UNIT 7 CAPACITY PLANNING

Objectives

After going through this unit, you should be able to:

- learn the capacity planning for long term, medium term and short term period depending upon the demand fluctuation
- under stage single-stage capacity planning and multiple-stage capacity planning under certanity and incertainty
- have a brief knowledge of financial implication capacity planning
- compute the requirement of machines and stage efficiency in capacity planning

Structure

7.1 INTRODUCTION

For any organization, the principle of matching demand with supply at any point of time is to be followed mainly for producing products or services at minimum total cost. This is possible when the utilization of supply capacity of the organization is maximized. Capacity planning is required basically to achieve this objective.

Determination of productive capacity requirements is a problem not only when designing a new system (factory, manufacturing setup, or production unit), or expanding an existing one, butt also for a shorter operating periods during which the plant size cannot be changed. Decisions about capacity determination or expansion are always important, because they provide the basis for both long and short-term managerial planning-and control of resources.

Productive capacity, generally measured in physical units, refers either to the maximum output rate products or services or to the amount of key resources available like machine= hours, man-hours, etc. in each operating period:

When the output of an operations system or the transformation process is fairly standardized, nominal physical capacity can be expressed as a maximum sustainable output rate achieved by a full complement of labour on regular time. However, for systems producing a wide variety of products or services which cannot be measured in common units. it becomes necessary to express capacity in terms of critical resource inputs e.g. labour-hours or machine-hours.

Since changes in capacity are made to satisfy expected changes in demand, capacity has the. same dimensions as demand. The relationship between the dimensions of demand and their effect on capacity can be explained in the following way (refer Table 7.1).

Table 7.1: Relationship between demand and productive capacity

Dimension of demand	Effect on capacity requirements
Quantity	How much capacity is needed?
Timing	When should capacity be available?
Quality	What kind of capacity is needed?
Location	Where should capacity be installed?

7.2 ASPECTS OF CAPACITY PLANNING

Capacity-related problems may exist in 'three basic form. First is the issue of large increments in capacity needed for changes in demand over the long term, say 5 to 10 years ahead. For most technologies capacity increments can be made only in large chunks at a time. even though they cannot be fully utilized when installed (another shift, or steel mill, or aircraft added when demand exceeds available capacity). Due to addition of productive capacity, there will be step increases in fixed costs that cannot be absorbed immediately in this case. This will be absorbed from the gradual increase in expected demand over a long period. This type of capacity change sets the upper limit of the productive capacity of a plant. This upper limit is also referred to as the system design capacity.

Second, within the constraints imposed by the system design capacity, limited adjustments can be made for periods up to a year or two in order to cover fluctuations in demand due to seasonality and business cycles. The resulting aggregate planning relics in the use of inventories, changes in the size of the wokforce through hiring and layoffs, use of overtime, and subcontracting orders to another firm.

Finally, finer adjustments in capacity may be needed to cope with short-terra random fluctuations in demand. This is done on a weekly or even daily basis and the corresponding methods used for this refinement is the subject of operation scheduling. Random fluctuations in demand, which are both unpredictable and uncontrollable, affect the accuracy of these methods in a given situation.

Activity A

In the context of your organisations critically evaluate the short time, medium-term, and long term capacity planning of the manufacturing unit on an service system. Find out the battik neck exists in each type of planning.

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7.3 DETERMINATION OF CAPACITY REQUIREMENTS

A feasibility study is usually performed to determine how much capacity will be needed and when. The phases in long-term capacity -related studies are shown in Fig. 7.1.

7.3.1 Capacity Planning for a Single-Stage System

For simplicity, we shall consider an example for an operations system as a whole. In practice, however; the analysis indicated must be carried out for each stage of the production process separately. The production stages, which are considered to be bottlenecks, are to be analysed first. Let us consider a manufacturing firm which has experienced an average annual increase in demand of one of its products equal to 200 units. Its present maximum capacity is equal to 2,400 units year. The trend line for annual demand has been estimated by analysing the past data as Y, = 600 if 200t (with t = 0 in 1984): Management is interested in adding enough capacity to cover expected demand for the next 12 years assuming that the linear upward trend will continue in future.

