurants and many other services must be sufficiently flexible to accommodate a highly variable demand. In addition, many services such as legal and medical involves professional or intellectual services judgments that are not easily standardized. This makes more difficult to accumulate costs and measure the productivity of the services.
3.3 DESIGN AND SYSTEMS CAPACITY

Production systems design involves planning for the inputs, transformation activities, and outputs of a production operation. Design plays a major role because they entail significant investment of funds and establish cost and productivity patterns that continue in future.

The capacity of the manufacturing unit can be expressed in number of units of output per period. In some situations measuring capacity is more complicated when they manufacture multiple products. In such situations, the capacity is expressed as man-hours or machine hours. The relationship between capacity and output is shown in the Figure 3.1.

**Fig. 3.1 Capacity and output relationship**

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**Design Capacity**

Designed capacity of a facility is the planned or engineered rate of output of goods or services under normal or full scale operating conditions. For example, the designed capacity of the cement plant is 100 TPD (Tonnes per day). Capacity of the sugar factory is 150 tonnes of sugarcane crushing per day. The uncertainty of future demand is one of the most perplexing problems faced by new facility planners.

Organisation does not plan for enough regular capacity to satisfy all their immediate demands. Design for a minimum demand would result in high utilisation of facilities but results in inferior service and dissatisfaction of customers because of inadequate capacity. The design capacity should reflect management’s strategy for meeting the demand. The best approach is to plan for some in-between level of capacity.

**System/effective capacity**: System capacity is the maximum output of the specific product or product mix the system of workers and machines is capable of producing as an integrated whole. System capacity is less than design capacity or at the most equal it because of the limitation of product mix, quality specification, and breakdowns. The actual is even less because of many factors affecting the output such as actual demand, downtime due to machine/equipment failure, unauthorized absenteeism.

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

These different measures of capacity are useful in defining two measures of system effectiveness: efficiency and utilization. Efficiency is the ratio of actual output to effective capacity. Utilization is the ratio of actual output to design capacity.

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

\[
\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}}
\]

It is common for managers to focus exclusively on efficiency, but in many instances, this emphasis can be misleading. This happens when effective capacity is low compared with design capacity. In those cases, high efficiency would seem to indicate effective use of resources when it does not.

### 3.4 CAPACITY PLANNING

Design of the production system involves planning for the inputs, conversion process and outputs of production operation. The effective management of capacity is the most important responsibility of production management. The objective of capacity management (i.e., planning and control of capacity) is to match the level of operations to the level of demand.

Capacity planning is to be carried out keeping in mind future growth and expansion plans, market trends, sales forecasting, etc. It is a simple task to plan the capacity in case of stable demand. But in practice the demand will be seldom stable. The fluctuation of demand creates problems regarding the procurement of resources to meet the customer demand. Capacity decisions are strategic in nature. Capacity is the rate of productive capability of a facility. Capacity is usually expressed as volume of output per period of time.

Production managers are more concerned about the capacity for the following reasons:
- Sufficient capacity is required to meet the customers demand in time.
- Capacity affects the cost efficiency of operations.
- Capacity affects the scheduling system.
- Capacity creation requires an investment.

Capacity planning is the first step when an organisation decides to produce more or new products.

### 3.5 PROCESS OF CAPACITY PLANNING

Capacity planning is concerned with defining the long-term and the short-term capacity needs of an organisation and determining how those needs will be satisfied. Capacity planning decisions are taken based upon the consumer demand and this is merged with the human, material and financial resources of the organisation.

Capacity requirements can be evaluated from two perspectives—long-term capacity strategies and short-term capacity strategies.

1. **Long-term capacity strategies:** Long-term capacity requirements are more difficult to determine because the future demand and technology are uncertain. Forecasting for five or ten years
into the future is more risky and difficult. Even sometimes company’s today’s products may not be existing in the future. Long-range capacity requirements are dependent on marketing plans, product development and life-cycle of the product. Long-term capacity planning is concerned with accommodating major changes that affect overall level of the output in long-term. Marketing environmental assessment and implementing the long-term capacity plans in a systematic manner are the major responsibilities of management. Following parameters will affect long-range capacity decisions.

