CHAPTER TWELVE

Aggregate Planning and Master Production Scheduling

Learning Objectives

After reading this chapter, you should be able to:

- Know the meaning of aggregate planning
- Know the objectives of aggregate planning
- Understand the importance of aggregate planning
- Discuss the steps in aggregate capacity planning
- Discuss the approches to aggregate planning
- Define the term "Rough-cut capacity planning
- Discuss the various types of capacity
- Define the term "capacity planning" and "capacity requirement planning"
- Describe the capacity requirement planning process
- Explain functions of master production schedule.

Environmental conditions and forecasts of future levels of demand are important inputs into long-term strategic planning and into shorter-term plans and decisions. Companies need to make investment in people, technology, R & D and capital assets in order to remain in business for the long run. Strategic planning therefore involves a long-term capacity plan that establishes some expectation of capacity which will be available to meet future demand. A company's strategic success depends on the amount and type of capacity it acquires and develops over time. Capacity affects the company's ability to meet market demand, the types of market it can enter and its ability to compete in those markets.

I AGGREGATE PLANNING

Aggregate planning involves planning the best quality to produce in the intermediate-range horizon (3 months to one year)

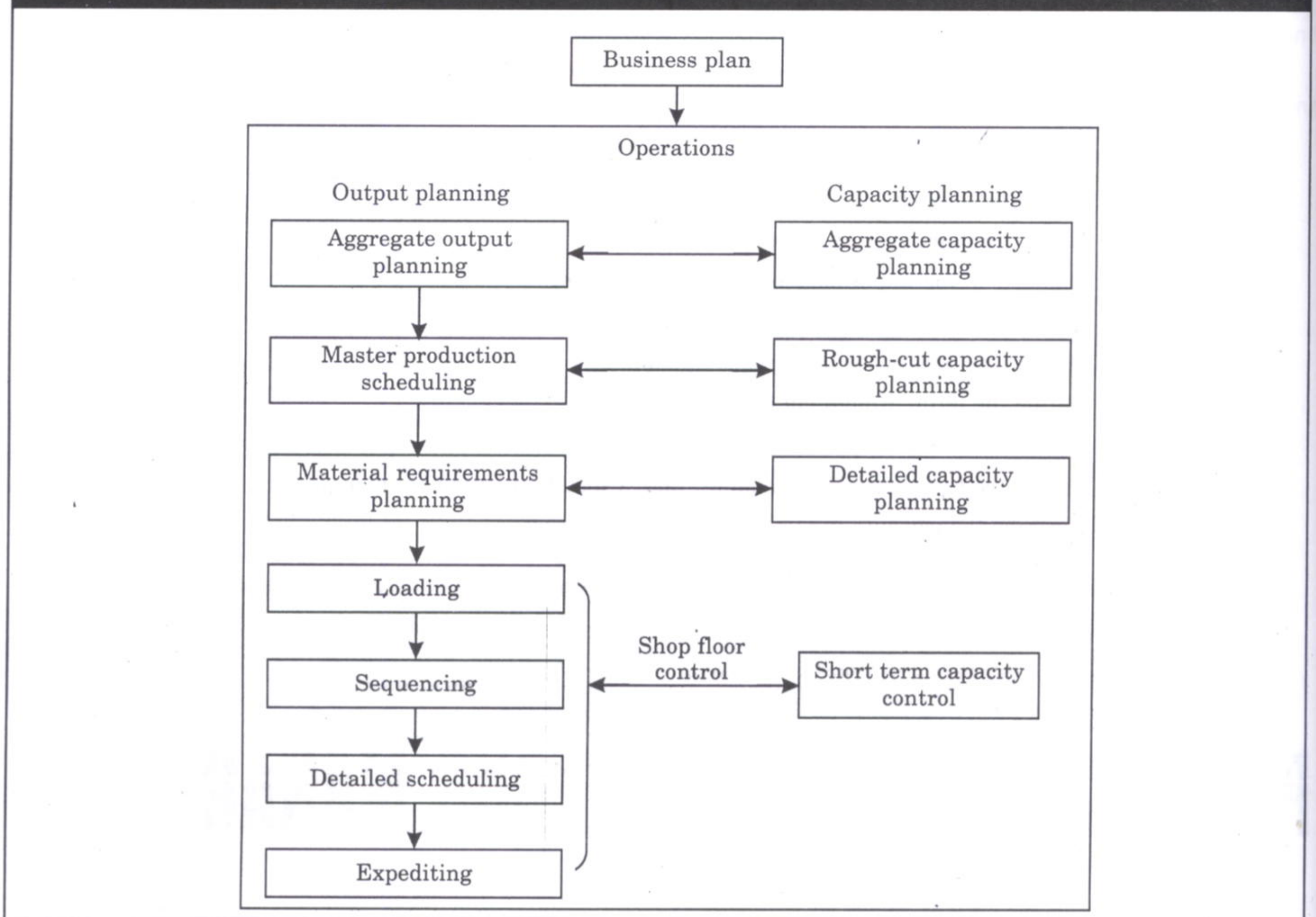
Aggregate planning involves planning the best quantity to produce during time periods in the intermediate-range horizon (often 3 months to 1 year) and planning the lowest cost method of providing the adjustable capacity to accommodate the production requirements. For manufacturing operations, aggregate planning involves planning workforce size, production rate (work hours per week) and inventory levels.

Operations Planning and Scheduling Systems

Operations planning and scheduling systems are concerned with the volume and timing of outputs, the utilization of operations capacity and balancing outputs with capacity at desired levels of competitive effectiveness.

Exhibit 12.1 illustrates the operations planning and scheduling system.

Exhibit. 12.1 The Operations Planning and Scheduling System



Aggregate Production (output) Planning

Aggregate production planning is the process of determining output levels of product groups over the next 6 to 18 months period.

It is the process of determining output levels (units) of product groups over the next 6 to 18 months period on a weekly or monthly basis. The plan indicates the overall level of outputs supporting the business plan.

Aggregate production planning determines the resource capacity a firm will need to meet its demand over an intermediate time horizon (6 to 12 months) in the future. The aggregate plan (also called a production plan) is a statement of a firm's production rates, work-force levels and inventory holding based on estimates of customer requirements and capacity limitations. The aggregate plan of a manufacturing firm is time phased (*i.e.*, projected for several time periods such as months into the future) and focuses on production rates and inventory holding whereas the aggregate plan of a service firm focuses on staffing and other employee-related factors.

The Concept of Aggregation

Aggregate planning is essentially a "big picture" approach to planning. We use the term *aggregate* plan because the plans are developed for product lines or product families rather than individual products. *For example,* aggregate plan in a firm producing television sets specifies how many television sets are to be produced without identifying them by size or model. Resource capacity is also expressed in aggregate terms, as labour or machine hours without specifying the type of labour or type of machine and they may be given only for critical machines or work centres.

Objectives of Aggregate Planning

(i) The overall objective is to balance conflicting objectives involving customer service, work force stability, cost and profit.

(ii) To establish company-wide strategic plan for allocating resources.

(iii) To develop an economic strategy to meet customer demand.

The Purpose and Scope of Aggregate Planning

Aggregate planning begins with a forecast of aggregate demand for a product, over the intermediate time horizon. Then a general plan is prepared to meet the demand requirement by setting output, work force and finished goods inventory levels. Alternate plans must be examined in light of feasibility and cost.

Within the intermediate time horizon (6 to 12 months) of the production plan, it is usually not feasible to increase capacity by building new facilities or purchasing new equipments. However, it is feasible to hire or lay-off workers, increase or reduce the working hours (add an extra shift, sub contract, use overtime) or build up or deplete inventory levels.

