Module-2

FORECASTING
AGGREGATE PLANNING
CAPACITY PLANNING

Content

- 2.1. Forecasting: Need for forecasting, role of forecasting in PPC, forecasting methods of qualitative type like judgment techniques. Forecasting methods of quantitative types like time series analysis, least square method, moving average method, exponential smoothing method. Forecasting Errors and Forecasting Bias

- 2.2. Aggregate planning: Concept of aggregate planning, decision rules, strategies and methods

- 2.3. Capacity Planning: Measurement of capacity, Measures of capacity, Factors influencing effective capacity, short range, medium range and long range capacity planning, Rough cut capacity planning.

FORECASTING

Introduction

- Forecasting is the art and science of predicting what will happen in the future
- Determined by a mathematical method or on the intuition of the Experts–combination

Basis of Comparison	Forecasting	Prediction
Meaning	Process of creating future predictions with relevant data	Process of creating future predictions with or without relevant data
Accuracy	More accurate	Lower probability of happening
Application	Mostly applied in the meteorology, economic and financial sectors	Can be applied almost anywhere
Bias	Forecasts are generated from calculation and data assessment	Is subject to bias
Quantification	Easily Quantified	Can't be quantified
Basis	Done using scientific methods	Arrived at by arbitrary methods e.g. instincts
Application level	Aggregate level	Customer level

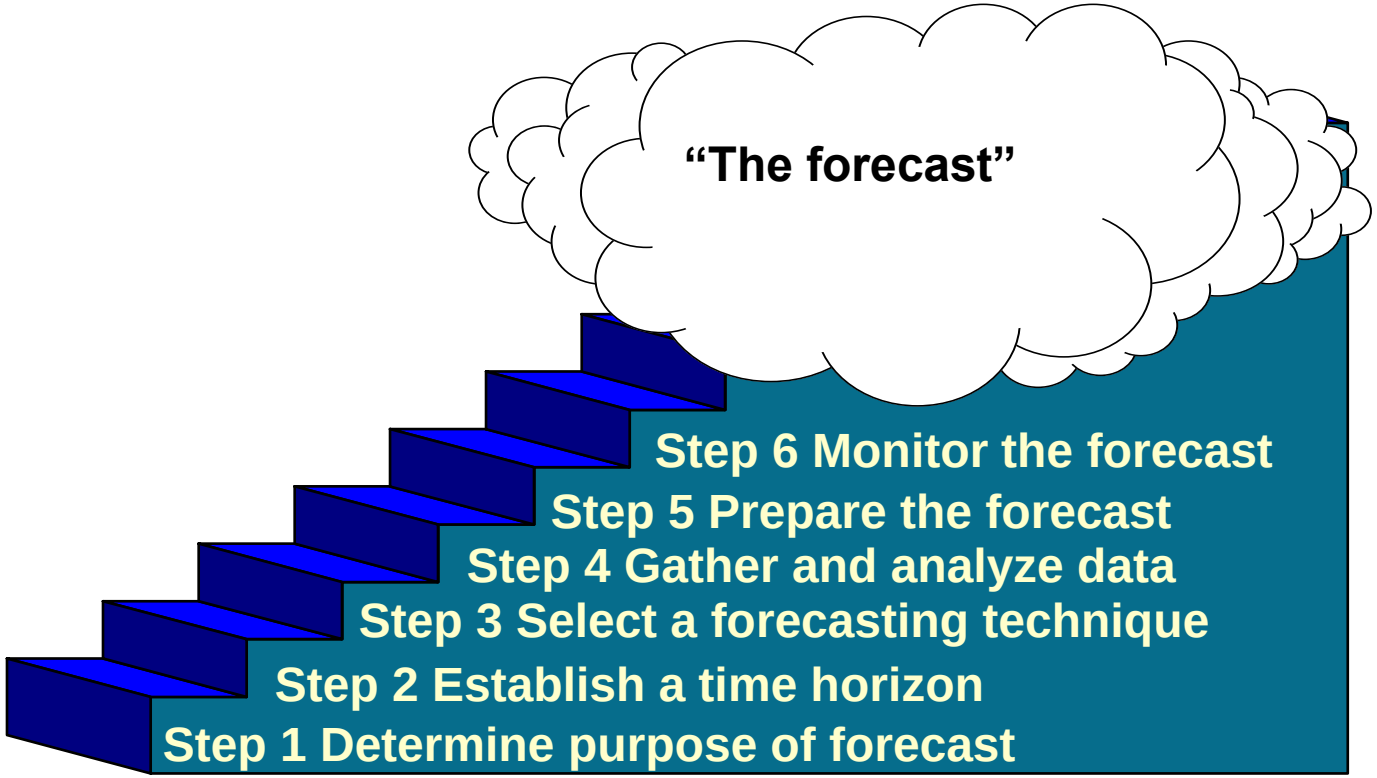
Need for forecasting

- Majority of the industrial activities depend upon the future sales.
- Projected demand for the future assists in decision making with respect to investment in plant and machinery, market planning and programmers.
- To schedule the production activity to ensure optimum utilization of plant's capacity.
- To prepare material planning to take up replenishment action to make the materials available at right quantity and right time.
- To provide an information about the relationship between demand for different products in order to obtain a balanced production in terms of quantity required of different products as a function of time.
- To provide a future trend which is very much essential for product design and development.

Role of forecasting in PPC

- Backbone of PPC
- What (Product type), How(Process), How much(Quantity) and of What quality, will be manufactured
- Strategic decision of investment in men(Skills), machines(Capacity & Precision) and materials(type)
- Plant Layout (Sequence of Machine arrangements)
- Budgets and control
- Inventory control
- Leading to Aggregate Planning, Capacity planning, Process Planning, Scheduling & Sequencing…
- Lays foundation for Long rang and Short range planning
  - long term: location, capacity, technology etc. questions
  - short term: production planning, material management, hiring and scheduling employees, allocating transportation etc.