- **Multiple products**: Company’s produce more than one product using the same facilities in order to increase the profit. The manufacturing of multiple products will reduce the risk of failure. Having more than on product helps the capacity planners to do a better job. Because products are in different stages of their life cycles, it is easy to schedule them to get maximum capacity utilisation.

- **Phasing in capacity**: In high technology industries, and in industries where technology developments are very fast, the rate of obsolescence is high. The products should be brought into the market quickly. The time to construct the facilities will be long and there is no much time, as the products should be introduced into the market quickly. Here the solution is phase in capacity on modular basis. Some commitment is made for building funds and men towards facilities over a period of 3-5 years. This is an effective way of capitalizing on technological breakthrough.

- **Phasing out capacity**: The outdated manufacturing facilities cause excessive plant closures and down time. The impact of closures is not limited to only fixed costs of plant and machinery. Thus, the phasing out here is done with humanistic way without affecting the community. The phasing out options makes alternative arrangements for men like shifting them to other jobs or to other locations, compensating the employees, etc.

2. **Short-term capacity strategies**: Managers often use forecasts of product demand to estimate the short-term workload the facility must handle. Managers looking ahead up to 12 months, anticipate output requirements for different products, and services. Managers then compare requirements with existing capacity and then take decisions as to when the capacity adjustments are needed.

   For short-term periods of up to one year, fundamental capacity is fixed. Major facilities will not be changed. Many short-term adjustments for increasing or decreasing capacity are possible. The adjustments to be required depend upon the conversion process like whether it is capital intensive or labour intensive or whether product can be stored as inventory.

   Capital-intensive processes depend on physical facilities, plant and equipment. Short-term capacity can be modified by operating these facilities more or less intensively than normal. In labour intensive processes short-term capacity can be changed by laying off or hiring people or by giving overtime to workers. The strategies for changing capacity also depend upon how long the product can be stored as inventory.

   The short-term capacity strategies are:

   1. **Inventories**: Stock finished goods during slack periods to meet the demand during peak period.

   2. **Backlog**: During peak periods, the willing customers are requested to wait and their orders are fulfilled after a peak demand period.

   3. **Employment level (hiring or firing)**: Hire additional employees during peak demand period and layoff employees as demand decreases.
4. **Employee training**: Develop multi skilled employees through training so that they can be rotated among different jobs. The multi skilling helps as an alternative to hiring employees.

5. **Subcontracting**: During peak periods, hire the capacity of other firms temporarily to make the component parts or products.

6. **Process design**: Change job contents by redesigning the job.

### 3.6 IMPORTANCE OF CAPACITY DECISIONS

1. Capacity decisions have a real impact on the ability of the organisation to meet future demands for products and services; capacity essentially limits the rate of output possible. Having capacity to satisfy demand can allow a company to take advantage of tremendous opportunities.

2. Capacity decisions affect operating costs. Ideally, capacity and demand requirements will be matched, which will tend to minimize operating costs. In practice, this is not always achieved because actual demand either differs from expected demand or tends to vary (e.g., cyclically). In such cases, a decision might be made to attempt to balance the costs of over and under capacity.

3. Capacity is usually a major determinant of initial cost. Typically, the greater the capacity of a productive unit, the greater its cost. This does not necessarily imply a one for-one relationship; larger units tend to cost proportionately less than smaller units.

4. Capacity decisions often involve long-term commitment of resources and the fact that, once they are implemented, it may be difficult or impossible to modify those decisions without incurring major costs.

5. Capacity decisions can affect competitiveness. If a firm has excess capacity, or can quickly add capacity, that fact may serve as a barrier to entry by other firms. Then too, capacity can affect delivery speed, which can be a competitive advantage.