Inputs to and Outputs from Planning

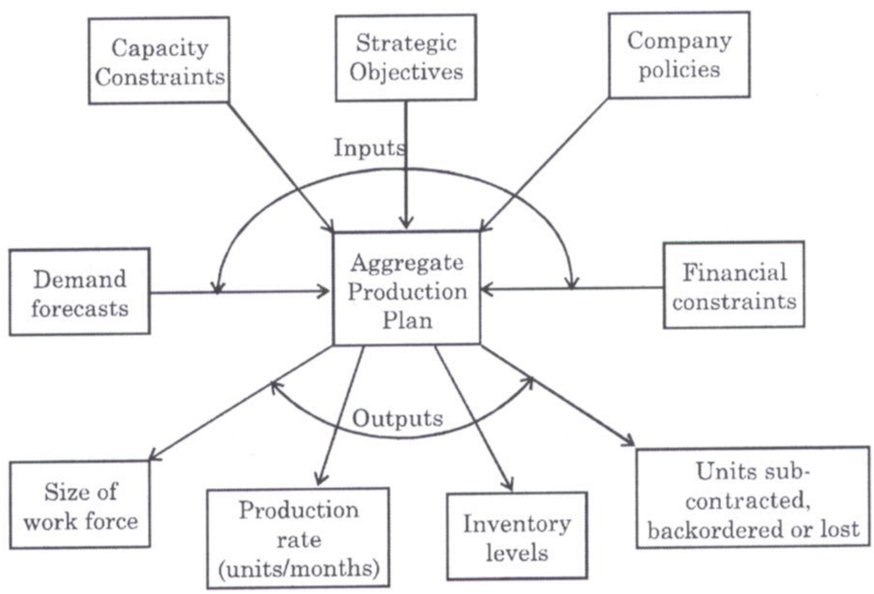
Effective aggregate planning requires good information such as *(i)* available resources over the planning period, *(ii)* forecast of expected demand and *(iii)* the policies regarding changes in employment levels (*i.e.*, hiring and lay-offs).

The inputs to aggregate planning are : *(i)* Resources (work force/production rates, facilities and equipment), *(ii)* Demand forecast, *(iii)* Policy statements on workforce changes, *(iv)* Subcontracting, *(v)* Overtime, *(vi)* Inventory levels/changes, *(vii)* Back orders and *(viii)* Costs-inventory carrying cost, back order cost, hiring/lay off cost, overtime cost, inventory changes cost and subcontracting cost.

The outputs from aggregate planning are *(i)* total cost of a plan, *(ii)* projected levels of inventory, output, employment, subcontracting and back ordering.

Exhibit 12.2 shows the inputs to and outputs from aggregate production planning.

Exhibit 12.2 : Inputs to and Outputs from Aggregate Production Planning



Importance of Aggregate Plans

The various inputs to aggregate plans that affect the performance of production and operations managers are:

(i) **Engineering** – New products, product design changes and machine standards

(ii) **Materials** – Supplier capabilities, storage capacity and materials availability

(iii) **Operations** – Current machine capacities, plans for future capacities, work force capacities and current staffing level.

(iv) **Marketing and distribution** – Customer needs, demand forecasts and competition behaviour.

(v) **Accounting and finance** – Cost data and financial condition of the firm.

(vi) **Human resources** – labour market conditions, and training capacity.

The many functional areas that provide input to the aggregate plan have conflicting objectives for the use of the firm's resources. These objectives are:

(i) Minimise costs/maximise profits : Minimising costs will result in maximisation of profits if customer demand is not affected by the aggregate plan.

(ii) Maximise customer service : Additional work force, machine capacity or inventory resources are required to improve delivery time and to achieve on-time deliveries in order to maximise customer service.

(iii) Minimise inventory investment : Excessive inventory is expensive because the capital tied up in the form of inventory could be used for more productive investments.

(iv) Minimise changes in production rates : Frequent changes in production rates may cause difficulty in coordinating the procurement of materials and require rebalancing of production line.

(v) Minimise changes in workforce levels : Fluctuating work force levels may reduce labour productivity because of the time needed to train new employees to become fully productive.

(vi) ***Maximise utilisation of plant and equipment :*** Process based on a line-flow strategy require uniformly high utilisation o f plant and equipment. Balancing these conflicting objectives to arrive at an acceptable aggregate plan involves consideration of various alternatives.

The basic types of alternatives are *(i)* **reactive alternatives** and *(ii)* **aggregessive alternatives**. Reactive alternatives are actions that respond to given demand patterns whereas aggressive alternatives are actions that adjust demand patterns. Reactive alternatives include

(i) ***Work force adjustment*** (*i.e.,* hiring or laying off).

(ii) ***Anticipation inventory*** – accumulating inventory during light demand periods and using it during heavy demand periods.

(iii) ***Work force utilisation*** – involves over time and under time (idling).

(iv) ***Subcontracting*** – Used to overcome short-term capacity shortages.

(v) ***Backlogs, back orders and stock outs :*** Backlog of orders grows during periods of high demand and reduces during periods of low demand. Generally back orders and stock outs are to be avoided.

Aggressive alternatives are actions that attempt to modify demand and consequently resource requirements. These include actions such as *(i)* producing complementary products to even out the load on resources and *(ii)* using promotional campaigns designed to increase sales with creative pricing.

AGGREGATE PLANNING OR AGGREGATE CAPACITY PLANNING

It is the process of devising a plan for providing a production capacity scheme to support the intermediate range sales forecast.

As forecasted demand becomes known in the form of customer orders, aggregate capacity plans may have to be revised upward and downward to avoid either overloaded or underloaded facilities.

Need for Aggregate Capacity Planning

1. It facilitates fully loaded facilities and minimizes overloading and underloading and keeps production costs low.
2. Adequate production capacity is provided to meet expected aggregate demand.
3. Orderly and systematic transition of production capacity to meet the peaks and valleys of expected customer demand is facilitated.
4. In times of scarce production resources, getting the maximum output for the amount of resources is enhanced.
5. To manage change in production/operations management by planning for production resources that adapt to the changes in customer demand.

Steps in Aggregate Capacity Planning

A general procedure for aggregate planning consists of the following steps:

(i) Determine the demand (*i.e.,* sales forecast) for each product for each time period (*i.e.,* weeks or months or quarters) over the planning horizon (6 to 12 months).

(ii) Determine the aggregate demand by summing up the demand for individual products.

(iii) Transform the aggregate demand for each time period into workers, materials, machines required to satisfy aggregate demand.

(iv) Identify company policies that are pertinent (*e.g.,* policy regarding safety stock maintenance, maintaining stable workforce etc.).

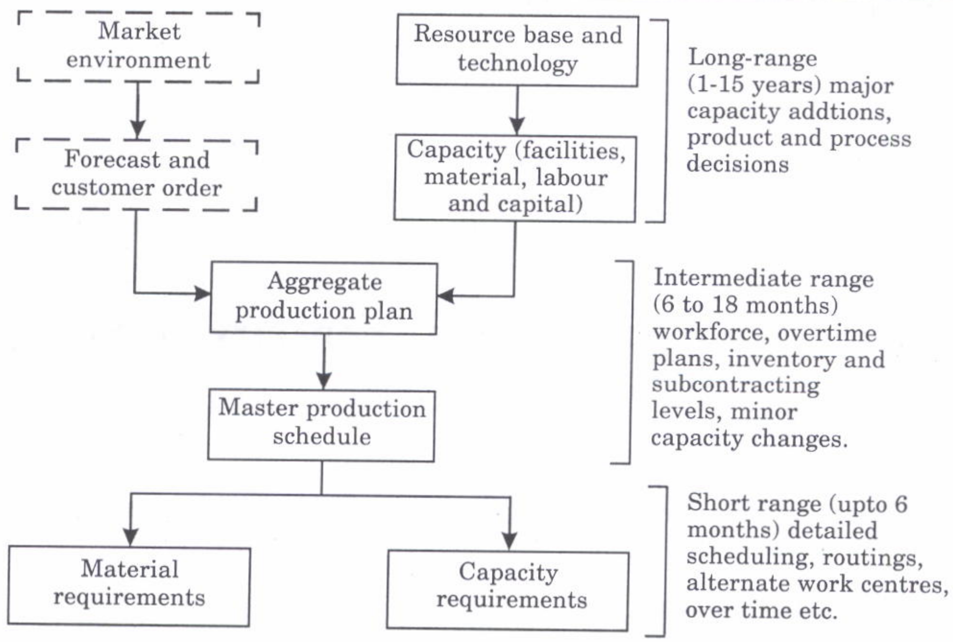
(v) Determine unit costs for regular time, overtime, subcontracting, holding inventories, back orders, layoffs etc.

(vi) Develop alternative resource plans for providing necessary production capacity to support the cumulative aggregate demand and compute the cost of each alternative plan.

(vii) Select the resource plan from among the alternatives considered that satisfies aggregate demand and best meets the objectives of the firm.

Exhibit 12.3 illustrates how aggregate planning links long-range, intermediate range and short range planning activities.

