2.02. Capacity Planning

→ Maximum amount of output a productive unit could produce within a stated time.

→ capacity = Rate of productive capability of a facility.

→ Usually expressed as volume of output per period of time.

→ capacity → maximum load an operating unit can handle.

operating unit might be
- a) plant
- b) department
- c) machine
- d) store
- e) worker.

→ capacity of plant ⇒ maximum rate of output the plant can produce.

→ The production capacity of a facility or a firm

is the maximum rate of production the facility or the firm is capable of producing.

It is usually expressed in terms of units produced per period of time. (i.e. hour, shift, day, week etc)

→ When firms are producing different types of products, it is difficult to use volume volume of output of each product to express capacity of firm

↓

In such cases, capacity of the firm is expressed in terms of monetary value (prodⁿ value) of various products produced put together.

→ While producing output if prodⁿ process consist of many sub processes, then capacity of productive unit is governed by the capacity of weakest link.

Sub Process 1 → Sub Process 2 → Sub Process 3

Productive Unit

If sub process 2 is the weakest link then capacity of the productive unit is governed by the capacity of weakest link.

But no single capacity measure is best for all situations.

Eg:- Retailer → Annual sales rupees generated per square ft.

Airline → Available seat miles per month.

Theater → Number of seats

Car Manufacturer → No. of car produced per day.

* General capacity can be expressed in one of two ways :-

Output measures of capacity

Input measures of capacity

A] Output measures of capacity :

→ best utilized when applied to individual processes within the firm.

OR

→ when firm provides a relatively small number of standardized services and products

Eg → High volume processes → such as car manufacturers.

→ capacity expressed as no. of cars produced per day.

→ method is less applicable when amount of customization and variety in the product mix increases.

B] Input measures of capacity :-

→ used for low volume, flexible processes such as furniture maker.

→ capacity usually expressed as no. of workstations or no. of workers.

* Capacity can be :-

1. Installed Capacity	2. Rated Capacity	3. Licensed capacity	4. Design capacity	5. Effective capacity
Capacity in terms of machines actually installed.	denotes highest output established by actual trial run of productive machines installed.	Actual capacity licensed by concerned Govt. Authorities	Maximum Output rate or Service capacity.	Design capacity minus allowance (personal time, maintenance etc)

* Factors for determining effective capacity :-

1. Facilities → design, location, layout & environment.
2. Product → Product design and product mix.
3. Process → Quantity and quality capabilities of the process are to be followed.
4. Human factors → Job content, Job design, motivation, compensation, training and experience of labour, learning rates etc.
5. Operational factors → scheduling, materials mgmt, quality assurance, maintenance policies and equipment breat down.
6. External factors → Product standards, safety regulations, union attitudes, pollution control standards.

Note :- Effective capacity is always less than design capacity owing to changing product mix, the need for periodic maintenance of facilities, tiffin breaks etc.

- Actual output can never exceed effective capacity and is usually less because of machine breakdown, absenteeism, shortages of materials etc.

* these different measures are useful in defining two measures of effectiveness of a system :

Capacity Utilisation ← → Efficiency

A] Capacity Utilisation :-

→ Is the degree to which a resource such as equipment, space or the workforce is currently being used.

→ Is measured as ratio of average output rate to maximum capacity.

Note :- Average output rate and maximum capacity needs to be measured in the same terms (i.e. time, customers, units or rupees)

$$\text{Utilisation} = \frac{\text{Actual output}}{\text{Design capacity}} \times 100\%$$

→ Utilization rate indicates the need for adding extra capacity or eliminating unneeded capacity.

→ Utilization can be increased by increasing actual output and hence effective capacity since actual output is born

out of effective capacity

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}} \times 100\%$$

* Capacity Planning

Concerned with
- what kind of capacity is needed?
- How much capacity is needed?
- When this capacity is needed?

Capacity Planning is long term strategic decision that establishes a firm's overall level of resources.

→ Goal of capacity planning → achieve match between long term supply capabilities & predicted level of long term demand.

