Industrial Engineering

For

Mechanical Engineering

By

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Syllabus of Industrial Engineering

Production Planning and Control: Forecasting models, aggregate production planning, scheduling, materials requirement planning.

Inventory Control: Deterministic and probabilistic models; safety stock inventory control systems.

Operations Research: Linear programming, simplex and duplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

Previous Year GATE Papers and Analysis

GATE Papers with answer key

thegateacademy.com/gate-papers

Subject wise Weightage Analysis

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Contents

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"If you don't set goals, you can't regret not reaching them."

.....Yogi Berra

CHAPTER 1

Production, Planning and Control

Learning Objectives

After reading this chapter, you will know:

1. Introduction, Production System, Productivity.
2. Break Even Analysis, Fixed and Variable Cost, Margin of Safety.
3. Break Even Point (B.E.P.).

Forecasting

The main purpose of forecasting is to estimate the occurrence, timing or magnitude of future events. Once, the reliable forecast for the demand is available, a good planning of activities is needed to meet the future demand. Forecasting thus provides the input to the planning and scheduling process.

Types of Forecasting

1. **Long Range Forecast**

   Long range forecast consists of time period of more than 5 years. The long range forecasting is useful in following areas,

   - Capital planning
   - Plant location
   - Plant layout or expansion
   - New product planning

2. **Medium Range Forecast**

   Medium range forecast is generally from 1 to 5 years. The medium range forecasting is useful in the following areas,

   - Sales planning
   - Production planning
   - Capital and cash planning
   - Inventory planning

3. **Short Range Forecast**

   The short range forecast is generally for less than 1 year.

   - Purchasing
   - Overtime decision
   - Job scheduling
   - Machine maintenance
   - Inventory planning

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Quantitative Methods of Forecasting

1. **Extrapolation**

Extrapolation is one of the easiest ways to forecast. In this method, based on the past few values of production capacity, next value may be extrapolated on a graph paper.

2. **Simple Moving Average**

In this method, mean of only a specified number of consecutive data which are most recent values in the series is calculated. Forecast for $(t+1)^{th}$ period is given by,

$$F_{t+1} = \frac{1}{n}\sum_{i=t+1-n}^{t} D_i$$

Where, D_i = Actual demand for i^{th} period & n= Number is periods included in each average.

3. **Weighted Moving Average**

In this method, more weightage of given to the relatively newer data. The forecast is the weighted average of data.

$$F_{t+1}\sum_{i=t+1-n}^{t} W_i D_i$$

Where, W_i = Relative weight of data for i^{th} period and

$$\sum_{i=t+1-n}^{t} W_i = 1$$

It may be noted that when more weight is given to the recent values, the forecast is nearer to likely trend. Weighted moving average is advantageous as compared to simple moving average as it is able to give more importance to recent data.

Example: The value of moving average base n lies between

(A) 0 & 1
(B) 2 & 10
(C) −1 & 1
(D) None of these

Solution: [Ans. A]

4. **Exponential Smoothing**

In the exponential smoothing method of forecasting, the weightage of data diminishes exponentially as the data become older. In this method all past data is considered. The weightage of every previous data decreases by (1 – α), where α is called as exponential smoothing constant.

$F_t = \alpha D_{t-1} + \alpha(1-\alpha)D_{t-2} + \alpha(1-\alpha)^2 D_{t-3} + \alpha(1-\alpha)^3 D_{t-3} \ldots\ldots$

Where,

D_i = One period ahead forecast made at time t

D_t = Actual demand for t^{th} period

α = Smoothing constant $(0 \leq \alpha \leq 1)$

Comments regarding Smoothing constant α,

Smaller is the value of α, more is the smoothing effect in forecast.

Higher value of α gives more robust forecast and response more quickly to changes

Higher value of α gives more weightage to past data as compared to smaller value.

Example: The limitation in moving average method for forecasting cans,

(A) Demand pattern is stationary
(B) Demand pattern is varying
(C) Demand pattern has a constant mean value
(D) Both A & C

Solution: [Ans. D]

Example: Find relationship between exponential smoothing coeff. (α) and N, so that responses are same.

Solution: Average life of data $S = 0 \times \frac{1}{N} + 1 \times \frac{1}{N} + 2 \times \frac{1}{N} + 3 \times \frac{1}{N} + \ldots\ldots + (N-1) \times \frac{1}{N}$

Or, average life of data $= \frac{(0+1+2+3\ldots\ldots+(N-1))}{N}$

$S = \frac{\frac{1}{2}(N-1)(N-1+1)}{N} = \frac{1}{2}(N-1)\frac{N}{N}$

$= \frac{1}{2}(N-1) \ldots . (i)$

Average life of data for exponential smoothing

$S = 0\times\alpha + 1\times \alpha\,(1-\alpha) + 2\times\alpha(1-\alpha)^2 + \ldots\ldots\ldots + (N-1)\,\alpha(1-\alpha)^{N-1} + \ldots\ldots \infty$