Exhibit 12.3 : Flow Chart of Aggregate Plan and Master Production Schedule



COSTS ASSOCIATED WITH AGGREGATE PLANNING

The choices concerning aggregate production, workforce and inventory levels influence several relevant costs. These costs need to be identified and measured so that alternative aggregate plans can be evaluated on a total cost criterion.

Some of the cost items that may be relevant are:

(a) Pay roll costs,

(b) costs of overtime, second shifts and subcontracting,

(c) costs of hiring and laying off workers,

(d) costs of excess inventory and backlog,

(e) costs of production rate changes.

APPROACHES TO AGGREGATE PLANNING

An aggregate plan takes into consideration the overall level of output and the capacity that is required to produce it. There are two basic approaches to estimating the capacity that will be required to produce an aggregation or grouping of a company's products.

Two approches to aggregate planning are:
- Top-Down approach
- Bottom-up approach.

1. ***Top down approach*** to aggregate planning involves development of the entire plan by working only at the highest level of consolidation of products. It consolidates the products into an average product and then develops one overall plan. This plan is disaggregated to allocate capacity to product families and individual products.
2. ***A bottom-up approach*** or ***subplan consolidation approach****,* involves development of plans for major products or product families at some lower level within the product line. These subplans are then consolidated to arrive at the aggregate plan which gives the overall output and the capacity required to produce it.

The bottom-up approach is more widely used. This approach starts with plans for major products or product families and aggregates (sums) the impact that these plans have on the capacity of the company. If the capacity requirements for individual plans appear to sum up to a satisfactory overall use of the company's resources, the plans are accepted to be implemented. If not, some of the individual plans are revised to improve the overall impact of the aggregate plan. Individual plans are revised until a desirable aggregate plan is evolved.

In top down approach, an overall or aggregate rate of production is developed, which is then allocated to the individual components (*i.e.*, disaggregated)

Top down Aggregate Planning

With the top down approach, the desirable overall plan is developed for the periods in the planning horizon, with the plan for the first few periods being fairly firm. This approach rests on the assumption that if the proper amount of total capacity is available, the right amount of capacity for all of the parts will be available.

Aggregate plan for a top down approach is performed in terms of a pseudo product which is a fictitious product that represents the average characteristics of the entire product line to be planned. However difficulties may arise in disaggregation if the product mix varies overtime and the different products require different production resources.

Bottom-up Aggregate Planning

This is also called as resource requirement planning (sometimes called rough-cut capacity planning) which is usually used in conjunction with material requirement planning (MRP-1). Both capacity and materials must be available for products to be made and hence material plans need to be coordinated with a more detailed production plan.

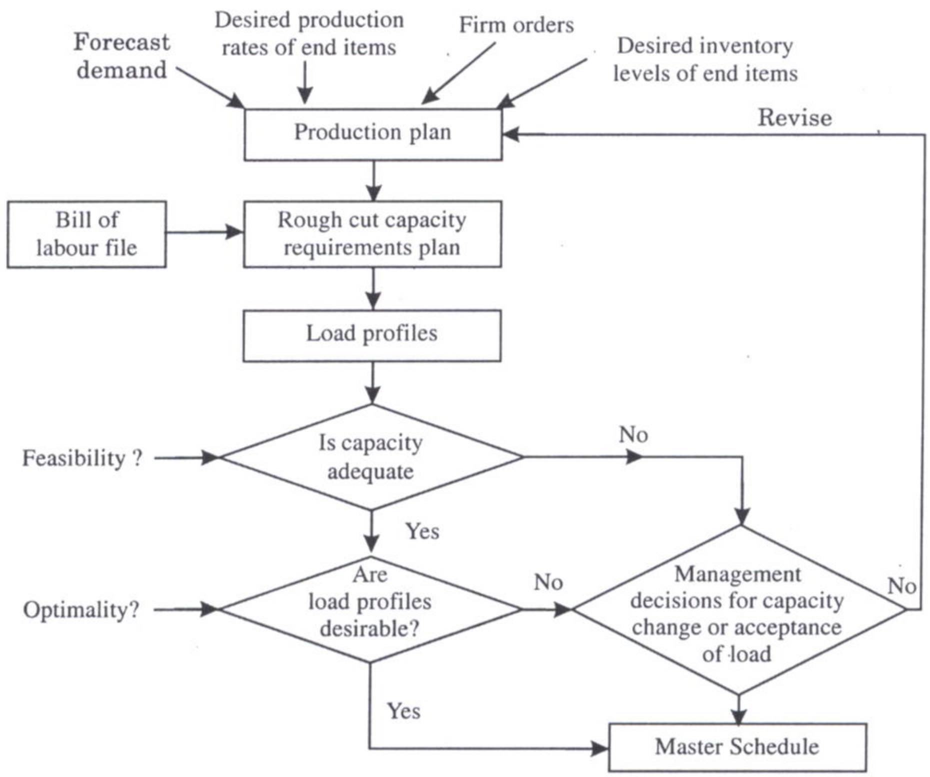
ROUGH-CUT CAPACITY PLANNING

This is done in conjunction with the tentative master production schedule to test its feasibility in terms of capacity before the master production schedule (MPS) is finalised.

This ensures that a proposed MPS does not inadvertently overload any key department, workcentre or machine, making the MPS unworkable. Although the check can be applied to all work centres, it is typically applied only to the critical work centres that are most likely to be bottlenecks. It is a quick and inexpensive way to find and correct gross discrepancies between the capacity requirements of the MPS and the available capacity.

Exhibit 12.4 illustrates the flow chart for rough-cut capacity planning process.

Exhibit 12.4 : Flow Chart for Rough-cut Capacity Planning



CAPACITY PLANNING AND CAPACITY REQUIREMENT PLANNING (CRP)

Facility planning includes determination of how much long-range production capacity is needed, when additional capacity is needed, where production facilities should be located and the layout and characteristics of the facilities.

Definition of Production Capacity

Production capacity is defined as the maximum production rate of a facility or a plant.

Capacity in general is the maximum production rate of a facility or a firm. It is usually expressed as volume of output per period of time.

Capacity indicates the ability of a firm to meet market demand.

Operations managers are concerned with capacity because

(a) They want sufficient capacity to meet customer demand in time.

(b) Capacity affects cost efficiency of operations, the ease or difficulty of scheduling output and the costs of maintaining the facility.

(c) Capacity requires an investment of capital.

Types of Capacity

1. **Fixed capacity :** The capital assets (buildings and equipments) the company will have at a particular time are known as the fixed capacity. They cannot be easily changed within

the intermediate range time horizon. Fixed capacity represents an upper limit to the internal capacity that the company can use in its efforts to meet demand.

Various types of capacity are:
- Adjustable Capacity
- Design Capacity
- System Capacity
- Potential Capacity
- Immediate Capacity
- Effective Capacity
- Rated Capacity
- Utilised Capacity.

2. **Adjustable capacity :** It is in the size of the workforce, the number of hours per week they work, the number of shifts and the extent of subcontracting.
3. **Design capacity** of a facility is the planned rate of output of goods or services under normal or full-scale operating conditions. It is also known as installed capacity. It sets the maximum limit to capacity and serves to judge the actual utilization of capacity.
4. **System capacity** is the maximum output of a specific product or product-mix that the system of workers and machines *i.e.,* the productive system is capable of producing as an integral whole. It is less than or equal to the design capacity of the individual components because the system may be limited by,

   (a) the product-mix

   (b) quality specifications

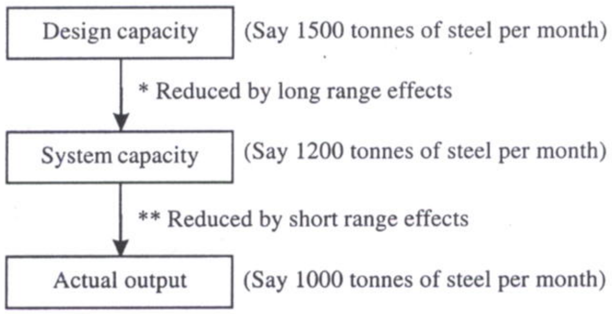
   (c) the current balance of equipment and labour
5. **Potential capacity** is that which can be made available within the decision horizon of the top management.
6. **Immediate capacity** is that which can be made available within the current budgeted period.
7. **Effective capacity** is the capacity which is used within the current budget period. It is also known as practical capacity or operating capacity. No plant can work upto the maximum or the theoritical capacity (installed or designed capacity) because of loss of capacity due to scheduling delays, machine breakdown, and preventive maintenance. This results in the plant working at an efficiency less than 100%. Also the actual output will be less than the designed output due to rejections and scrap.

$$\text{Practical capacity} = \begin{cases}\text{Theoretical capacity minus capacity lost} \\ \text{due to inefficiency and scrap factor}\end{cases}$$

   Usually the practical capacity ranges from 75% to 85% of theoretical capacity.
8. **Normal capacity or rated capacity :** This is the estimated quantity of output or production that should be usually achieved as per estimation done by Industrial Engineering department. Actual capacity is usually expressed as a percentage of rated capacity. *For example,* the rated capacity of a steel plant may be expressed as 1 lakh tonnes of steel per month. This is also sometimes called as average capacity of the plant.
9. **Actual or utilised capacity :** This is the actual output achieved during a particular time period. The actual output may be less than the rated output because of short-range factors such as actual demand, employee absenteeism, labour inefficiency and low productivity levels.