The minimum duration of the planning horizon is determined by the lead time needed to add new capacity, i.e., for activities like engineering design, construction, equipment

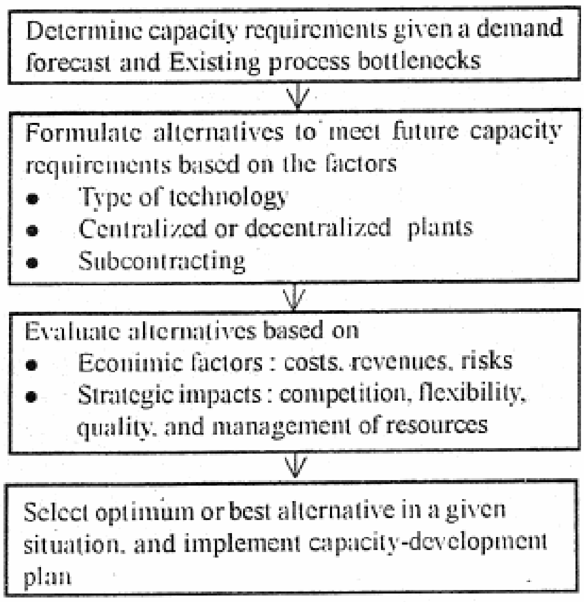

Fig. 7.1: Capacity planning Procedure

installation etc. The frequency with which management reviews such issues is also an important consideration. If the lead like for adding the new facility is 3 years and management reviews such issues 5 years after the latest additions, the minimum planning horizon should be 3 + 5 = 8 years.

For the last year in the planning horizon, i.e. in 2004, the value oft in the trend-line equation will be 20: therefore, the annual expected demand then will be Y 2004 = 600 + (20t)) (20) - 4600. Thus, if the present trend continues, we must provide enough capacity to produce at an annual output rate equal to Y 2004 = 4,600 units. Given a current capacity limit of 2400 units, the projected increase in capacity requirements for 2004 is equal to 4600-2400⁼2200 units. Whether the required capacity will be added all at once, or in smaller increments depends on the process technology. A typical manufacturing unit might decide to build facilities for a new large plant, and acquire equipment gradually as needed. A typical process plant, however , is more severely restricted by the technology used to large-capacity increments. The choice depends on balancing the lower variable costs for large-capacity increments against high fixed costs that cannot be absorbed due to underutilization in near future. The projected capacity requirements to handle increase in demand is explained in Fig. 7.2.

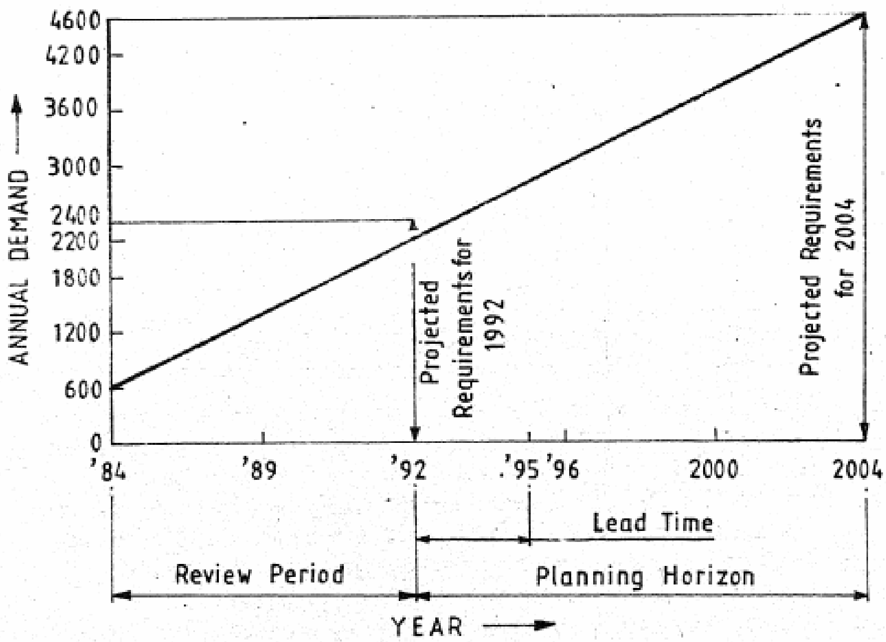

Fig. 7.2 : Matching of Capacity Requirements with Demand Over Time

The above procedure does not account for the degree of uncertainty in future demand.