Capacity decisions often involve long term irrevocable commitment of resources.

* Capacity decisions affect :-

A] Product lead times
B] Customer Responsiveness
C] Operating Cost
D] Firm's ability to compete.

Capacity decisions are strategic because this decisions can affect competitiveness.

* Objective of capacity planning & control of capacity :-

↓

Match level of operations to level of demand.

Out of balance capacity occurs when →
there is a gap between current & desired capacity.

Capacity decisions are made in light of several long term issues such as :-

a) economies & diseconomies of scale.
b) capacity cushions
c) timing
d) trade offs between customer service & capacity utilisation etc.

* While taking capacity decisions into the system, concerns are on factors :-

1] Flexibility :

Flexibility is introduced into the system

Provision for future requirements must be there in system.

↓

i.e. adequate capacity commensurate with future need.

Flexibility should also be incorporated

While designing location & layout of equipments.

While making Prodⁿ planning scheduling & inventory policies.

2) Life cycle:-

The product life cycle is the process a product goes through from when it is first introduced into the market until it declines or is removed from the market.

The life cycle has four stage:

Introduction Growth Maturity Decline.

At Introduction :-

→ size of overall market & org^n's share of market is uncertain.

→ large & inflexible capacity planning needs to be avoided.

At Growth :-

→ size of overall market grows.

→ Rate of growth of individual org^n's market share influences its capacity planning.

→ Opens opportunities to all org^n to bring competitive advantage
(Product differentiation, Investing in technology & process improvements)

→ Brings risk of overcapacity in market

→ Results in higher unit costs of output.

At maturity :-

→ size of market levels off.

→ orgn tend to have stable share.

→ orgn could increase profitability ⟷ cost reduction & full capacity utilisation.

→ orgn with lower capacity in earlier phases of life cycle could go for capacity addition if maturity phase is thought to be prolonged.

At decline :-

→ overall market demand declines.

→ orgn face under utilisation of capacity.

→ Excess capacity could be sold off.

→ Excess capacity can be used for producing other products / services.

3) Interrelation :-

1) parts of any system are always interrelated.
2) capacity of one part has impacts on other parts. (eg: Increasing no. of routes from airport
+
security check-in-capacity of station).
3) capacity decisions related to a process has a role on supply chain of orgn as a whole. (Increasing prodn capacity → more RM → more time)

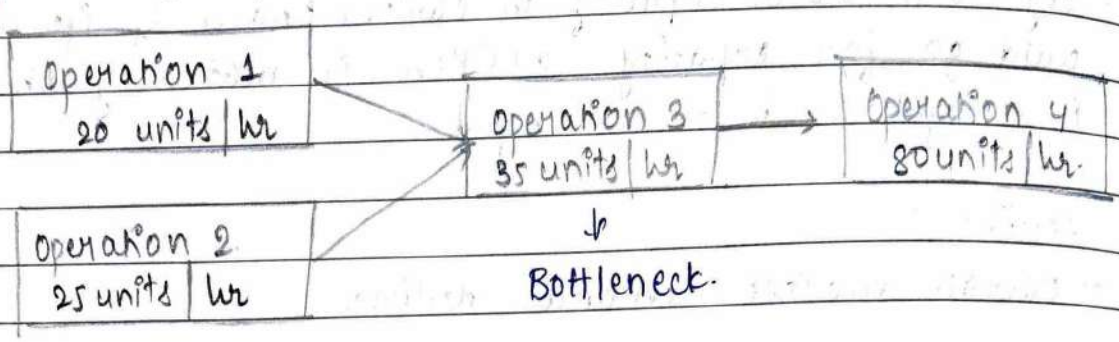
4) So capacity planning decisions must be made with collaboration among all the interelated players including suppliers, distributors, transporters etc.

4) Bottleneck :-

Bottleneck operation is an operation in a sequence of operations whose capacity is lower than the capacities of other operation in the sequence.

Bottleneck operation limits the capacity utilisation of previous and successive operation in the whole sequence of operation.