Steps of forecasting



Type of Forecasting

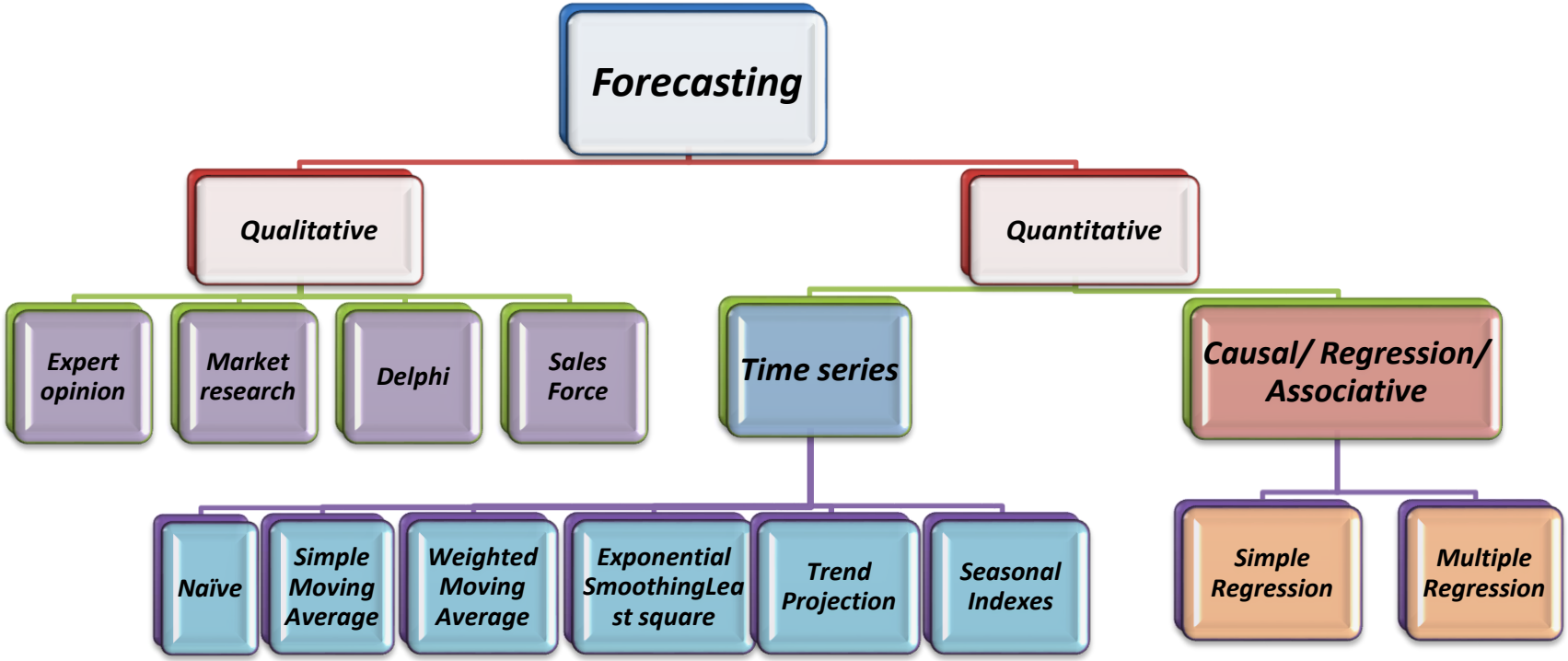
Principles- Many types of forecasting models that differ in complexity and amount of data & way they generate forecasts:

1. Forecasts are rarely perfect
2. Forecasts are more accurate for grouped data than for individual items
3. Forecast are more accurate for shorter than longer time periods

Types of Forecasts

- Economic forecasts -Predict a variety of economic indicators, like money supply, inflation rates, interest rates, etc.
- Technological forecasts - Predict rates of technological progress and innovation.
- Demand forecasts - Predict the future demand for a company's products or services.

Forecasting Methods



Comparison

	Qualitative Methods	Quantitative Methods
1. Characteristics	Based on human judgment, opinions; subjective and nonmathematical.	Based on mathematics; quantitative in nature.
2. Strengths	Can incorporate latest changes in the environment and "inside information."	Consistent and objective; able to consider much information and data at one time.
3. Weaknesses	Can bias the forecast and reduce forecast accuracy.	Often quantifiable data are not available. Only as good as the data on which they are based.

Qualitative Forecasting methods

- Used when little data exist
  - New products
  - New technology
- Involves intuition, experience
  - e.g., forecasting sales on Internet

Expert Opinion

- Consultants who specialise in the motor industry, in food retailing, in internet marketing and so on
- Different types of economists such as motor industry economists, energy economists, and political economists, all of whom have opinions on future demand and expenditure patterns in the country and the global markets
- Some businesses, affected by seasonal variations in sales, consult specialists on long term weather forecasts in an attempt to predict sales of weather-dependent products
- Other experts to be consulted can include distributors, wholesalers, suppliers and trade organisations
- Experts are useful for gaining specialised insights into likely future patterns and trends but should not be used on a ‘standalone basis’.
- Panels of experts are more reliable than consulting individual

Market Research

- ***Surveys of consumers' intentions-*** makes predictions by asking people directly what they intend to do in the future
- Market research companies that are continually gathering vast quantities of information and make money by selling this research to businesses
- The results of surveys allow businesses to predict sales patterns and plan for the future in terms of staffing and production levels
- ***Test marketing - C***onsumers' response to a product, before the full release of the product
- Involve the release of a product in a limited geographical area, or to a small section of the target market
- For example, many films are test marketed before they are put on general release (by being shown to invited audiences), and if the response of the test marketing process is negative then changes can be made to the films before being made available to be general market.

Delphi

- Developed by the RAND Corporation in the late 1950s
- Based on researching the views of a panel of experts
- Begins with the initial development of a questionnaire focusing on the problem or issue in question
- A panel of experts is selected, and then the questionnaire is sent to each of them
- Each participant answers the questionnaire independently and returns it
- Responses to the questionnaire are summarised before a further questionnaire is developed
- The members of the expert panel independently rate and prioritise ideas included in the second questionnaire
- This enables the group of experts to arrive at a consensus forecast
- Based on the principle that forecasts from a structured group of experts are more accurate than those from individuals or unstructured groups.

Delphi- Adv. & Disadv.

Advantages –

- Flexible enough to be used in a variety of situations and can be applied to a range of complex problems
- Provides a structured way for a group of people to make decisions
- Participants have time to think through their ideas leading to a better quality of response
- Creates a record of the expert group's responses and ideas which can be used when needed.

Disadvantages-

- Require a substantial period of time to complete as the process is time consuming to coordinate and manage
- It assumes that experts are willing to come to a consensus and allow their opinions to be altered by the views of other experts
- Monetary payments to the experts may lead to bias in the results of the study.

Sales Force

- Sales teams within businesses interact closely with customers
- Sales staff might notice any developing trends, and they have the experience to spot market changes and shifts in customer preferences and attitudes
- This direct sales information can be collected by management requesting statistical predictions of future sales, and by encouraging the upward flow of information through their organisation.