This may be evaluated subjectively by top management planners, or statistically by computing a measure of dispersion 'f actual demand points in the past from the trend line.

The projected estimate for net capacity requirements cat be adjusted further to allow for planned shutdowns to handle preventive maintenance or for planning for unexpected growth or decline. For example, suppose that the firm has decided to build the new plant with a capacity of 2.500 tonnes/year overseas. If management wants to increase this by 20 Pe[r] cent for planned maintenance and another 10 per cent for further growth, the capacity adjustment needed would be.

Normal plant capacity = (2500 v fits (1.20) = 3000

Adjusted plant capacity = (300) (1.10) = 3300 units

The adjusted plant capacity represents an average annual output rate for the overseas plant. If there are no seasonal fluctuations the monthly rate will be 3300/12 = 275 tonnes. but in the presence of a strong seasonal cycle typical of plants actual requirements will exceed this monthly average during the peak season, and in slack periods, they will be less than the average. If management can rely on seasonal inventories, overtime, or subcontracting, the annual capacity requirements can be met by the above monthly rate.

If inventories cannot be used, the production rate must be continually changed to follow the actual demand over time period. Let t s assume that the plant in this case can handle demand with a monthly maximum capacity equal to 300 tonnes. On annual basis, this corresponds to increasing capacity to 310() tonnes. Between the extremes of 3300 tonnes needed for producing at a constant rate of 275 tonnes /month and 3600 tonnes to absorb peaks of up to 300 tonnes per month1, it is often possible to adopt a compromise plan. For example, we may assume that an amount of (290) (12) = 3400 tonnes/year is needed. This amount is definitely influenced by the feasible scale Of production and technology of the process. Therefore, in the determination of long-term capacity we must be aware of the feasibility of using short-range alternatives such as inventories.overtimes. Multiply workshifts, or subcontracting.

7.3.2 Capacity Planning for a Multiple-Stage System

When the production process consists of one stage only, the determination of capacity requirements by previous methods refers to the output rate for the entire new system directly. More often, however, capacity planning for multistage processes becomes a necessity. Different equipment configurations at each stage make it virtually impossible to have all stages operate with the same maximum capacity requirements in done for the bottleneck operations or production stages. This can result in higher operating costs due to under utilization of facilities at other non-bottleneck operations. However, this may well be the only feasible way or alternative: in a given situation.

Activity B

Briefly describe a practical approach toward managing capacity change. Would-it be important for a person workings to be a general manager not an operations manager, to under and, this process? Why or why not?

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7.4 EVALUATION OF ALTERNATIVE PLANT SIZES

The amount of capacity needed for a future planning period can be obtained from one or several plant sizes each having a different maximum capacity limit The choice involves critical strategic decisions not only about the technology to be used but also about whether capacity will be available iii one centralized or several geographically dispersed locations Here management n lust consider not only production and distribution costs but the effects of such decisions on competition the organizational structure and managerial style, and the flexibility needed to adapt in future changes in the environment Sometimes these strategic issues have a greater influence in the final selection than the more quantifiable aspects pertaining to technology and costs

Activity C

If you will be asked to design an alternate plant size w.r.t.. your existing one/ what solution you are likely to suggest'? What factors are you considering for this type of decision?

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7.4.1 Traditional Economic Analysis

Notwithstanding the importance of subjective factors, a proposal for capacity expansion should fulfill certain economic criteria. When the investment is expected to provide a satisfactory return without excessive risks within a given timeframe, the expansion, project may be funded from the capital budgeting allocations, the financial-performance measures derived from a cash-flow analysis can take the form of a net present value (NPV). or rate of return on the required investment for new capacity. Once the revenues and costs for the project have been estimated, the calculation of such measures is routine, and can be computerized so that it can be repeated for various assumptions.

Let us assume that the new capacity requirements of 3300 units per year, determined from the previous example, can be met from three different plant sizes with the cost characteristics listed in Table 7.2.