Exhibit 12.5 illustrates the relationship between design capacity, system capacity and actual output.

Exhibit 12.5 : Relationship Between Capacities and Output



* Long-range effects : Product-mix, long-range market conditions, tight quality specifications, inherent imbalance between equipment and labour.

** Short-range effect : Actual demand, managerial performance *viz.*, scheduling, staffing, strategy and control, labour inefficiencies, wear scrap loss, machine breakdown etc.

System Eficiency: Ratio of the actual measured output of goods/services to the system capacity.

System efficiency is the ratio of the actual measured output of goods/services to the system capacity

$$\text{System efficiency} = \frac{\text{Actual output}}{\text{System capacity}}$$

Measurement of Capacity

Capacity of a plant can be expressed as the rate of output viz., units per day or per week or per month, tonnes per month, gallons per hour, labour hours/day, etc. But for organizations whose product lines are more diverse, it is difficult to find a common unit of output. More appropriate measure of capacity for such firms is to express the capacity in terms of money value of output per period of time (day, week or month)

Capacity may be measured in terms of inputs or outputs of the conversion process. Some of the examples of common measures of capacity are given below:

Organization		Measure of capacity	
Automobile factory	—	No. of vehicles	Output rate capacities
Steel mill	—	Tonnes of steel	
Power plant	—	Megawatts of electricity generated	
Brewery	—	Barrels of beer	
Job shop	—	Labour hours worked	
Airline	—	No. of seats	Input rate capacities
Hospital	—	No. of beds	
Movie theatre	—	No. of seats	
Restaurant	—	No. of seats	
University	—	No. of students	
Warehouse	—	Cubic space of storage space	
	—	(in cubic metre)	
Bank	—	No. of accounts	

Capacity Decisions

Capacity Decisions:
- What size of plant?
- When Capacity is needed?
- At what cost?

Major considerations in capacity decisions are

(a) What size of plant? How much capacity to install?

(b) When capacity is needed? When to phase-in capacity or phase-out capacity?

(c) At what cost? How to budget for the cost?

Determination of Capacity

Capacity determination is a strategic decision in plant planning or factory planning. Capacity decisions are important because

(a) They have a long term impact

(b) Capacity determines the selection of appropriate technology, type of labour and equipments, etc.

(c) Right capacity ensures commercial viability of the business venture.

(d) Capacity influences the competitiveness of a firm.

Factors Affecting Determination of Plant Capacity

1. Market demand for a product/service.
2. The amount of capital that can be invested.
3. Degree of automation desired.
4. Level of integration (*i.e.*, vertical integration).
5. Type of technology selected.
6. Dynamic nature of all factors affecting determination of plant capacity, viz., changes in product design, process technology, market conditions and product life cycle, etc.
7. Difficulty in forecasting future demand and future technology.
8. Obsolescence of product and technology over a period of time.
9. Present demand and future demand both over short-range, intermediate range and long-range time horizons.
10. Flexibility for capacity additions.

Interrelationship Between Capacity and Other Issues

1. **Relationship between capacity and location decisions :** Decisions about capacity are often inseparable from location decisions. Usually capacity is expanded by installing new units at new locations taking into considerations location factors such as market segment, transportation costs, location of competitors, etc.
2. **Relationship between capacity and plant layout :** The plant capacity determines the physical relation between various processes used in the conversion process which in turn determines the layout of the plant. In product-layout or product-focused productive system, the capacities of various work centres or machines have to be balanced to get approximately the same rate of output from various work centres or machines. Once the layout is installed it is not possible to change the capacity in the short term time horizon.
3. **Relationship between capacity and process design :** In some cases, the rated capacity depends on the type of conversion process selected. *For example,* the conversion processes selected for manufacture of steel is different for mini steel plants from that used for major steel plants.

4. **Relationship between capacity and equipment selection :** The installed capacity of plant determines the standard labour or equipment hours that can be achieved and also determines the number of machines or equipments that must be installed to get the desired output capacity.

I CAPACITY PLANNING

Capacity planning is concerned with defining the long term and short term capacity needs of a firm and determining how these needs will be met.

The Need for Capacity Planning

Capacity planning is necessary when an organization decides to increase its production or introduce new products into the market. Once capacity is evaluated and a need for new or expanded facilities is determined, decisions regarding facility location and process technology selection are taken.

Capacity Planning Decisions

Capacity planning involves activities such as:

(a) Assessing existing capacity

(b) Forecasting future capacity needs

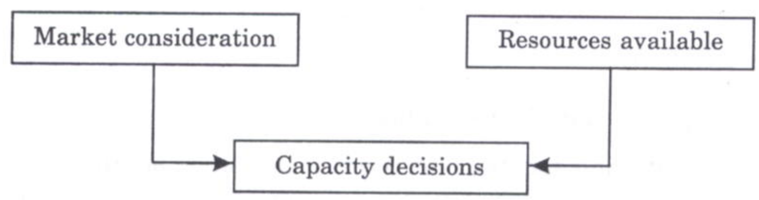
(c) Identifying alternative ways to modify capacity

(d) Evaluating financial, economical and technological capacity alternatives

(e) Selecting a capacity alternative most suited to achieve the strategic mission of the firm. Capacity planning involves capacity decisions that must merge consumer demands with human, material and financial resources of the organization.

Exhibit 12.6 illustrates the inputs to capacity decisions.

Exhibit 12.6 : Inputs to Capacity Decisions



Classification of Capacity Planning

4 Types of Capacity Planning are:
- **Long term Capacity Planning**
- **Short-term Capacity Planing**
- **Finite Capacity Planning**
- **Infinite Capacity Planning.**

Capacity planning can be classified as:

(a) Long-term capacity planning } based on time horizon
(b) Short-term capacity planning

(c) Finite capacity planning } based on amount of resources employed.
(d) Infinite capacity planning

Long-term and Short-term Capacity Planning

Long-term or long-range capacity planning is concerned with accommodating major changes that affect the overall level of output in the longer run. Major changes could be decisions to develop new product lines, expand existing facilities and construct or phase out production plants.

Short-term or short-range capacity planning is concerned with responding to relatively intermediate variations in demand. In the short-term planning horizon, capacity concerns involve the fluctuations in demand caused by seasonal or economic factors.

Ways of adjusting the capacity to the varying demand in the short-term time horizon are:

(i) Use of overtime or idle time

(ii) Increasing the number of shifts per day to meet a temporary strong demand.

(iii) Subcontracting to other firms.

Service industries use flexible work hours, part-time employees and overtime work scheduling to meet peaks in demands.

Finite and Infinite Capacity Planning

In operations planning, two conflicting constraints are time and capacity. If time is fixed by customer's required delivery date or processing cycle, it is possible to accept time as the primary constraint and plan backwards to accommodate these times. In such cases, planning backwards to infinite capacity offers a potential solution to the problem. On the other hand, if the processing time is not a constraint in cases where products are produced to stock and sell, it is simpler to use a forward plan based on finite capacity *i.e.,* based on available resources.

Factors Affecting Capacity Planning

The capacity variables are:

(a) Controllable factors such as amount of labour employed, facilities installed, machines, tooling, shifts worked per day, days worked per week, overtime work, subcontracting, alternative routing of work, preventive maintenance and number of production set ups.

(b) Less controllable factors are absenteeism, labour performance, machine breakdowns, material shortages, scrap and rework and unexpected problems such as strike, lockout, fire accidents, etc.