Eg :-



5) Chunk :-

→ Capacities are available in chunks.
→ Creates mismatch between desired capacity & available capacity.
→ Creates either shortfall / surplus in prodn.

6) Variability :-

→ Demand is variable.
→ Variability ⇒ seasonal, chance, random, cyclical etc.
→ Variable demand brings unevenness in cap. planning.
→ Capacity strategies should provide allowances for these.
→ Capacity should be for complementary products & services to cater seasonality.

7) Optimal Operating level :

Ideal or optimal level of operation in terms of unit cost of output.

→ Economies of scale
→ Diseconomies of scale

Economies of scale	Diseconomies of scale
↓	↓
Avg unit cost can be reduced by increasing its output rate.	Avg cost per unit increases as the facility's size increases.

& Miscellaneous :

Incremental Expansion / single step expansion of capacity considering :-

- competitive pressure.
- Market Opportunities
- cost and availability of funds.
- Disruption of operation.
- Training Requirements.

* Why is Capacity Planning Required ?

- To meet the customers demand in time
- Cost effiency of operations
- Affects the scheduling system.
- Requires investment
- Post selection of req. capacity, facility location, process, tech. etc.

* Capacity Planning is mainly of two types.

Long Term Capacity Plans	Short term Capacity Plans.
↓	↓
Investments in new facilities & equipments (More than 2 years)	work force size, overtime budgets, inventories etc.

* Capacity Planning Involves Activities such as :-
  - Assessing the capacity of existing facilities.
  - Forecasting the long range future capacity needs.
  - Identifying & Analysing sources of capacity for future needs.
  - Evaluating alternative sources of capacity. (financial, technological, economic considerations)
  - Selecting a capacity alternative most suited to achieve strategic mission of firm.

* An Operating Unit may face two situations :-

Over Capacity

Excess or surplus capacity situation where the present capacity exceeds the expected future demand.

Under Capacity

capacity shortage situation where present capacity is not enough to meet the forecast demand for product.

* When is Over capacity Preferred ?

1) Fixed Cost is Not Very high.

2) Sub contracting is not possible.

3) Time required to add capacity is long.

4) Co. cannot afford to miss stipulated delivery date and cannot afford to lose the customer.

5) There is an economic capacity size below which it is not economical to operate the plant.

Excess capacity → Drain Company's resources.
→ Prevent investments in other more lucrative ventures.

* When is under capacity Preferred ?
1) Fixed cost is very high.
2) Shortage of products does not affect company.
3) Technology changes fast (obsolescence of P/M are high)
4) Cost of creating the capacity is prohibitively high.

Inadequate capacity → Loss of customers
→ Restricts Growth.

* Two kinds of factors affecting capacity planning are :-

Controllable Factors	Less Controllable Factors
Amount of labour employed, facilities installed, machines, tooling, shifts of work per day, days worked per week, overtime work, subcontracting, preventive maintenance, no. of prodn set-ups	Absenteeism, labour performance, machine break-down, material shortages, scrap and rework, strike, lock-out, fire, accidents, natural calamities etc.

* Forms of Capacity Planning

Based on Time Horizon

Long Term → new facilities & equipments → more than 2 yrs.

Short Term → work force size, overtime budgets, inventories.

Based on Amount of Resources employed.

Finite capacity planning

Infinite capacity planning.

* Operations managers must examine three dimensions of capacity strategy before making capacity decisions:-

A] Sizing capacity cushions.

B] Timing & Sizing Expansion

C] Linking capacity decisions with other operating decisions.

↓ Sizing Capacity Cushions :-

Capacity cushions is the amount of reverse capacity a process uses to handle sudden increases in demand or temporary losses of production capacity.

Capacity cushion = 100% - Avg utilisation rate (%)

Appropriate size of cushion varies by industry

Capital Intensive Industries → 10% cushion

Less capital Intensive Industries → 40 to 30% cushion.

→ unused capacity cost money & brings low return on investment.

→ Business keeps large when –
a) demand varies
b) future demand is uncertain
c) with a changing product mix.