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Table 7.2: Data for three alternative plant sizes

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Annual capacity units/year	Initial investment (Rs.)	Annual fixed cost (Rs.)	Variable cost per unit (Rs.)	Average unit cost at full capacity (Rs.)
2500	7,00,000	25,000	50	60
5000	12,00,000	30,000	47	53
10000	18,00,000	36,000	45	48

From the data in Table7.2, we note four points of special significance in capacity studies : (i) An increase in plant size requires a large investment, but can lead to significant economics of scale near the full-capacity production volume. This usually results for savings in construction and equipment per unit of capacity. (ii) Fixed costs per unit become smaller, because items like utilities, supervision, insurance, etc., are almost same over a wide range of plant capacity. (iii) Certain variable costs are also allocated over more units, thus decreasing unit variable costs. (iv) Variable costs also tend to be lower in large plants due to economics in raw-materials purchases and shipping, and lower processing costs from more specialized equipment that are economical only from more specialized equipment that are economical only for large production volume. For larger plant sizes, with more advanced technology used for production, we are. in effect, substituting capital for labour, resulting in higher organizational efficiencies through application of more advanced management techniques for planning and control of operations (computer-aided scheduling, maintenance: inventory control and other functions) in most cases.

The concept of economics of scale has been a powerful force in shaping economic activities both in the private and public sector. Organizations, where this plays an important role, may come from industries, such as oil refining, steel, communications, transportation and service systems, like supermarkets, departmental stores, education, government. etc. In addition, the choice of the correct plant size must be determined not only by cost performance; but also by the level of expected demand. This requires the cost-volume-profit analysis in many cases.

7.4.2 Cost-Volume-Profit Analysis

The selection of optimum plant size given capacity requirements must be based on adequate analysis of cash flows for each alternative plant size. This in turn requires the estimation of total costs (TC) and total revenues (TR) at different production volumes for each plant size. The total costs in each case are determined from the estimates of fixed and variable costs that apply for each plant size. Total revenues are obtained from the level of expected demand and the pricing policy of the firm. Given a demand forecast for each year in the planning horizon, the plant size that maximizes the return on investment in new capacity is selected. These relationships are known through a cost-volume-profit analysis for each plant size.

Activity D

Carry out a cost-volume-profit analysis of year existing plant and critically evaluate the bottleneck exists.

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7.5 DETERMINATION OF EQUIPMENT REQUIREMENTS

After the design capacity needed for the system as a whole and the individual production stage is estimated, capacity should be translated in terms of the requirements for equipment and the workforce necessary to operate it. The procedure employed to determine these requirements for one stage (which may include a work station, or an entire department) is very straight forward, and explained in the following steps. The same procedure maybe followed to determine requirements for multi-stage production system.

7.5.1 Equipment Requirements for a Single Production Stage

In order to convert a measure of capacity into equipment requirements, we require (i) an estimate of demand for each period in the planning horizon, expressed by the number of acceptable or good or conforming units needed per period, and obtained from a detailed demand forecast; and (ii) an estimate of processing time for the work station where the equipment will be used. This is usually obtained by one of the work-measurement methods.

Let P = production rate of a work station, in units of output per period

T = processing time per unit in minutes

D = duration of an operating period in hours (for one shift,

D = 8: for two, D = 16: and for three, D = 24)

E = efficiency of equipment expressed as percentage of running time per period. This accounts for downtime due to setups, breakdown repair, or other reasons that force idleness.

N = Number of machines required by work station

The calculation of requirements is based on the formula:

$$N = \frac{T \quad P}{60 \; D.E}$$

or

$$(\text{Number of machines needed}) = (\text{processing time per unit, hour}) \left(\frac{\text{Required output rate}}{\text{Available time/period}}\right)$$

To illustrate this relationship with an example, suppose that a fabrication section of a department must supply 4000 good parts daily to another department for assembly. Processing time is 3.00 min/unit, and the equipment efficiency for two-shift daily is estimated at 80 per cent. The equipment requirements for this case will be

$$N = \frac{T \quad P}{60 \quad D.E} = \frac{3.00 \times 4000}{60 \times (16)\,(.80)} = 15.63 = 16 \text{ machines}$$

In practice the proposed method for determining equipment requirement must be used with caution. In particular, it is important to examine P and D more extensively. To estimate P correctly, we must keep in mind that the total number of units processed at a work station may consist of both conforming (non-defective) and non-conforming (defective) units in the traditional productional management system. Hence total number of units (P) is given by :

$$P = p_g + p_d$$

Where, P_g are the number of conforming units and P_d are the number of non-conforming units.