Two catagories of factors affecting capacity planning are:
- **Controllable Factors**
- **Less Controllable Factors.**

Ways of Changing Capacity

Once the long-range capacity needs are estimated through long-range forecasts there are many ways to provide for the needed capacity. Firms may have a capacity shortage situation where present capacity is insufficient to meet the forecast demand for their products and services or have excess capacity *i.e.,* capacity in excess of the expected future needs.

Long-range capacity planning hence may require either expansion or reduction of present capacity levels. *Table 12.2* lists some of the ways by which changing long-range capacity needs of organization can be met.

CAPACITY REQUIREMENT PLANNING (CRP)

Capacity requirement planning is a technique for determining what labour/personnel and equipment capacities are needed to meet the production objectives symbolised in the master production schedule (MPS) and the Material requirement Planning (MRP-I)

Capacity Requirement Planning: A technique to determine the labour and equipment capacities needed to meet the objectives.

MRP-I and CRP establish specifically what materials and capacities are needed and when they are needed.

Table 12.1 : Capacity Time Horizons

Time Frame	Technique and Strategies	Applies to
1. Long-range	Resource planning of land, facilities, equipment and human resources. Involves strategy of changing facilities and employment levels over long-range time horizon.	Business/ corporate objectives
2. Medium-range	(*a*) Resource requirement planning of total resources needed to satisfy master production schedule (*i.e.*, MRP-II), uses load profiles for each product and simulation of alternative MPS. Managing through work force re-allocation, inventory and back order and subcontracting strategies. (*b*) Capacity requirement planning of labour and equipment in key work centres (uses finite loading) managing through employment and work force re-allocation inventory, subcontracting, make or buy decisions, alternative routing and more tooling	Aggregate plans and MPS items (*i.e.*, end products) MRP Items
3. Short-range	Capacity control of inputs-output and operation sequencing (uses finite loading) Managing via overtime, idle time, workforce reallocation, sub-contracting and alternative toolings.	Production activity control

Table 12.2 : Ways of Changing Long-range Capacity

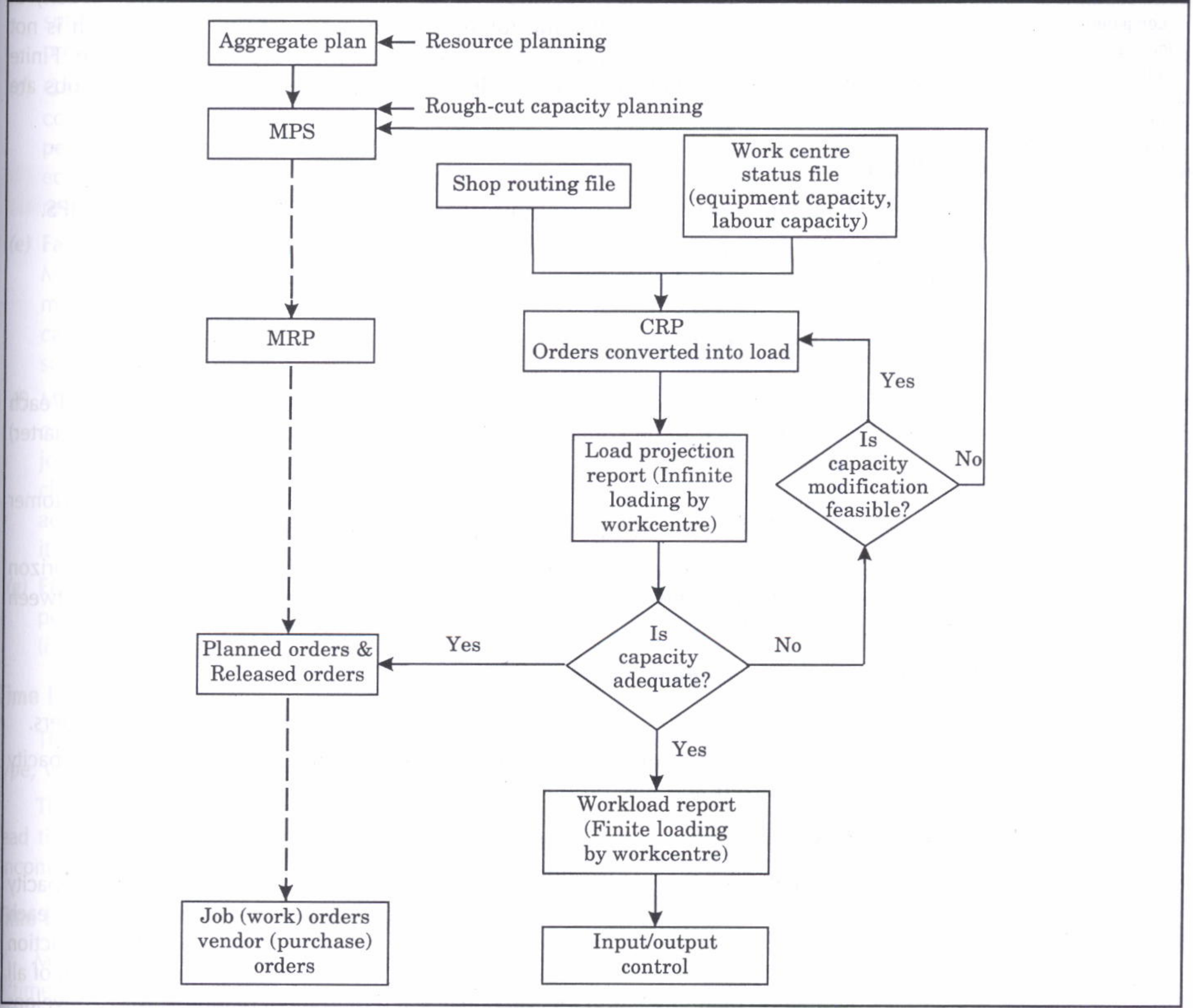
Types of capacity change	Ways of accommodating long-range capacity changes
1. Expansion	(*a*) Subcontracting with other companies to become suppliers of the expanding firm's components or entire products. (*b*) Acquiring other company's facilities or resources (*c*) Developing new sites, building new buildings, buying new equipments (*d*) Reactivating facilities on stand-by status
2. Reduction	(*a*) Selling off existing facilities, selling inventories and laying off or transferring employees to other units. (*b*) Developing and phasing in new products as demand for other products decline.

Capacity Requirement Planning (CRP) Process

Exhibit 12.7 describes the CRP process in a schematic form (flow chart). End item requirements arising from the aggregate plan and MPS are exploded into tentative planned orders for components by the MRP system.

The CRP system converts those orders into standard labour and machine hours of load on the appropriate workers and on the machines as identified from the work centre status and shop routing files. The output is a load-projection report work centre wise. If the work centre capacities are adequate, the planned order releases are verified for the MRP systems and released orders become purchase and shop orders. Work load reports are also used for controlling input and outputs. If the initial load projection report reveals inadequacy of capacity in any work centre, either the capacity must be increased (by using overtime or sub contracting) or the master production schedule must be revised.

Exhibit 12.7 : Capacity Requirement Planning Process (Flow Chart)



CRP Inputs

The major inputs for CRP process are:

(a) Planned orders and released orders from MRP system

(b) Loading information from the work centre status file

(c) Routing information from the shop routing file

(d) Changes which modify capacity, give alternative routings or altered planned orders.

All these input must be given in time if the system is to function effectively.

Planning activity : Infinite loading and finite loading.

Infinite loading is the process of loading work centres with all the loads when they are required without regard to the actual capacity of work centres. This given information about actual released order demand upon the production system so that decisions about overtime, using alternative routings, delaying selected orders, etc., can be taken.

Infinite Loading: Process of loading work centres with all the loads when they are required without regard to the actual capacity of work centres.

Finite Loading: Done automatically with computerised loading system limiting the load assigned to work centres in each period as per the available capacity at each work centre.

Finite loading can be done automatically with computerized loading systems, limiting the load assigned to work centres in each period as per the installed/available capacity at each work centre. This method of loading forces changes back into the MPS which is not always the best solution to scheduling problems and hence not useful at CRP stage. Finite loading is more useful to single workcentres in the capacity control stage where jobs are being scheduled.