→ In long run it buffers the orgn against uncertainity.

→ Any change in any decision area needs change in capacity cushion.

→ Capacity cushions can be lowered
- If If competitive priorities are given.
- If Co. is willing to smooth the output rate by raising prices when inventory is low
- decreasing prices when it is high

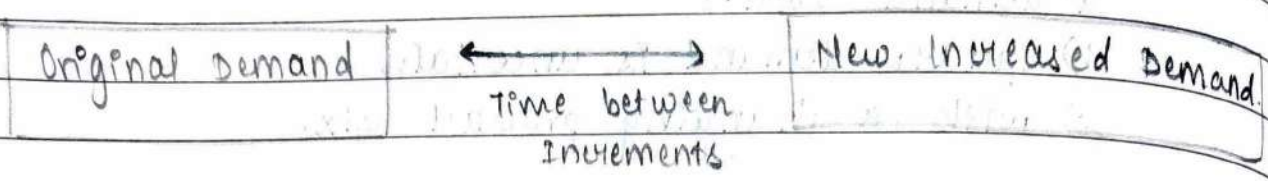
If Timing & Sizing Expansion
→ Has concern when to adjust capacity and by how much.

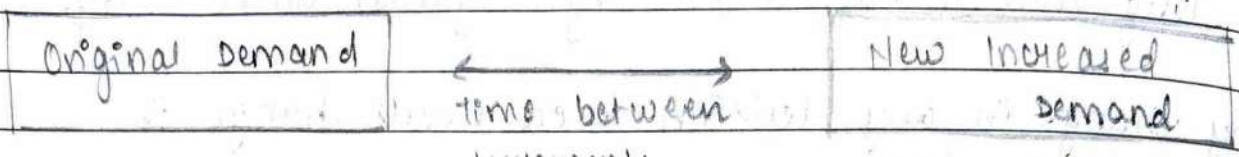
Two extreme strategies for expanding capacity :-

Expansionist strategy (involves large, infrequent jumps in capacity)
↓
Stays ahead of demand, minimises the chance of sales lost to insufficient capacity.

Wait & see strategy. (involves smaller more frequent jumps)
↓
Lags behind demand & ∴ to meet any shortfalls it relies on short term options (overtime, temporary workers, subcontracts etc)

* Timing & sizing of expansion are related :-
If demand is increasing and the time between increments increases, the size of increments must also increase.





Factors favouring expansionist strategy.
- Results economies of scale
- Results reducing cost of operation.
- facilitates a firm to compete on price.
- might increase the firm's market share.

Factors favouring wait and see strategy.
- reduces risk of overexpansion
- facilitates firm to avoid obsolete technology
- guards against inaccurate assumptions regarding competition.

Advantages / Disadvantages of Expansionist strategy:-

1. Results in economies of scale & faster rate of learning.
2. This helps a firm to reduce its costs and compete on price.
3. This might increase firm's market share.
4. It may bring risk of over expansion.

Advantages / Disadvantages of wait & see strategy:-

1. Reduces risk of over expansion.
2. Unable to respond if demand is unexpectedly high.
3. Fits the short term outlook but can erode market share over the long run.

Managers may choose one of these two strategies or one of the many between these extremes.

* 3 basic strategies for the timing of capacity expansion in relation to a steady growth in demand are :-

1. Capacity lead strategy :
   → Capacity is expanded in anticipation of demand growth.
   → Used to lure customers from competitors who are capacity constrained or to gain a foothold in a rapidly expanding market.

2. Capacity Lag Strategy :-
   → Capacity is increased after an increase in demand has been documented.
   → This strategy produces higher return on investment but may lose customers in the process.
   → It is used in industries with standard products and cost based or weak competition.

→ This strategy assumes that lost customers will return from competitors after capacity has expanded.

3) Average capacity strategy :-
→ Capacity is expanded to coincide with average expected demand.

→ This is a moderate strategy in which managers are certain they will be able to sell at least some portion of the additional output.