6. Capacity affects the ease of management; having appropriate capacity makes management easier than when capacity is mismatched.

**ILLUSTRATION 1**: Given the information below, compute the efficiency and the utilization of the vehicle repair department:

- **Design capacity** = 50 trucks per day
- **Effective capacity** = 40 trucks per day
- **Actual output** = 36 trucks per day

**SOLUTION**

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\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} = \frac{36 \text{ trucks per day}}{40 \text{ trucks per day}} = 90\%
\]

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\text{Utilisation} = \frac{\text{Actual output}}{\text{Design capacity}} = \frac{36 \text{ trucks per day}}{50 \text{ trucks per day}} = 72\%
\]

**ILLUSTRATION 2**: The design capacity for engine repair in our company is 80 trucks per day. The effective capacity is 40 engines per day and the actual output is 36 engines per day. Calculate the utilization and efficiency of the operation. If the efficiency for next month is expected to be 82%, what is the expected output?
SOLUTION

Utilization = \frac{\text{Actual output}}{\text{Design capacity}} = \frac{36}{40} = 45\%

Efficiency = \frac{\text{Actual output}}{\text{Effective capacity}} = \frac{36}{40} = 90\%

Expected output = (\text{Effective capacity})(\text{Efficiency}) = (40)(0.82) = 32.8 \text{ engines per day}

ILLUSTRATION 3: Given: \( F = \text{Fixed Cost} = \text{Rs. 1000}, V = \text{Variable cost} = \text{Rs. 2 per unit} \) and \( P = \text{Selling price} = \text{Rs. 4 per unit} \), Find the break-even point in Rs. and in units. Develop the break-even chart.

SOLUTION

\text{Break-even point (\$)} = \text{BEP(\$)} = \frac{F}{1-V/P} = \frac{1000}{1-2/4} = \frac{1000}{0.5} = \$2,000

\text{Break-even point (x)} = \text{BEP(x)} = \frac{F}{P-V} = \frac{1000}{4-2} = 500

ILLUSTRATION 4: Jack’s Grocery is manufacturing a “store brand” item that has a variable cost of Rs. 0.75 per unit and a selling price of Rs. 1.25 per unit. Fixed costs are Rs. 12,000. Current volume is 50,000 units. The Grocery can substantially improve the product quality by adding a new piece of equipment at an additional fixed cost of Rs. 5,000. Variable cost would increase to Rs. 1.00, but their volume should increase to 70,000 units due to the higher quality product. Should the company buy the new equipment? What are the break-even points (Rs. and units) for the two processes? Develop a break-even chart.
SOLUTION

Profit = \( TR - TC \)

**Option A:** Current Equipment
BEP Sales in value (Rs.)
BEP Sales in Quantity (Units)

**Option B:** Adding New Equipment
BEP Sales in value (Rs.)
BEP Sales in Quantity (Units)

Profit = 50000 * (1.25 – 0.75) – 12000 = Rs.13000.

Option B: Add equipment:
Profit = 70000 * (1.25 – 1.00) – 17000 = Rs.500.

Therefore, the company should continue as is with the present equipment as this returns a higher profit.

Using current equipment:

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\text{BEP (sales is value)} = \frac{F}{1 - \frac{V}{P}} = \frac{12,000}{1 - \frac{0.75}{1.25}} = \frac{12,000}{0.40} = \text{Rs. 30,000}
\]

\[
\text{BEP (is quality)} = \frac{F}{P - V} = \frac{12,000}{1.25 - 0.75} = 24,000 \text{ units}
\]

Adding a new equipment:

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\text{BEP (sales is value)} = \frac{F}{1 - \frac{V}{P}} = \frac{17,000}{1 - \frac{1.00}{1.25}} = \frac{17,000}{0.2} = \text{Rs. 85,000.}
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\text{BEP (is quality)} = \frac{F}{P - V} = \frac{17,000}{1.25 - 1.00} = \frac{17,000}{0.25} = 68,000 \text{ units}
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Fig. 3.3