Quantitative Forecasting methods

- Used when situation is ‘stable’ and historical data exist
  - Existing products
  - Current technology
- Involves mathematical techniques
  - e.g., forecasting sales of LCD televisions

Quantitative Forecasting methods

- Naive approach
- Moving averages
- Exponential smoothing
- Trend projection

} **time-series models**

- Linear regression

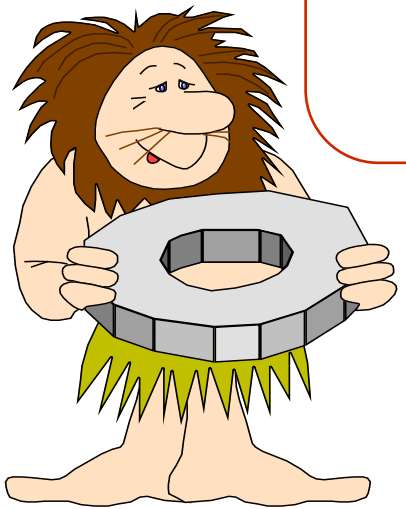
} **associative model**

Time Series

- Set of evenly spaced numerical data
  - Obtained by observing response variable at regular time periods
- Forecast based only on past values, no other variables important
  - Assumes that factors influencing past and present will continue influence in future

Naive

Uh, give me a minute.... We sold 250 wheels last week.... Now, next week we should sell....



The forecast for any period equals the previous period's actual value.

Naive

- Simple to use
- Virtually no cost
- Quick and easy to prepare
- Data analysis is nonexistent
- Easily understandable
- Cannot provide high accuracy
- Can be a standard for accuracy

Simple Moving Average

- This method consists of computing an average of the most recent “n” data values in the time series. This average is then used as a forecast for the next period.
- Moving average = $\frac{\sum \text{(most recent n data values)}}{n}$
- Moving average usually tends to eliminate the seasonal and random components.

Simple Moving Average Example

Week	Actual Cash Demand (Thousands of Dollars)	Forecasts: AP – 3 Weeks	Forecasts: AP – 5 Weeks	Forecasts: AP – 7 Weeks
1	100			
2	125			
3	90			
4	110			
5	105			
6	130			
7	85			
8	102	106.7	104.0	106.4
9	110	105.7	106.4	106.7
10	90	99.0	106.4	104.6
11	105	100.7	103.4	104.6
12	95	101.7	98.4	103.9
13	115	96.7	100.4	102.4
14	120	105.0	103.0	100.3
15	80	110.0	105.0	105.3
16	95	105.0	103.0	102.1
17	100	98.3	101.0	100.0

Sample computations — forecasts for the tenth week:

$$F_3 = \frac{85 + 102 + 110}{3} = 99.0 \qquad F_5 = \frac{105 + 130 + 85 + 102 + 110}{5} = 106.4$$

$$F_7 = \frac{90 + 110 + 105 + 130 + 85 + 102 + 110}{7} = 104.6$$

Weighted Moving Average

- *Weighted moving average* – More recent values in a series are given more weight in computing the forecast
  - Used when some trend might be present
    - Older data usually less important
  - Weights based on experience and intuition

$$\text{Weighted moving average} = \frac{\sum (\text{weight for period } n) \times (\text{demand in period } n)}{\sum \text{weights}}$$

Cont..

Weights Applied	Period
3	Last month
2	Two months ago
1	Three months ago
6	Sum of weights

Month	Actual Shed Sales	3-Month Weighted Moving Average
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (10)]/6 = 12^1/_6$
May	19	$[(3 \times 16) + (2 \times 13) + (12)]/6 = 14^1/_3$
June	23	$[(3 \times 19) + (2 \times 16) + (13)]/6 = 17$
July	26	$[(3 \times 23) + (2 \times 19) + (16)]/6 = 20^1/_2$

Exponential Smoothing

- It is a forecasting technique that uses a smoothed value of time series in one period to forecast the value of time series in the next period. The basic model is as follows:
- $F_t = \alpha D_{t-1} + (1- \alpha)F_{t-1}$
- Where:
- F_t= the forecast of time series for period t
- D_{t-1} = the actual value of the time series in period t-1
- F_{t-1} = the forecast of time series for period t-1
- α = the smoothing constant $0<\alpha\leq1$

Exponential Smoothing- Example

One of the two wheeler manufacturing company experienced irregular but usually increasing demand for three products. The demand was found to be 420 bikes for June and 440 bikes for July. They use a forecasting method which takes average of past year to forecast future demand. Using the simple average method demand forecast for June is found as 320 bikes (Use a smoothing coefficient 0.7 to weight the recent demand most heavily) and find the demand forecast for August.

$$F_t = \alpha D_{t-1} + (1-\alpha) F_{t-1}$$

where α = Smoothig Coefficient

D_{t-1} = Actual Demand for Recent Period

F_{t-1} = Demand Forecast for Recent Period

F_t = Forecast of Next Period Demand

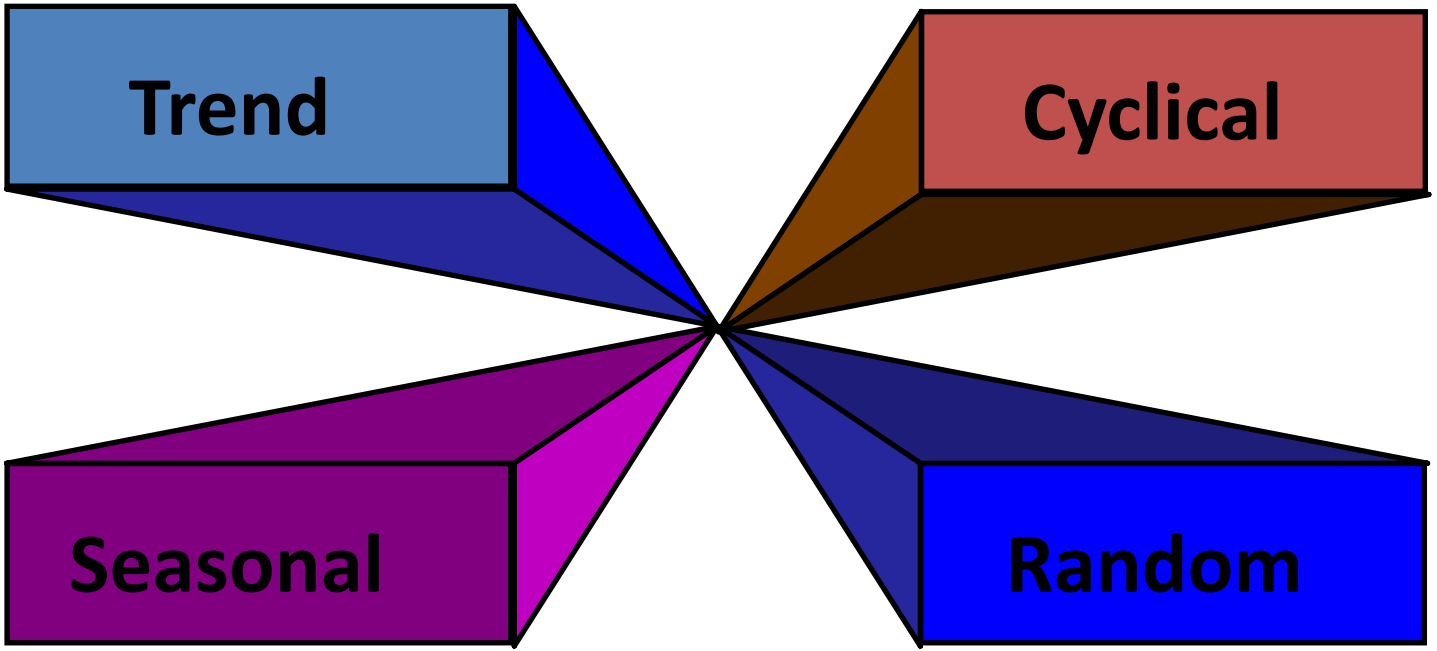
for July :