3] Linking Process Capacity And other Operating decisions.
→ Capacity decisions should be closely linked to processes and supply chains throughout the organisations.

→ Capacity decisions must link backward & forward channels in the whole operation chain.

A) Level Capacity Plan :-
Based on 'produce to stock and sell' wherein prodn systems are operated at uniform prodn levels.
&
FG inventories rise and fall depending upon whether prodn levels exceeds demand or vice versa from time period to time period.

B] Matching Capacity with demand plan :-
→ Prodn capacity is matched with the demand in each period (weekly, monthly or quarterly demand)

→ material flows & machine capacity are changed from quarter to quarter to match the demand.

→ Main Advantage :- low levels of finished goods inventory resulting in lesser inventory carrying cost.

→ Also the back-ordering cost is reduced.

→ disadvanges are high labour & material cost because of frequent changes in workforce

* Higher capacity plant offers some economies of scale :-
- Automation is possible in a high capacity plant.
- Labour economies = lower variable cost/unit → increase of skill of worker
- managerial economies, technical competence.
- Marketing economies - Purchase in bulk.
- Financial economies - better security, attract investment at lower cost.

* Economies of scale - Occurs when it cost less per unit to produce or operate at high levels of output. This is true when :-

1) Fixed cost can be spread over a larger no. of units.
2) Prodn or operating cost do not increase linearly with output levels.
3) Quantity discounts are available for material purchases.
4) Operating efficiency increases as workers gain experience.

* Economies of scale do not continue indefinitely. Above a certain level of output diseconomies of scale can occur like :-
- Overtaxed machines and material handling equipment break down.
- Slowing of service time.
- Quality suffers requiring more rework.
- Labour cost increase with more overtime.
- Increase in difficulties in coordination & management activities.

* Once long term forecast is found out additions of increments to existing capacity can be done:

1) Add capacity increments but more often (less new capacity at a time)

2) Add capacity increments but less often (high new capacity at a time)

3) Add capacity before the requirements exceed the capacity available.

4) Add capacity after the requirements has overtaken the available capacity.

* A systematic approach to long term decisions for capacity would typically include:-

1) whether to add a new plant.
2) whether to add a new workstation.
3) whether to reduce the no. of existing workstations/ warehouses etc.

* Four step systematic Approach involves:-

1) Estimate future capacity requirements
2) Identify gaps by comparing requirements with available capacity.
3) Develop alternative plans for reducing the gaps.
4) Evaluate each alternative, both qualitatively and quantitatively and making a final choice

* when just one service or product is processed, then capacity requirement of a single capacity per year is :-

Capacity Requirement (CM) = Processing hrs required to meet year's demand / Hrs available from a single capacity unit per year after deducting desired cushion.

(Single capacity means an employee, a machine, a computer etc)

$$= \frac{D_p}{N\left[1-\left(\frac{C}{100}\right)\right]} \quad \text{(1)}$$

D = demand forecast for the year.
P = Processing time
N = total no. of hours per year during which the process operates.
C = desired capacity cushion.

After accounting for both processing and setup times eqn (1) above for multiple products / services can be modified as :-

Capacity Requirement (CM) = Processing & Set up hrs required to meet year's demand summed over all services / products / Hrs available from a single capacity unit per year after deducting desired cushion

$$\frac{\left[Dp+\left(\frac{D}{Q}\right)S\right]_{\text{product 1}} + \left[Dp+\left(\frac{D}{Q}\right)S\right]_{\text{product 2}} \cdots \text{product n}}{N\left[1-\left(\frac{C}{100}\right)\right]}$$

Q = no. of units in each lot.
S = set up time (in hrs) per lot.

* Optimum plant capacity :-

→ As the volume of output increases outward from zero in a particular production facility, average unit cost fall.

→ These declining cost are because of following reasons:-
1. Fixed cost are spread over more unit produced.
2. Plant construction cost are less.
3. Reduced costs of purchased material due to quantity discounts for higher volume of material purchased.
4. Cost advantages in mass production process.