For a given operation, the number of defective units can be expressed as a percentage of defective units, p over the total number of units processed. Thus, we have,

$$P_g = P - P_d = P - \frac{P_d}{P} P = P - P^p = P(1-p)$$

$$P = \frac{P_g}{(1-p)}$$

where p is the percentage defective output of the work station.

For our example_ if the number of required conforming parts is 4000 daily, and for the work station under study, the defective output amounts to 5 per cent, the output rate must be revised as follows:

$$P = \frac{P_g}{(1-p)} = \frac{4000}{1 - .05} = 4211 \text{ units}$$

For the estimation of D. the use of 8 hours per shift is appropriate when the processing time T refers to an average required time per unit. If T represents a standard time, it includes not only the strictly productive time, but also allowances for operator fatigue, personal needs, and uncontrollable delays due to existing level of interference and other disturbances in the existing system. Therefore, when using standard times for T, the duration of an operating period must also be expressed in standard working hours. For example, if we have 25 working days per month and use two shifts, we have (2) (25) (8) = 400 actual hours. However, lithe average output rate of the workforce is 120, per cent of that based on standard times, possibly due to wage incentives or other performance enhancement schemes, the 400 hours are equivalent to (400) (1.20) = 480 standard hours per month.

The revised equipment requirements for our example, assuming that the standard processing time is 3.50 minutes will be

$$N = \frac{T_s P}{60 D_s E} = \frac{3.50 \times 4211}{60(480/25)(.80)} = 15.99 = 16.$$

where T_s = standard processing time per unit

D_s = duration of operating period in standard hours

7.5.2 Determination of the Stage Efficiency, E

Equally important, but more difficult to assess, is the efficiency of a given work-station. Efficiency, E is normally defined as:

$$E = \frac{H}{D}$$

$$= 1.00 - \frac{DT + ST}{D}$$

where E = work-station efficiency

H = expected running, time per period, in hours

D = duration of an operating period, in hours

DT = Downtime, in hours

ST = setup time for processing different orders per period, in hours.

Even with advanced production technologies. a certain percentage of an operating period is spent in forced idleness. This may arise due to the need for repair special adjustments of machines during operation, power failures. or delays in the deliveries of raw materials and other components and parts. The efficiency at a given stage depends basically on the following three factors

i) the type of equipment used:

ii) how the equipment is operated (speeds, feeds. adjustments. etc.): and

iii) the maintenance policy followed for the equip=nt.

The trend toward extensive mechanization of certain tasks or even automation of groups of operations has created complex problems in achieving reliable performance. For (term ill types of equipment. preventive maintenance can be a most effective approach for reducing, downtime due to breakdown repairs and thus increasing efficiency directly. This requires close and coordination with the function of operations scheduling to minimize the combined cost from repairs, downtime, and preventive maintenance while maintaining prompt deliveries. Another approach emphasized on the training and motivation of operators so that source or root causes of breakdown can be sensed and corrected before costly and time-consuming failures occur.

Activity E

Fabrication unit of your department should supply 5000 good parts to another department assembly. Processing time in 4 min/unit and the equipment efficiency for 3 shift daily is estimated at 80%. Calculate the equipment requirement of the department. Also calculate the revised output if the defective output amounts to 5 per cent.

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7.6 SUMMARY

Selection of the most desirable combination of products and /or services is a critical issue for any organization. Determination of the amount of productive capacity needed is also important. For specifictime frames, capacity specifies the maximum sustainable output rate if the items produced can be expressed in common units. otherwise it refers to the maximum amount of available critical resources, i.e. labour-hours, machine-hours, etc.

Productive-capacity determination provides tile unifying thread for long, medium, and short-term planning. The long-term capacity decision must lake into account how capacity will be used in the medium term, for which the maximum is fixed. but during which, demand follows pronounced seasonal fluctuations. Depending on company strategy and available production-alternatives. the design capacity may be less than what is needed to cover peak demand. The balance call be satisfied from inventories, workforce changes subcontracting or other feasible alternatives for the short run. available capacity must adjust to the random fluctuations ill demand as estimated in a forecast.