$$= 0.7(420) + (1-0.7)320$$
$$= 294 + 96$$
$$= 390 \text{ units}$$

for August :

$$= 0.7(440) + (1-0.7)\,390$$
$$= 308 + 117$$
$$= 425 \text{ units}$$

Trend Projection & Seasonal

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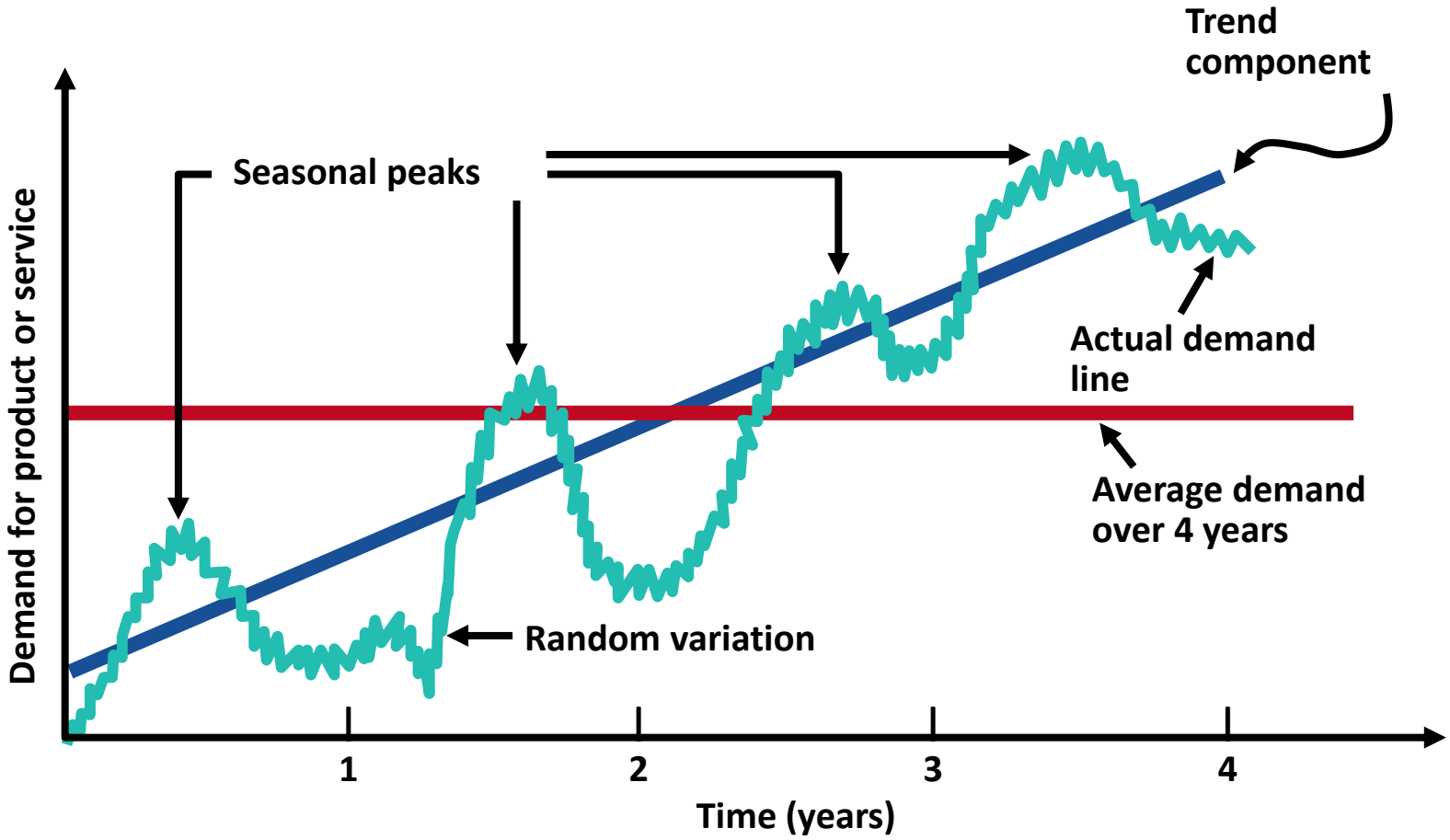
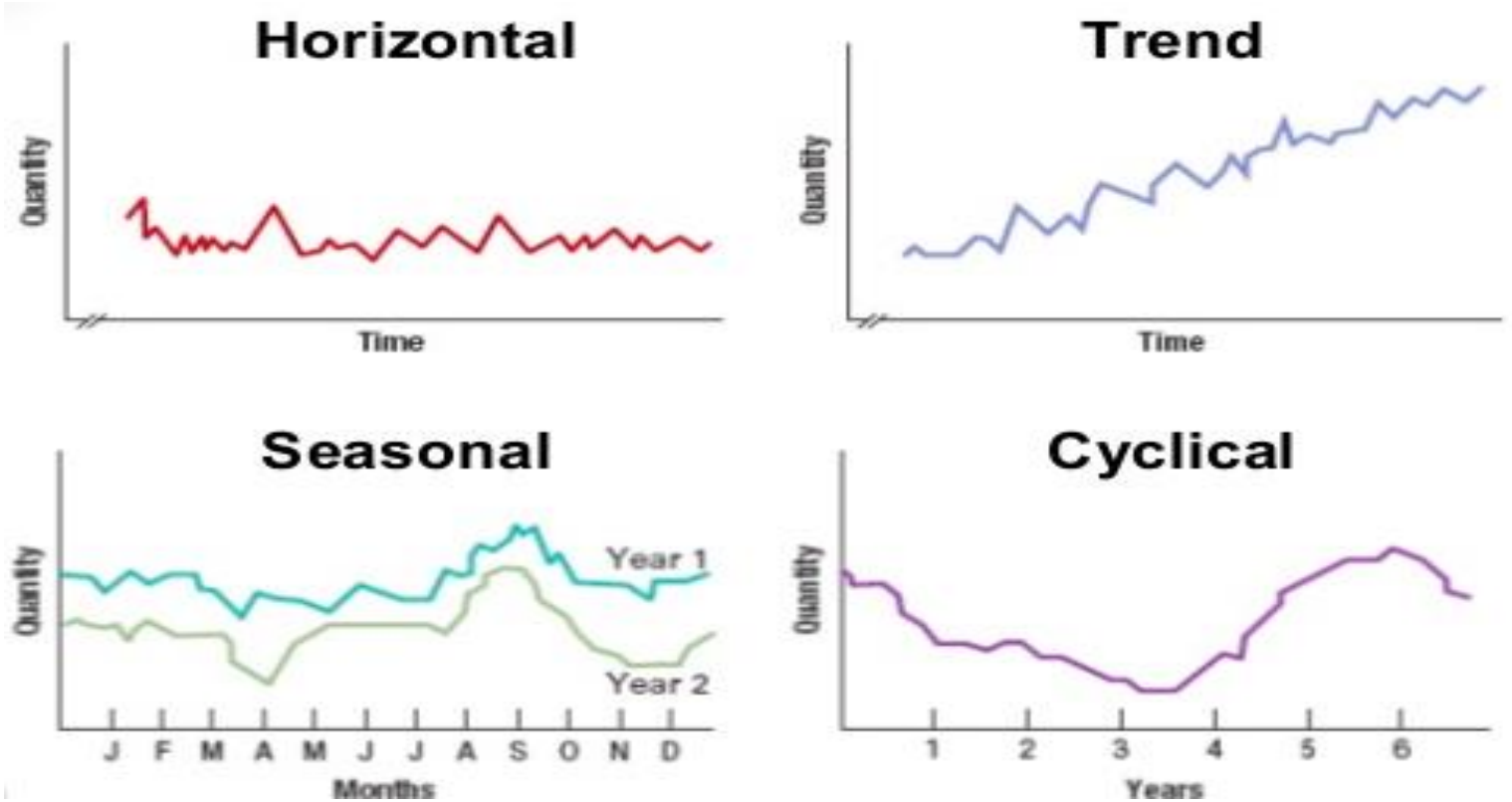