→ So, for a given production facility, there is an optimum volume of output per year that results in the least average unit cost.

→ This level of output is called the 'best operating level' of the plant.

* Balancing the capacity :-

→ In firms manufacturing many products, the load on different machines & equipments vary due to changes in product mix.

→ When output rates of different machines do not match with the required output rate for products to be produced, there will be imbalance between workloads of different machines.

→ This will result in machine / equipment becoming a 'bottleneck work centre'.

→ To overcome problem of imbalance between different machines, additional m/c or equip. are added to the bottleneck to increase the capacity of bottleneck work centre and match with other work centre.

→ Adding new machines/equipments to bottleneck is found to be more economical than giving excessive overtime to workers working in bottleneck work centres.

→ Another method to remove imbalance is to subcontract excess work load of bottleneck to outside vendors or subcontractors.

→ Another way to balance capacities is to try to change the product mix by manipulating the sales for different products to arrive at a suitable product mix which loads all work centres almost uniformly.

Eg 1 :-

i) The no. of hours of operation, per year $N = \frac{3 \text{ shifts}}{\text{day}} = \frac{8 \text{ hrs}}{\text{shift}} = \frac{5 \text{ days}}{\text{week}} \times 50 \text{ weeks}$

$= 6000$ hours.

The no. of machines required M is the sum of m/c hour requirements for all three products divided by the number of productive hours available for one machine.

$$\text{Capacity Requirements (M)} = \frac{\text{Processing \& Set up hours required to meet year's demand summed over all services/products}}{\text{Hours available from a single capacity unit per year after deducting desired cushion.}}$$

$$= \frac{[Dp + (\frac{D}{Q})s]_A + [Dp + (\frac{D}{Q})s]_B + [Dp + (\frac{D}{Q})s]_C}{N\left[1 - (\frac{c}{100})\right]}$$

$$= \frac{[18000 \times 2 + (\frac{18000}{300})0.5] + [50000 \times 5 + (\frac{50,000}{500})1] + [9000 \times 3 + (\frac{9000}{1000})1]}{6000\left[1 - \frac{5}{100}\right]}$$

$$= \frac{313139}{5700} = 54.9 = 55 \text{ machines.}$$

ii) The capacity gap is $55 - 50 = 5$ machines.
So more machines should be purchased unless management decides to use short term options, if any available, to fill the gap.

Eg 2]

Year	0 (Current year)	1	2	3	4	5
Forecasted sale (meals)	80,000	90,000	1,00,000	1,10,000	1,20,000	1,30,000
Incremental sale compared to base i.e. C.Y units		10,000	20,000	30,000	40,000	50,000
Avg profit p.u.		15	15	15	15	15
Incremental profit flow (Rs)		1,50,000	3,00,000	4,50,000	6,00,000	7,50,000

	Year	0 (C.Y)	1	2	3	4	5
1.	Initial Investment	-120000					
2.	Incremental profit flow on investment.		150000	300000	450000	600000	750000
3.	Additional Investment				-200000		
4.	Net cash flows (Inflows/Outflows)	-120000	150000	300000	250000	600000	750000
5.	PV factor ($1/(1.10)^n$ (Since cost of fund 10%, n = no. of years)	1	0.909	0.826	0.751	0.683	0.621
6.	PV (4 x 5)	-120000	136363.6	247933.9	187828.7	409808.1	465691
7.	NPV (Sum of Row 4)	1327625.286					

Eg 3]

The no. of hours of operation per year, $N = \frac{2 \text{ shifts}}{\text{day}}$

$= \frac{8 \text{ hours}}{\text{shift}} \times 200 \text{ days} = 3200 \text{ hours.}$

The no. of machines required is the sum of machine hour requirements for all two products divided by the no. of productive hours available for one machine.

$$\text{Capacity Requirement (M)} = \frac{[Dp + (\frac{D}{q})s]_K + [Dp + (\frac{D}{q})s]_W}{N\left[1 - (\frac{c}{100})\right]}$$

$$= \frac{[30,000 \times 0.3 + (\frac{30,000}{20})3] + [12000 \times 1 + (\frac{12000}{70})4]}{3200\left[1 - \frac{25}{100}\right]}$$

$$= \frac{26185.71}{2400} = 10.91 \cong 11 \text{ machines.}$$

So another $11 - 4 = 7$ machines are to be purchased.