The choice of an "optimum" plant size is based on economic analysis using traditional cost-volume-profit (or break-en en) analysis. The objective here is lo balance the potential savings from economics of scale against the increased average unit costs due to under utilization of capacity in the early years of operation. '1 he same problem can also be solved under conditions of uncertainty using a decision-tree approach.

After the design capacity has been established, the requirements in equipment for each period in the planning horizon can be determined by a straightforward method which balances demand for capacity against equipment output rate. At this point. it is important to realize that a production stage must usually process more units Man estimated for final demand due to losses from defective or non-conforming output: Capacity requirements must also be adjusted to account for limited efficiency attributed to setup lime and downtime for repairs delays. etc. the analysis employed for one stage can be easily extended to cover several other stages of the manufacturing system: Adjustments arc also possible when processing times are in the form of standard times obtained from work measurement. Economics in equipment investment and operating costs are possible when machines can be shared by several items and when operators can be scheduled to alternative tasks during machine-cycle idle periods.

The methodologies usually employed to determine productive capacity over time for a manufacturing, organization may also be applicable in service organizations for capacity determination. The service systems are characterized by considerable randomness both in the pattern of units arriving for service, and in the time required to receive it. These are also known as waiting-time or queueing system. The queueing models can be used to determine capacity requirements for a service facility.

7.7 SELF-ASSESSMENT EXERCISES

1. What relationship exist between layout decisions, capacity decisions & scheduling?
2. Define and describe the operating capacity of a college of business administration. How should its capacity be measured?
3. Capacity will be modified in response to demand. Demand will be modified in response to capacity. Which of these two statement is correct? Why?
4. How would the results of a decision free analysis will be affected if people made announcing probability estimates? Demonstrate with an examples.
5. Outline the units and drawbacks of incremental capacity changes and large lump changes.
6. Suppose you were considering expanding the local fire fighting system. Show what factors should be considered and how you would relate them to one another in your analysis.
7. Water sight Tours. Inc., is deciding whether to hire an additional boat machine on to just keep their one current machanic. Their two tourist boats have daily failure probabilities of 0.04 and 0.08, respectively. With one boat out of commission, the company loses $ 400 /hr; the operating loss in $ 900/hr. When both boats are inoperable. The lime for a mechanic to repair one boat is four hours.

   Two mechanics working together can repair a boat in three hours. The second mechanic can be employed at a daily wage of $ 201) should watersight hire the second mechanic? if so. how should the mechanics be used if both boats fail Simultaneously?
8. A manufacturer of dishware is considering three alternative plant size. Demand depends upon the selling price of the product; cost of manufacture depend on the sic of the plant scheduled. Demand is expected to be as follows:

   Demand probabilities:

	Selling price/set of dishware		
Annual demand (in sets of dishware)	$ 60	$ 42	$ 40
10,000	0.2	0.1	0.05
20,000	0.4	0.4	0.25
30,000	0.3	0.4	0.40
40,000	0.1	0.1	0.30

Anticipated operating costs for the three plant sizes for different levels of operations are:

Variable manufacturing cost /unit

Level of plant operations (in units of output)	Plant size		
	Small	Medium	Large
10,000	$21	$25	$32
20,000	16	14	18
30,000	19	13	12
40,000	26	18	14
Annual fixed cost of operation	$4.00,000	4.20,000	$ 5.00,000

Which alternative is most attractive on the basis of annual net earning?

9. How would you answer to problem 8 change of variable manufacturing costs were changed to those shown below?

Variable manufacturing cost/unit

Level of plant operation	Plant size		
(in Units of output)	Small	Medium	Larg
10,000	$21	$20	$25
20,000	19	16.	18
30,000	19	15	10
40,000	23	18	12

10. Work Centre 17 has the following input/output table and a standing backlog of 130 hrs. what would be backlog be at the end of the third week?

	1	23	45		6
Planned input	300	300300	300300	.	300
Actual input	305	305305	305155		150
Planned output	310	310310	300300		300
Actual output	290	290290	290190		150

What would be the backlog be at the end of the third week if planned rates had been met?

11. An industrial engineer has been complaining that the workers in work centre 17 (in problem 10) are lazy. As evidences, she displays data showing that they are working at half their capacity. What could be your explanation?

7.8 FURTHER READINGS

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