Trend component
Seasonal peaks
Actual demand line
Average demand over 4 years
Random variation
Demand for product or service
1
2
3
4
Time (years)

Demand Pattern



Least Square/ Simple Regression

A time series technique that computes a forecast with trend by drawing a straight line through a set of data using this formula:

Y = a + bX where

Y = forecast for period X

X = the number of time periods from X = 0

A = value of y at X = 0 (Y intercept)

B = slope of the line

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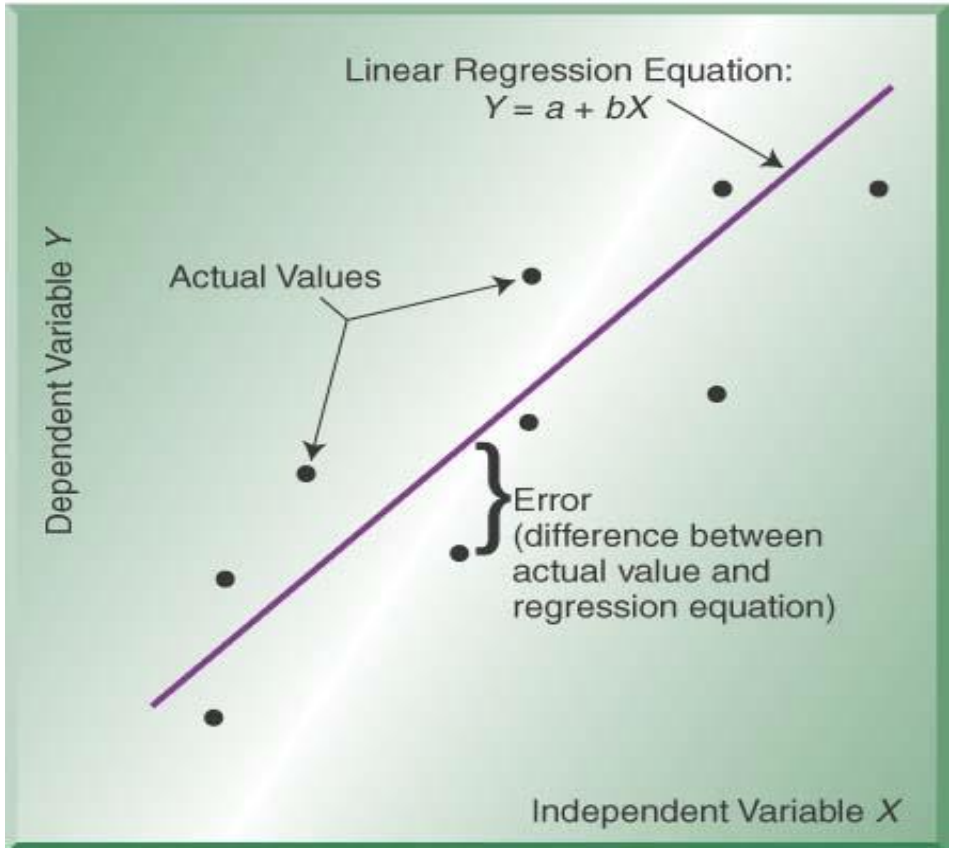


- Identify dependent **(y)** and independent **(x)** variables
- Solve for the slope of the line

$$\mathbf{b} = \frac{\sum \mathbf{XY} - \mathbf{n}\overline{\mathbf{X}}\,\overline{\mathbf{Y}}}{\sum \mathbf{X}^2 - \mathbf{n}\overline{\mathbf{X}}^2}$$

- Solve for the y intercept

$$\mathbf{a} = \overline{\mathbf{Y}} - \mathbf{b}\overline{\mathbf{X}}$$

- Develop your equation for the trend line

Y=a + bX

Cont..