CRP Outputs

1. Rescheduling information which call for capacity modifications or revision of MPS.
2. Verification of planned orders for MRP system
3. Load reports

MASTER PRODUCTION SCHEDULING

Master Production Schedule: Sets the quantity of each finished product to be completed in each time period of the short range planning horizon.

The master schedule (or master production schedule or MPS) sets the quantity of each end item (finished product) to be completed in each time period (week or month or quarter) of the short range planning horizon.

Master production schedules are developed by reviewing market forecasts, customer orders, inventory levels, facility loading and capacity information regularly.

The MPS is a plan for future production of end items over a short-range planning horizon that usually spans from a few weeks to several months. It is an important link between marketing and production.

Objectives of Master Production Scheduling

1. To schedule end items to be completed promptly and when promised to customers.
2. To avoid overloading or underloading the production facility so that production capacity is efficiently utilized and low production costs result.

Functions of Master Production Schedule

Functions of MPS:
- Translating aggregate plans
- Evaluating alternative master schedules
- Generating material and capacity requirements
- Facilitating information processing
- Maintaining priorities
- Utilizing the capacity effectively.

The MPS formalizes the production plan and converts it into specific material and capacity requirements. This leads to the assessment of labour, material and equipment needs for each job. Then the MPS derives the entire production and inventory system by setting production targets and responding to feed back from all downstream operations. It is the beginning of all short-range production planning. From the MPS, material requirement planning (MRP) develops short-range schedules for producing parts that go into the end items in every work centre of the production system. The MRP develops short-range plans for purchasing the raw materials and components that are required to produce the products.

Some key functions of MPS are:

(a) **Translating aggregate plans :** The aggregate plan sets the level of operations that roughly balances market demands with the material, labour and equipment capabilities of the firm. The aggregate is translated into specific number of end products to be produced in specific time periods. Products are grouped into economical lot sizes that can realistically load the firm's facilities. The MPS represents a manufacturing plan of what the firm intends to produce and not the forecast of what the firm hopes to sell.

(b) **Evaluating alternative master schedules :** Master scheduling is done on a trial and error basis. Trial-fitting of alternative MPS can be done by simulation using computers. Detailed material and capacity required are then derived from the firm MPS.

(c) **Generating material requirements :** The MPS is the prime input to the MRP-1 system. The MRP-1 system provides for purchasing or manufacturing the necessary items in sufficient time to meet the final assembly dates specified based on the MPS for end products.

(d) **Generating capacity requirements :** Capacity needs arise for manufacturing the components in the required time schedule to meet the requirements of end products as per MPS. Capacity requirement planning is based on the MPS which should reflect an economic usage of labour and equipment capacities. Master schedules will have to be revised when capacity requirements are inadequate.

(e) **Facilitating information processing :** By controlling the work load on work centres, the MPS determines the delivery schedules for end products both for make-to-stock and make-to-order items. It co-ordinates other management information such as marketing capabilities, financial resources (for carrying inventory) and personnel policies (for supplying labour)

(f) **Maintaining valid priorities :** The absolute or relative priorities for various jobs to be completed should reflect the true needs. This means that the due date and the ranking of jobs should correspond with the time the order is actually needed. When customers change their orders or materials get scrapped sometimes, either the components are not actually needed or end items cannot be produced because of shortage of some materials, it is necessary that the MPS should be modified to reflect this change.

(g) **Effectively utilizing the capacity :** By specifying the end item requirements over a time period, the MPS establishes the load and utilization parameters for labour and equipment (*i.e.*, shifts worked or overtime or idle time)

Time Interval and Planning Horizon for MPS

The time interval used (*for example,* weekly, monthly, or quarterly) depends upon the type, volume and component lead times of the products being produced.

The time horizon covered by the MPS also depends upon product characteristics and lead times. The time horizon may vary from a few weeks to an year or more and should encompass the lead times for all purchased and assembled components.

Time Fences in Master Production Schedules

MPS can be divided into four sections, each section separated by a point of time called a 'time fence'. The first section includes the first few weeks of the schedule and is referred to as 'frozen', the second section of a few weeks is referred to as 'firm', the third section is referred to as 'full' and the last section of a few weeks is referred to as 'open'.

(i) **"Frozen"** means that this early part of the MPS cannot be changed except under extraordinary circumstances and only with authorization from the highest levels in the organization. It is not desirable to change this section of MPS because it would be costly to reverse the plans to purchase materials and produce the parts that go into the products belonging to this section of MPS.

(ii) **"Firm"** means that changes can occur in this section of MPS but only in exceptional situations

(iii) **"Full"** means that all of the available production capacity has been allocated to orders. Changes in this section of the schedule can be made and production costs will be only slightly affected but the effect on customer satisfaction is uncertain.

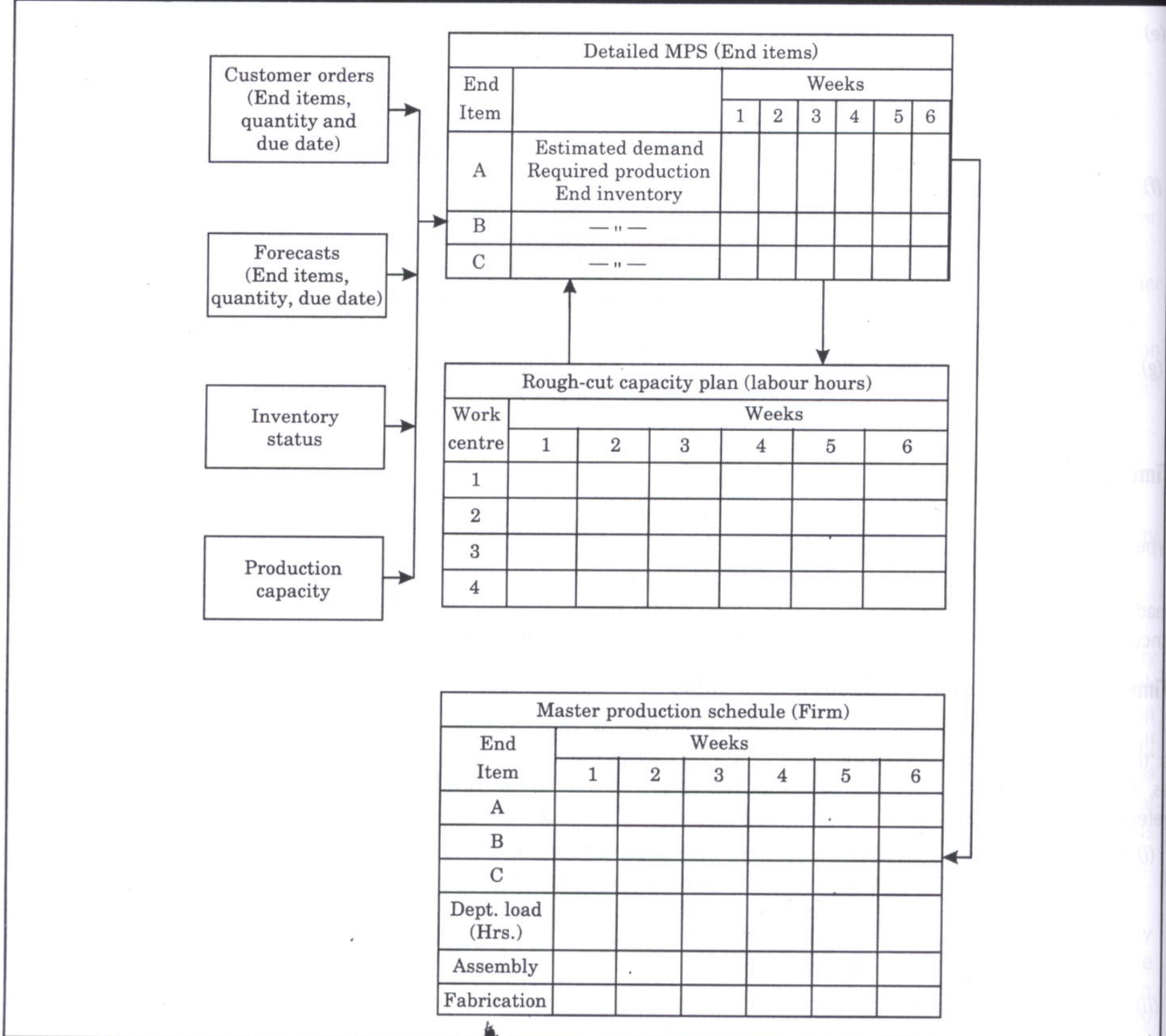
(iv) **"Open"** means that not all of the production capacity has been allocated and in this section of MPS, new orders are ordinarily slotted.