$= \alpha(1-\alpha) + 2\alpha(1-\alpha)^2 + 3\alpha(1-\alpha)^3 + \ldots\ldots\ldots$

$= \alpha[(1-\alpha) + 2(1-\alpha)^2 + 3(1-\alpha)^3 + \ldots\ldots\ldots] \ldots\ldots\ldots (ii)$

Now, multiplying (ii) by (1 – α) and subtracting from (ii) we get

$$S = \alpha[(1-\alpha) + 2(1-\alpha)^2 + 2(1-\alpha)^3 + 3(1-\alpha)^4 \ldots\ldots\ldots]$$
$$-(1-\alpha)S = \quad -\alpha[(1-\alpha)^2 - 2(1-\alpha)^3 - 3(1-\alpha)^4 \ldots\ldots\ldots]$$
$$S[1-(1-\alpha)] = \alpha[(1-\alpha) + (1-\alpha)^2 + (1-\alpha)^3 + (1-\alpha)^4 + \ldots\ldots\ldots]$$

$\text{Or, } S\times\alpha = \alpha\frac{(1-\alpha)}{1-(1-\alpha)} = \frac{\alpha(1-\alpha)}{\alpha} = 1-\alpha \text{ or, } S = \frac{1-\alpha}{\alpha} \ldots\ldots (iii)$

From (i) & (iii)

$\frac{1-\alpha}{\alpha} = \frac{N-1}{2}$

$2 - 2\alpha = N\alpha - \alpha$

$\text{Or, } N\alpha = -2\alpha + 2 + \alpha = -\alpha + 2 = 2 - \alpha$

Or, $N\alpha + \alpha = 2$

Or, $\alpha(N+1) = 2$, Or, $\boxed{\alpha = \frac{2}{N+1}}$

Statistical Forecasting

Statistical forecasting is based on the past data. We evaluate the expected error for the statistical technique of forecasting. Some common regression functions are as follows.

Let,

F_t = Forecast for time period t
d_t = Actual demand for time period t
t = time period

1. Linear Forecaster

$F_t = a + b(t)$

Where a and b are parameters

2. **Cyclic Forecaster**

$F_t = a + u \text{ Cos } (2\pi/N)t + v \text{ Sin } (2\pi/N)t$

Where a, u and v are parameters and N is periodicity

3. **Cyclic Forecaster with Growth**

$F_t = a + b(t) + u \text{ Cos } (2\pi/N)t + v \text{ Sin}(2\pi/N)t$

Where a, b, u and v are parameters and N is periodicity

4. **Quadratic Forecaster**

$F_t = a + b(t) + c(t)^2$

Where a, b and c are parameters

Accuracy of Forecast

Many factors affect the trend in data therefore it is impossible to obtain an exact right forecast. Below are the tools that are used to determine the error in the forecasted value.

1. **Mean Absolute Deviation (M.A.D.)**

This is calculated as the average of absolute value of difference between actual and forecasted value.

$$\text{MAD} = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n}$$

Where,

F_t = Actual demand for period t

D_t = Forecasted demand for period t

n= number of periods considered for calculating the error

2. **Mean Sum of Square Error (M.S.E.)**

The average of squares of all errors in the forecast is termed as MSE. Its interpretation is same as MAD.

$$\text{MSE} = \frac{\sum_{n=1}^{n} (D_t - F_t)^2}{n}$$

3. **BIAS**

BIAS is calculated as the average of the difference between actual and forecast value. A positive value means under-estimation and negative value means over-estimation.

$$\text{BIAS} = \frac{\sum_{t=1}^{n} (D_t - F_t)}{n}$$

Production Planning and Control

Production planning and control is one of the most important areas of industrial management. This aims at achieving the efficient utilization of resources in any organization through planning, co-ordination and control of production activities.

Phases of P.P.C.

1. **Preplanning**
   - Product development and design
   - Process design
   - Work station design
   - Factory layout and location

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2. Planning Different Resources
   - Material
   - Method
   - Machine
   - Men
3. Control
   - Inspection
   - Expedition
   - Evaluation
   - Dispatching

Production Planning and Control Steps

Routing: Routing is the process of deciding sequence of operations (route) to be performed during production process, the main objective of routing is the selection of best and cheapest way to perform a job. Procedure for routing is as follows,

- Conduct an analysis of the product to determine the part/ component/ sub-assemblies required to be produced.
- Conduct the analysis to determine the material needed for the product.
- Determine the required manufacturing operations and their sequence.
- Determine the lot size.
- Determine the scrap.
- Estimate product cost.
- Prepare different forms of production control.

Scheduling: Scheduling involves fixing the priorities for different jobs and deciding the starting and finishing time of each job. Main purpose of scheduling is to prepare a time-table indicating the time and rate of production, as indicated by starting and finishing time of each activity. Scheduling will be discussed in detail in next section.