- In least squares regression
  - The sum of squared residuals is minimised
  - The mean of residuals is zero
  - residuals are assumed to be randomly distributed around the mean according to the normal distribution

Example: College Enrollment

At a small regional college enrollments have grown steadily over the past six years, as evidenced below. Use time series regression to forecast the student enrollments for the next three years.

Year	Students Enrolled (1000s)	Year	Students Enrolled (1000s)
1	2.5	4	3.2
2	2.8	5	3.3
3	2.9	6	3.4

Example: College Enrollment

x	y	x^2	xy
1	2.5	1	2.5
2	2.8	4	5.6
3	2.9	9	8.7
4	3.2	16	12.8
5	3.3	25	16.5
6	3.4	36	20.4
$\Sigma x=21$	$\Sigma y=18.1$	$\Sigma x^2=91$	$\Sigma xy=66.5$

Example: College Enrollment

$$a = \frac{91(18.1) - 21(66.5)}{6(91) - (21)^2} = 2.387$$

$$b = \frac{6(66.5) - 21(18.1)}{105} = 0.180$$

$$Y = 2.387 + 0.180X$$

Example: College Enrollment

$Y_7 = 2.387 + 0.180(7) = 3.65$ or 3,650 students

$Y_8 = 2.387 + 0.180(8) = 3.83$ or 3,830 students

$Y_9 = 2.387 + 0.180(9) = 4.01$ or 4,010 students

Note: Enrollment is expected to increase by 180 students per year.

Simple Linear Regression

- Simple linear regression can also be used when the independent variable X represents a variable other than time.
- In this case, linear regression is representative of a class of forecasting models called causal forecasting models.

Example: Railroad Products Co.

- **Simple Linear Regression – Causal Model**

  The manager of RPC wants to project the firm's sales for the next 3 years. He knows that RPC's long-range sales are tied very closely to national freight car loadings. On the next slide are 7 years of relevant historical data.

  Develop a simple linear regression model between RPC sales and national freight car loadings. Forecast RPC sales for the next 3 years, given that the rail industry estimates car loadings of 250, 270, and 300 Thousands.

Example: Railroad Products Co.

Year	RPC Sales (Rs.Thousand)	Car Loadings (Rs.Thousand)
1	9.5	120
2	11.0	135
3	12.0	130
4	12.5	150
5	14.0	170
6	16.0	190
7	18.0	220

Example: Railroad Products Co.

x	y	x^2	xy
120	9.5	14,400	1,140
135	11.0	18,225	1,485
130	12.0	16,900	1,560
150	12.5	22,500	1,875
170	14.0	28,900	2,380
190	16.0	36,100	3,040
220	18.0	48,400	3,960
1,115	93.0	185,425	15,440

Example: Railroad Products Co.

$$a = \frac{185,425(93) - 1,115(15,440)}{7(185,425) - (1,115)^2} = 0.528$$

$$b = \frac{7(15,440) - 1,115(93)}{7(185,425) - (1,115)^2} = 0.0801$$

$$Y = 0.528 + 0.0801X$$

Example: Railroad Products Co.

$Y_8 = 0.528 + 0.0801(250) = \text{Rs. } 20.55 \text{ thousand}$

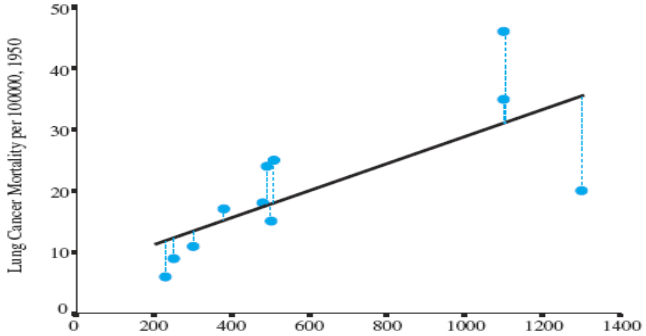
$Y_9 = 0.528 + 0.0801(270) = \text{Rs. } 22.16 \text{ thousand}$

$Y_{10} = 0.528 + 0.0801(300) = \text{Rs. } 24.56 \text{ thousand}$

Note: RPC sales are expected to increase by Rs. 80,100 for each additional million national freight car loadings.

Simple & Multiple Regression

- A simple regression model (one independent variable) fits a regression *line* in 2-dimensional space



- A multiple regression model with two explanatory variables fits a regression plane in *3*-dimensional space

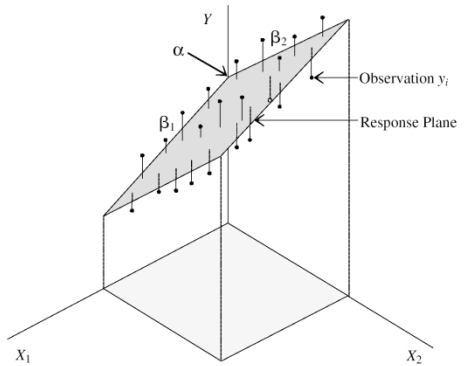


FIGURE 15.1 Three-dimensional response plane.

Multiple Regression

- Multiple regression analysis is used when there are two or more independent variables.
- An example of a multiple regression equation is:

$$Y = 50.0 + 0.05X_1 + 0.10X_2 - 0.03X_3$$

where: Y = firm's annual sales (Rs. thousands)

X_1 = industry sales (Rs. thousands)

X_2 = regional per capita income (Rs. thousands)

X_3 = regional per capita debt (Rs. thousands)

Multiple Regression

Coefficient of Correlation (*r*)

- The coefficient of correlation, *r*, explains the relative importance of the relationship between *x* and *y*.
- The sign of *r* shows the direction of the relationship.
- The absolute value of *r* shows the strength of the relationship.
- *r* can take on any value between –1 and +1.
- ***r* is computed by:**

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - (\sum x)^2\right]\left[n\sum y^2 - (\sum y)^2\right]}}$$

Multiple Regression

Coefficient of Correlation (*r*)

Meanings of several values of *r*:

-1 a perfect negative relationship (as *x* goes up, *y* goes down by one unit, and vice versa)

+1 a perfect positive relationship (as *x* goes up, *y* goes up by one unit, and vice versa)

0 no relationship exists between *x* and *y*

+0.3 a weak positive relationship

-0.8 a strong negative relationship

Multiple Regression

Coefficient of Correlation (r)

- The coefficient of determination, r^2, is the square of the coefficient of correlation.
- The modification of r to r^2 allows us to shift from subjective measures of relationship to a more specific measure.
- r^2 is determined by the ratio of explained variation to total variation:

$$r^2 = \frac{\sum(Y - \bar{y})^2}{\sum(y - \bar{y})^2}$$

Example: Railroad Products Co.