Procedure for Developing MPS

Exhibit 12.10 describes the process for developing the MPS and *Exhibit 12.11* describes the flow chart for developing the MPS.

The total demand for the end items (produced) from all sources is estimated, orders are assigned to production slots, delivery promises are made to customers before detailed calculations are made of work load on work centres for a MPS.

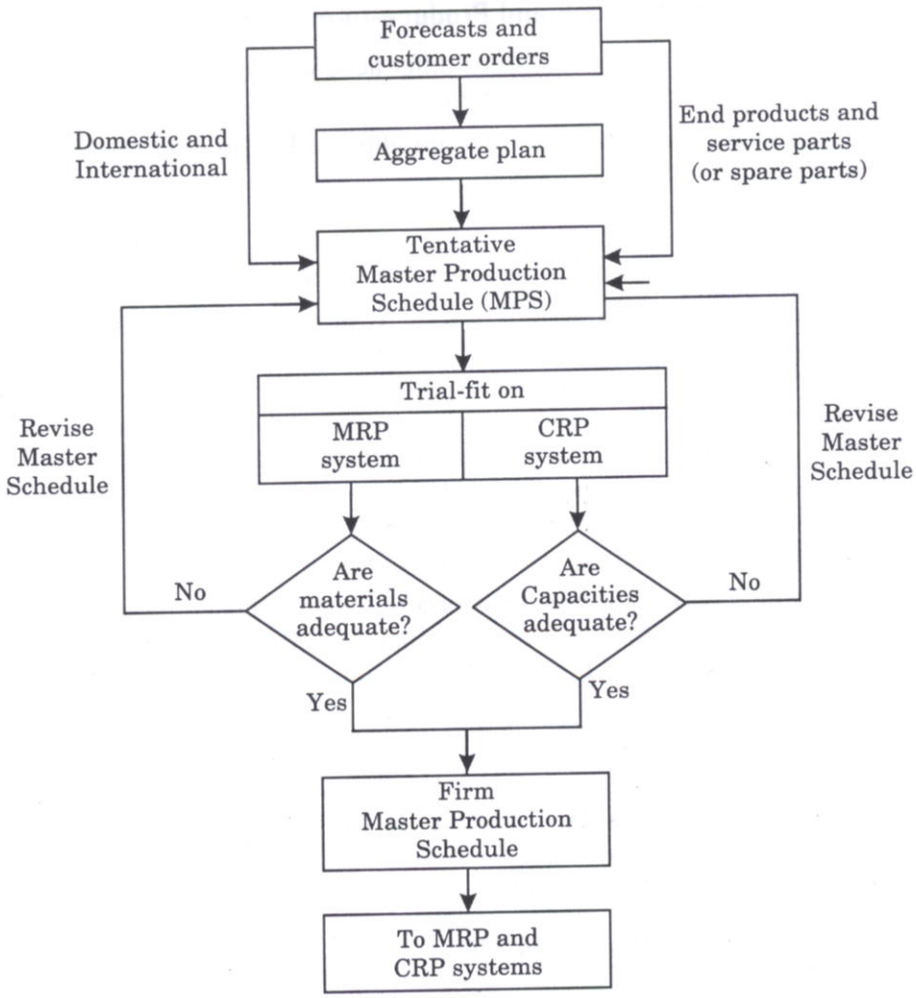
Exhibit 12.10 : The Master Production Scheduling Process



As orders are slotted in the MPS, the effects on the loading of the production work centres are checked. This preliminary checking of the MPS is called as **"rough-cut capacity planning"**. The main goal in rough-cut capacity planning is to identify any week in the MPS when underloading or overloading of the production capacity occurs and to revise the MPS as required.

Exhibit 12.11 illustrates the flow chart for Master Production Scheduling.

Exhibit 12.11 : Master Production Schedule - Flow Chart



Guidelines for Master Scheduling

Although master scheduling depends on the type of demand (*i.e.*, forecast versus firm orders) and the planning horizon, the following guidelines are widely applied

1. Work from an aggregate production plan
2. Schedule common modules when possible
3. Load facilities realistically
4. Release orders on a timely basis
5. Monitor inventory levels closely
6. Reschedule as required

Updating of MPS

The MPS is usually updated weekly, *i.e.*, after one week has passed, one week is taken off the front end of the MPS, one week is added on to the back end and the demands for the whole MPS are estimated anew. The early part of the MPS tends to be dominated by actual on-hand customer orders whereas the latter part of the schedule tends to be dominated by forecasts. In the middle of the schedule the demand estimate is a combination of actual orders and forecasts.

MPS in Produce-to-stock and Produce-to-order Firms

Three elements of the MPS affected by the type of production system are:
- **Demand Management**
- **Lot-Sizing**
- **Number of products to be scheduled.**

Master scheduling procedures differ according to whether a firm is a produce-to-stock or produce-to-order production system.

The elements of the MPS that are affected by the type of production system are:

(a) Demand management

(b) Lot-sizing

(c) Number of products to be scheduled (product-mix).

In produce-to-order system, the focus in demand management is customer orders. The MPS is worked out based on the back-log of customer orders and product demand forecasts may not be used. The lot size and the number of products to be produced on an order are determined by the customer order. *For example,* if a customer orders 100 numbers of a particular product, 100 numbers of the products will be produced on that order. This approach to lot sizing is called lot-for-lot (LFL). Because produce-to-order firms have many product designs, the number of products and orders that have to be placed in the MPS is high and much effort is required to prepare the MPS.

In produce-to-stock firms, the orders for products come mainly from warehouse orders within the company. These orders are based on forecasts of future demand for products from many customers. Hence, forecasts play an important role in demand management in produce-to-stock firms.

The lot sizes of orders in produce-to-stock firms depend on economics. A balance must be struck between the set up costs of production and costs of carrying the inventory of the products in determining the economic lot sizes in produce-to-stock firms. Because produce-to-stock firms produce only a few standard product designs, the effort required to prepare the MPS is relatively less than in produce-to-order firms.

Length of Planning Horizon of MPS

The planning horizon in master scheduling may vary from a few weeks in some firms to more than a year in others. The dominant factor in deciding the length of planning horizon is that the planning horizon should at least equal the longest cumulative lead time required for the end product. Cumulative lead time is the amount of time to get the materials in from suppliers, produce all the parts and assemblies, get the end item assembled and ready for shipment and deliver it to the customers. The end product with the maximum cumulative lead time determines the least amount of time that a planning horizon should span.

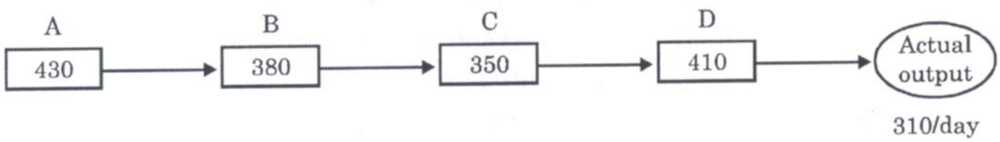
Symptoms of a Poorly Designed MPS

1. Overloaded facilities.
2. Underloaded facilities.
3. Excessive inventory levels on some end items and frequent stockouts on others.
4. Unrealistic schedules that production personnel do not follow.
5. Unreliable delivery promises to customers.
6. Excessive expediting or follow up.

A MPS when properly done results in development of positive customer relations, low inventory levels and full utilization of production resources.

SOLVED PROBLEMS

1. *A firm has 4 work centre a, b, c and d in series with individual capacities in units per day shown in figure below. The actual output is also shown in the figure:*



(i) What is the system capacity? (ii) What is the system efficiency?