Eg 4]

The no. of hours of operation per year =

$$N = \frac{8 \text{ shifts}}{\text{day}} = \frac{8 \text{ hours}}{\text{shift}} = \frac{5 \text{ day}}{\text{week}} \times 50 \text{ week} = 6000 \text{ hours.}$$

The no. of machines required n is the sum of machine hour requirements for all two products divided by the no. of productive hrs available for one machine.

Capacity Req. (M) = Processing & set up hours required to meet year's demand summed over all services/products.
Hrs available from a single capacity unit per year after deducting desired cushion.

$$= \frac{\left[Dp + \left(\frac{P}{Q}\right)s\right]_n + \left[Dp + \left(\frac{P}{Q}\right)s\right]_m}{N\left[1 - \left(\frac{C}{100}\right)\right]}$$

$$= \frac{\left[5000 \times 25 + \left(\frac{5000}{100}\right)2\right] + \left[10000 \times 50 + \left(\frac{10,000}{100}\right)3\right]}{6000\left[1 - \frac{15}{100}\right]}$$

$$= \frac{625400}{5100}$$

$$= 122.63 \cong 123 \text{ workstations.}$$

Q.5

Step:1 : Calculate processing time needed.

X	=	300 x 4	= 1200 hrs
Y	=	400 x 6	= 2400 hrs
Z	=	500 x 3	= 1500 hrs
		Total :-	5100 hrs

Step: 2 Annual prodn capacity of one machine.

8 x 250 = 2000 hrs per year.

Step 3:- No. of M/c required.

$$\frac{\text{Workload per year}}{\text{Prodn capacity}} = \frac{5100}{2000} = 2.55 \text{ machines}$$

i.e. 3 machines.

Q6

$$\text{Efficiency} = \frac{\text{Actual Output}}{\text{Effective capacity}} = \frac{36,000}{40,000} \times 100 = 90\%$$

$$\text{Utilisation} = \frac{\text{Actual Output}}{\text{Design capacity}} = \frac{36,000}{50,000} \times 100 = 72\%$$

Q.7

1) Bottleneck centre is the work centre having minimum capacity. Hence, work centre 'C' is bottleneck centre.

2) System capacity is the maximum units that are possible to produce in a system as a whole.
Hence, system capacity is the bottleneck centre i.e. 340 u.

3) System efficiency = $\frac{\text{Actual}}{\text{System cap.}} = \frac{300}{340} \times 100$

= 88.23%.

Q.8 Calculation of Break-even point:

$$BEP = \frac{\text{Fixed Cost}}{\text{Contri p.u.}}$$

M/c 1 = $\frac{12,000}{50-20} = \frac{12000}{30}$ = 400 units.

M/c 2 = $\frac{15,000}{50-20} = \frac{15000}{30}$ = 500 units.

M/c 3 = $\frac{21,000}{50-20} = \frac{21000}{30}$ = 700 units.

i) The projected demand is between 600 to 650 units.

a) The break even point for single m/c option (i.e. 400 units) is not feasible because it exceeds the range of volume that can be produced with one m/c. (i.e. 0 to 300)

b) Also, the BEP for 3 m/c is 700 units. which is more than the upper limit of projected demand of 600 to 650 units and hence not feasible. For 2 machines option the BE volume is 500 units and volume range is 301 ~~to~~ to 600.

c) Hence, the demand of 600 can be met with 2 machines and profit is earned because the prodn volume of 600 is more than the breakeven volume of 500.
If manager wants to produce 650 units with 3 machines, there will be loss because the break even volume with three machines is 700 units.

Hence, the manager would choose two machines and produce 600 units.