Coefficient of Correlation

x	y	x^2	xy	y^2
120	9.5	14,400	1,140	90.25
135	11.0	18,225	1,485	121.00
130	12.0	16,900	1,560	144.00
150	12.5	22,500	1,875	156.25
170	14.0	28,900	2,380	196.00
190	16.0	36,100	3,040	256.00
220	18.0	48,400	3,960	324.00
1,115	93.0	185,425	15,440	1,287.50

Example: Railroad Products Co.

Coefficient of Correlation

$$r = \frac{7(15,440) - 1,115(93)}{\sqrt{\left[7(185,425) - (1,115)^2\right]\left[7(1,287.5) - (93)^2\right]}}$$

$r = 0.9829$

$r^2 = (0.9829)^2 = 0.966$

96.6% of the variation in RPC sales is explained by national freight car loadings.

Example 1

The past data regarding the sales of ABC for the last five years is given below. Using the least square method, fit a straight line. Estimate the sales for the year 2021 and 2022.

Year	2016	2017	2018	2019	2020
Sales (‘00)	35	56	79	80	40

Solution 1

Year	Sales (y)	Deviation(x)	x^2	xy
2016	35	-2	4	-70
2017	56	-1	1	-56
2018	79	0	0	0
2019	80	1	1	80
2020	40	2	4	80
N=5	$\sum y=290$	$\sum x=0$	$\sum x^2=10$	$\sum xy=34$

Cont..

- In this case, as the number of periods is odd, we make $\sum x=0$, the deviations are calculated from the middle period
- Now to fit straight lie y = a+bx, the a and b are calculated as
- $a= \sum y/n=290/5=58$
- $b=\sum xy/\sum x^2 =34/10=3.4$
- $y= 58+3.4x$
- Deviation for 2021 is x=3 and for 2022 x=4
- Substituting values of x, we get
- Year 2021=58+3.4 X 3= 68.2, forecast is 6820 units
- Year 2022=58+3.4 X 4= 71.6, forecast is 7160 units

- Least square method when the sum of deviation is not zero ($\sum x \neq 0$)
- For y= a + bx,

$$a = \frac{(\sum y \cdot \sum x^2) - (\sum x \cdot \sum xy)}{(N\sum x^2) - (\sum x^2)}$$

$$b = \frac{N(\sum xy) - (\sum x \cdot \sum y)}{(N\sum x^2) - (\sum x^2)}$$

Example 2

A company manufacturing washing machine establishes a fact that there is a relationship between sale of washing machine and population of the city. The market research carried out reveals the following information. Fit linear equation and estimate demand for 45 million population.

Population (million)	5	7	15	22	27	36
Washing machine demand (‘000)	28	40	65	80	96	130

Solution 2

Population (x)	Demand (y)	x^2	xy
5	28	25	140
7	40	49	280
15	65	225	975
22	80	484	1760
27	96	729	2592
36	130	1296	4680
$\sum x=112$	$\sum y=439$	$\sum x^2=2808$	$\sum xy=10427$

Cont..

$$a = \frac{(\sum y \cdot \sum x^2) - (\sum x \cdot \sum xy)}{(N\sum x^2) - (\sum x^2)} = 15.07$$

$$b = \frac{N(\sum xy) - (\sum x \cdot \sum y)}{(N\sum x^2) - (\sum x^2)} = 3.11$$

Regression equation y=15.07 +3.11x

For 45 million, forecast demand

y=155.02=155020

Forecasting Errors/Bias

- Error - difference between actual value and predicted value
- Mean Absolute Deviation (MAD)
  - Average absolute error
- Mean Squared Error (MSE)
  - Average of squared error
- Mean Absolute Percent Error (MAPE)
  - Average absolute percent error

Forecasting Errors/Bias

$$MAD = \frac{\sum |Actual - forecast|}{n}$$

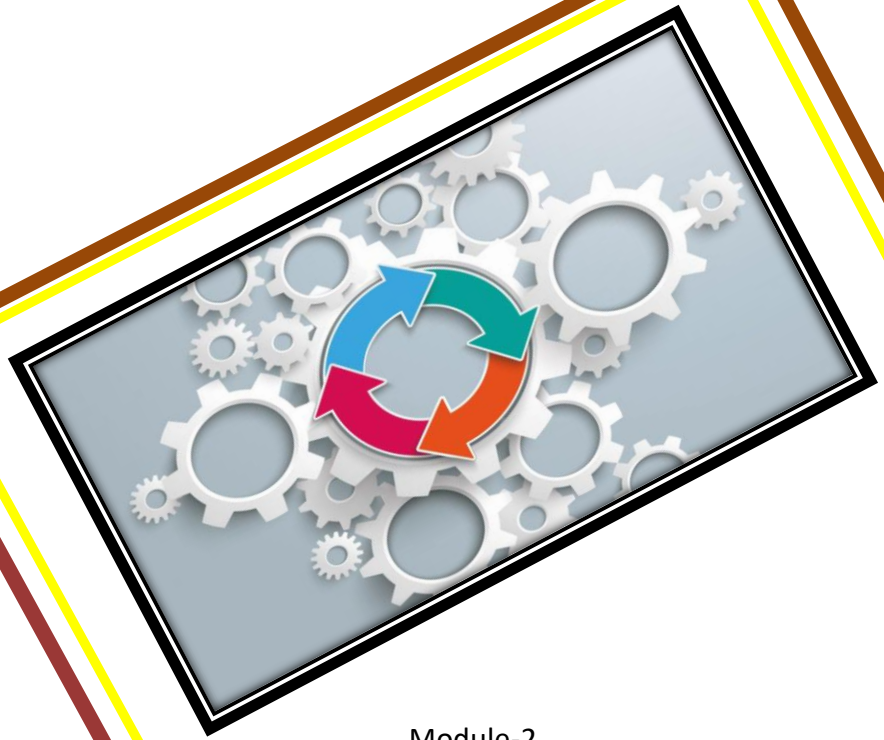
$$MSE = \frac{\sum (Actual - forecast)^2}{n - 1}$$

$$MAPE = \frac{\sum (|Actual - forecast| / Actual) * 100}{n}$$

Forecasting Errors/Bias

Period	Actual	Forecast	(A-F)	|A-F|	(A-F)^2	(|A-F|/Actual)*100
1	217	215	2	2	4	0.92
2	213	216	-3	3	9	1.41
3	216	215	1	1	1	0.46
4	210	214	-4	4	16	1.90
5	213	211	2	2	4	0.94
6	219	214	5	5	25	2.28
7	216	217	-1	1	1	0.46
8	212	216	-4	4	16	1.89
			-2	22	76	10.26
MAD=	2.75					
MSE=	10.86					
MAPE=	1.28					

Aggregate planning



Concept of aggregate planning

- Aggregate Planning is an intermediate planning method used to determine the necessary resource capacity a firm will need in order to meet its expected demand with minimization of costs
- Medium range capacity planning that typically covers a 3 to 18 month period of time
- Used in a manufacturing environment and determines overall output levels planned as well as appropriate resource input mix to be used for related groups of products
- The term "aggregate" is used because planning at this level includes all resources "in the aggregate;" for example, as a product line or family
- Aggregate resources could be total number of workers, hours of machine time, or tons of raw materials

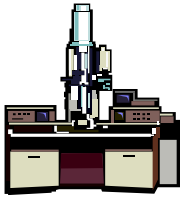
Cont..