Solution :

System Capacity is the capacity of the bottleneck centre (ie., the centre having minimum capacity)

(i) System capacity = 350 units/day

(ii) $$\text{System efficiency} = \frac{\text{Actual output}}{\text{System capacity}} = \frac{310}{350} = 88.57\%$$

2. *A work centre operates 5 days a week on a 2 shifts per day basis, each shift of 8 hours duration. There are five machines of the same capacity in this work centre. If the machines are utilized 80% of the time at a system efficiency of 90%, what is the rated output in standard hours per week.*

Solution :

$$\left.\begin{array}{r}\text{Rated capacity}\\ \text{per week}\end{array}\right\} = \begin{pmatrix}\text{Number of}\\ \text{machines}\end{pmatrix} \times \begin{pmatrix}\text{Machine hours}\\ \text{per week}\end{pmatrix} \times \begin{pmatrix}\text{Percentage}\\ \text{of utilization}\end{pmatrix} \times \begin{pmatrix}\text{System}\\ \text{efficiency}\end{pmatrix}$$

$$\left.\begin{array}{r}\text{Rated capacity}\\ \text{per week}\end{array}\right\} = (5) \times (8 \times 2 \times 5) \times (0.80) \times (0.90) = 288 \text{ standard Hours}$$

3. *The following is a tentative master schedule for four weeks*

Product	Week			
	1	2	3	4
A	3000	4000	1200	2500
B	2000	1500	3000	3500
C	1200	1800	2500	2000

The bill of labour in key work centres for the company's three major products A, B and C is as below:

Department	Product		
	A	B	C
X	0.20 hr	0.05 hr	0.10 hr
Y	0.08 hr	0.15 hr	0.20 hr
Z	0.11 hr	0.08 hr	0.05 hr

Determine the load on department x, y and z over the next 4 weeks.

Solution :

(a) Calculation of load on department 'X'

For week No.1 : (3000 × 0.20) + (2000 × 0.05) + (1200 × 0.10)
= 600 + 100 + 120 = 820 hours

For week No.2 : (4000 × 0.20) + (1500 × 0.05) + (1800 × 0.10)
= 800 + 75 + 180 = 1055 hours

For week No.3 : (1200 × 0.20) + (3000 × 0.05) + (2500 × 0.10)
= 240 + 150 + 250 = 640 hours

For week No.4 : (2500 × 0.20) + (3500 × 0.05) + (2000 × 0.10)
= 500 + 175 + 200 = 875 hours

(b) Calculation of load on Department 'Y'

For week No.1 : (3000 × 0.08) + (2000 × 0.15) + (1200 × 0.20)
= 240 + 300 + 240 = 780 Hours

For week No.2 : (4000 × 0.08) + (1500 × 0.15) + (1800 × 0.20)
= 320 + 225 + 360 = 905 Hours

For week No.3 : (1200 × 0.08) + (3000 × 0.15) + (2500 × 0.20)
= 96 + 450 + 500 = 1046 hours

For week No.4 : (2500 × 0.08) + (3500 × 0.15) + (2000 × 0.20)
= 200 + 525 + 400 = 1125 hours.

(c) Calculation of load on department 'Z'

For week No.1 : (3000 × 0.11) + (2000 × 0.08) + (1200 × 0.05)
= 330 + 160 + 60 = 550 hours

For week No.2 : (4000 × 0.11) + (1500 × 0.08) + (1800 × 0.05)
= 440 + 120 + 90 = 650 hours

For week No.3 : (1200 × 0.11) + (3000 × 0.08) + (2500 × 0.05)
= 132 + 240 + 125 = 497 hours

For week No.4 : (2500 × 0.11) + (3500 × 0.08) + (2000 × 0.05)
= 275 + 280 + 100 = 655 hours

Load on departments X, Y, Z over the 4 weeks is as below:

Department	Week			
	1	2	3	4
X	820 hrs	1055 hrs	640 hrs	875 hrs
Y	780 hrs	905 hrs	1046 hrs	1125 hrs
Z	550 hrs	650 hrs	497 hrs	655 hrs

4. *A department works on 8 hours shift, 250 days a year and has the usage data of a machine, as given below :*

Product	Annual demand (units)	Processing time (standard time in hours)
X	300	4.0
Y	400	6.0
Z	500	3.0

Determine the number of machines required.

Solution :

Step 1 : Calculate the processing time needed in hours to produce product x, y and z in the quantities demanded using the standard time data.

Product	Annual demand (units)	Standard processing time per unit (Hrs.)	Processing time needed (Hrs.)
X	300	4.0	300 × 4 = 1200 Hrs
Y	400	6.0	400 × 6 = 2400 Hrs
Z	500	3.0	500 × 3 = 1500 Hrs
			Total 5100 Hours

Step 2 : Annual production capacity of one machine in standard hours

$$= 8 \times 250 = 2000 \text{ hours per year}$$

Step 3 : Number of machines required

$$= \frac{\text{Work load per year}}{\text{Production capacity per machine}}$$

$$= \frac{5100}{2000} = 2.55 \text{ machines} \approx 3 \text{ machines.}$$

5. *A steel plant has a design capacity of 50,000 tons of steel per day, effective capacity of 40,000 tons of steel per day and an actual output of 36,000 tons of steel per day. Compute the efficiency of the plant and its utilisation.*

Solution :

$$\text{Efficiency of the plant} = \frac{\text{Actual output}}{\text{Effective capacity}} = \left(\frac{36000 \times 100}{40,000}\right) \times 100 = 90\%$$

$$\text{Utilisation} = \frac{\text{Actual output}}{\text{Design capacity}} = \left(\frac{36000 \times 100}{50,000}\right) \times 100 = 72\%$$

6. *A manager has to decide about the number of machines to be purchased. He has three options i.e., purchasing one, or two or three machines. The data are given below.*

Number of machines	Annual fixed costs	Corresponding range of output
One	Rs. 12,000	0 to 300
Two	Rs. 15,000	301 to 600
Three	Rs. 20,000	601 to 900

Variable cost is Rs. 20 per unit and revenue is Rs. 50 per unit

(a) Determine the break-even point for each range

(b) If projected demand is between 600 and 650 units how many machines should the manager purchase?

Solution :

(a) Break-even point

Let Q_{BEP} be the break even point.

FC = Fixed cost, R = Revenue per unit, VC = Variable cost

Then $$Q_{BEP} R = FC + (VC)\, Q_{BEP}$$

$$Q_{BEP} = \frac{FC}{(R - VC)}$$

Let Q_1 be the break-even-point for one machine option

Then, $Q_1 = \frac{12,000}{(50-20)} = \frac{12,000}{30} = 400$ units. (Not with in the range of 0 to 300)

Let Q_2 be the break-even-point for two machines option.

$Q_2 = \frac{15,000}{(50-20)} = \frac{15,000}{30} = 500$ units (within the range of 301 to 600)

Let Q_3 be the break-even-volume for 3 machines option.

$Q_3 = \frac{21,000}{(50-20)} = \frac{21,000}{30} = 700$ units (with in the range of 601 to 900)

(b) The project demand is between 600 to 650 units.

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

Also, the break even point for 3 machines 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 break even volume is 500 units and volume range is 301 to 600.

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

QUESTIONS

1. What is aggregate planning? What are its objectives?
2. Describe the operations planning and scheduling system.
3. Discuss the concept of aggregation.
4. Discuss the purpose and scope of aggregate planning.
5. What are the inputs to and outputs from aggregate planning?
6. Discuss the importance of aggregate plans.
7. Discuss the need for aggregate capacity planning.
8. Discuss the steps in aggregate capacity planning.
9. Describe the two basic approaches to aggregate planning.
10. What is rough cut planning? Illustrate with a flow chart.
11. Discuss the various types of capacity.
12. What is system efficiency? How it is measured?
13. Discuss the major considerations in capacity decisions.
14. Define the term "capacity" How can it be measured? State the factors affecting determination of plant capacity.
15. How plant capacity is related with plant layout, process design and equipment selection?
16. Define the term "capacity planning". How is it different from "capacity requirement planning".
17. Distinguish between
    (a) Short term capacity planning and long term capacity planning
    (b) Finite capacity planning and infinite capacity planning
18. Describe the capacity requirement planning process with a flow chart.
19. What is master production scheduling? What are its objectives?
20. Discuss the key functions of master production schedule.
21. Describe the guidelines for master scheduling.

CHAPTER THIRTEEN

Resource Requirements Planning

Learning Objectives

After reading this chapter, you should be able to:

- Understand the meaning of "resource requirements planning".
- Know the meaning of "materials requirements planning (MRP I) and manufacturing resources planning (MRP II)
- Know the objectives and purpose of MRP.
- Discuss the advantages and disadvantages of MRP.
- Discuss the operation of the MRP system, its inputs and outputs.
- Discuss the potential benefits from MRP.
- Discuss the factors on which successful implementation of MRP depends.
- Understand what is "distribution requirements planning" (DRP)
- Explain the functioning of ERP.