Dispatching: Dispatching is the selection and sequencing of available jobs to be run at the individual workstations and assignments of those jobs to workers. Functions of dispatching are as under,

- Collecting and issuing work centre.
- Ensuring right material, tools, parts, jigs and fixtures are available.
- Issues authorization to start work at the pre-determined date and time.
- Distribute machine loading and schedule charts.

Expediting: This is the final stage of production planning and control. It is used for ensuring that the work is carried out as per plans and due dates are met. The main objective is to arrest deviations from the plan. Another objective is to integrate different production activities to meet the production target. The following activities are done in expediting phase.

- Watching the progress of the production process.
- Identification of delays, disruptions or discrepancies.
- Physical control of work-in-progress through checking.
- Expediting corrective measures.

- Coordinating with other departments.
- Report any production related problems.

Scheduling Method

Scheduling is used to allocate resources over time to accomplish specific tasks. It should take account of technical requirement of task, available capacity and forecasted demand. The output plan should be translated into operations, timing and schedule on the shop floor. Detailed scheduling encompasses the formation of starting and finishing time of all jobs at each operational facility.

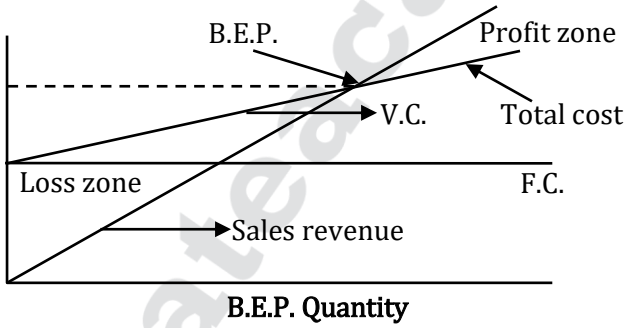
Gantt Chart: Gantt chart is a graphical tool for representing a production schedule. Normally, Gantt chart consists of two axis. On X-axis, time is represented and on Y-axis various activities or tasks, machine center's and facilities are represented. The Gantt chart is explained by an example as under

Break – Even – Point (B.E.P.)

Break even analysis is used to show a relationship between the cost, revenue and profit with sales volume.

B.E.P. refers to the sales paint, at which the total sales income (revenue) because equal to the total cost (fixed + variable cost).

Below the B.E.P. the result shows losses



Here F.C. = Fixed cost (cost of building etc.)

V.C. = Variable cost (unit price)

Fixed cost + Variable = Total sales revenue

If X = Units, V = Variable cost per unit, S= Selling cost per unit, F = Fixed Cost

$F + VX = SX$

$\frac{F}{S - V} = X(\text{Quantity at B. E. P.})$

Assumption

(i) Selling price will remain constant with quantity levels.

(ii) Linear relationship between sales volume with cost.

(iii) No other factors effects only cost and quantity is included.

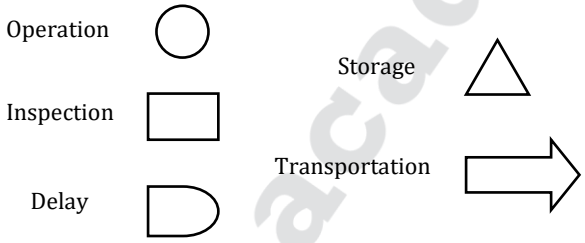
Work – Study

Work Study = Method Study + Time Study

- **Method Study:** Used in process to reduce the processes are to find effective process as method for job.
- **Time Study:** Used in operation to reduce the operation time by using time based study as operation.
- **Standard Time (S.T.):** Used to find cycle time and wages as incentives of labors.
  S.T. = N.T. + Relaxation Allowance
  N.T. = Normal time
  $= \text{Observed time} \times \frac{\text{Rating}}{100}$
  Allowance = given in % of N.T.
  Note: A qualified worker is used to find the N.T. as S.T.

Process Flow Symbol

(i) Used to represent the process flow in graphical manner
(ii) Basic five symbols are used to define process flow



Line Balancing (L.B.)

(i) L.B used for grouping tasks and workers in a effective manner in order to maintain optimum balance.
(ii) Tasks are group in such manner that these total time perfectly equal to as little lesses than the time available at each work station. This reduce the idle time.

Terminology

(i) Cycle time (C. T.): $\frac{\text{Available Prodution Time}}{\text{Required Production}}$

(ii) No. of work stations: $\frac{\text{Total worl content (Processing time)}}{\text{C.T.}}$

Balance delay: $\frac{\text{N} \times \text{C. T.} - \text{Total work content}}{\text{N} \times \text{C. T.}} \times 100$

Line efficiency: 1 – Balance Delay

Note: If cycle time is not given then max station time is consider as 'cycle time'.

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