- It does not distinguish among sizes, colors, features, and so forth. For example, with automobile manufacturing, aggregate planning would consider the total number of cars planned for not the individual models, colors, or options
- It serve as a foundation for future short-range type planning, such as production scheduling, sequencing, and loading.
- Steps taken to produce an aggregate plan begin with the determination of demand and the determination of current capacity
- Capacity is expressed as total number of units per time period that can be produced
- Demand is expressed as total number of units needed
- If the two are not in balance (equal), the firm must decide whether to increase or decrease capacity to meet demand or increase or decrease demand to meet capacity

Marketplace and Demand

Product Decisions

Research and Technology



Demand Forecasts, orders

Process Planning & Capacity Decisions

Work Force

Raw Materials Available

Inventory On Hand

Aggregate Plan for Production

External Capacity Subcontractors

Master Production Schedule, and MRP systems

Detailed Work Schedules

Cont..

The main objectives :

- Maximize customer service.
- Minimize inventory investment.
- Minimize changes in workforce levels.
- Minimize changes in production rates.
- Maximize utilization of plant and equipment.

Importance of Aggregate Planning

- Plays an important part in achieving long-term objectives of the organization
- Achieving financial goals by reducing overall variable cost and improving the bottom line
- Maximum utilization of the available production facility
- Provide customer delight by matching demand and reducing wait time for customers
- Reduce investment in inventory stocking
- Able to meet scheduling goals there by creating a happy and satisfied work force

Decision Rules

- To minimize total production costs (labor, overtime, hiring/lay off, inventory carrying cost)
- Helps achieve balance between operation goal, financial goal and overall strategic objective of the organization
- It serves as a platform to manage capacity and demand planning.
- In a scenario where **demand** is not matching the capacity, an organization can try to balance both by **pricing, promotion, order management and new demand creation**.
- In scenario where **capacity** is not matching demand, an organization can try to balance the both by
  1. **Laying off/hiring excess/inadequate excess/inadequate excess/inadequate workforce until demand decrease/increase.**
  2. **Including overtime as part of scheduling there by creating additional capacity.**
  3. **Hiring a temporary workforce for a fix period or outsourcing activity to a sub-contractor.**

Strategies & Methods

There are two pure planning strategies available to the aggregate planner:

- LEVEL STRATEGY
- CHASE STRATEGY

Level Strategy

Production rate is constant

Chase Strategy

Production equals demand

LEVEL STRATEGY

- Steady production rate even though customer demand is low
- A first alternative would be to maintains a level workforce and a steady rate of
- Higher inventory levels than are currently needed
- As demand increases, the firm is able to continue a steady production rate/steady employment level, while allowing the inventory surplus to absorb the increased demand

A second alternative would be to use a backlog or backorder.

- A backorder is simply a promise to deliver the product at a later date when it is more readily available
- The backorder is a device for moving demand from one period to another, preferably one in which demand is lower, thereby smoothing demand requirements over time.

➢ A level strategy allows a firm to maintain a constant level of output and still meet demand maintaining employee relations

➢ Negative results - include the cost of excess inventory, subcontracting or overtime costs, and backorder costs, which typically are the cost of expediting orders and the loss of customer goodwill.

LEVEL STRATEGY

- Demand Options — change demand:
  - influencing demand
  - backordering during high demand periods
  - Counter seasonal product mixing

CHASE STRATEGY

- Matching demand and capacity period by period
- Results in
  - A considerable amount of hiring, firing or laying off of employees-insecure and unhappy employees, problems with labour unions
  - Increased inventory carrying costs
  - Erratic utilization of plant and equipment
- The major advantage
- Flexibility of plant & worker utilization
- Allows inventory to be held to the lowest level possible
- Considerable savings

Most firms embracing the just-in-time production concept utilize a chase strategy approach to aggregate planning.

- Most firms find it advantageous to utilize a combination of the level and chase strategy. A combination strategy (sometimes called a hybrid or mixed strategy) can be found to better meet organizational goals and policies and achieve lower costs than either of the pure strategies used independently.

CHASE STRATEGY

Capacity Options — change capacity:

- changing inventory levels
- varying work force size by hiring or layoffs
- varying production capacity through overtime or idle time
- subcontracting
- using part-time workers

Advantages and Disadvantages

Option	Advantage	Disadvantage	Some Comments
Changing Inventory level	Changes in human resources are gradual, not abrupt production changes	Inventory holding costs; Shortages may results in lost sales	Applies mainly to production, not service, operations
Varying workforce size by hiring or layoffs	Avoids use of other alternatives	Hiring, layoff and training costs	Used where size of labour pool is large

Advantages and Disadvantages

Option	Advantage	Disadvantage	Some Comments
Varying production rates through overtime or idle time	Matches seasonal Fluctuations hiring/training costs	Overtime premiums, tired workers, may not meet demand	Allows flexibility within the aggregate plan
Subcontracting	Permits flexibility and smoothing of the firm's output	Loss of quality control; reduced profits; loss of future business	Applies mainly in production settings

Advantages and Disadvantages

Option	Advantage	Disadvantage	Some Comments
Using part-time workers	Less costly and more flexible than full-time workers	High turnover/ training costs; quality suffers; scheduling difficult	Good for unskilled jobs in areas with large temporary labor pools
Influencing demand	Tries to use excess capacity Discounts draw new customers	Uncertainty in demand. Hard to match demand to supply exactly	Creates marketing ideas. Overbooking used in some businesses

Advantages and Disadvantages

Option	Advantage	Disadvantage	Some Comments
Back ordering High demand period	May avoid overtime. Keeps Capacity constant	Customer must be willing to wait, but goodwill is lost	Many companies backorder
Counter seasonal And service mixing	Fully utilizes Resources ; allows stable workforce	May require skills or equipment outside a firm's area of expertise	Risky finding Products or services with opposite demand pattern

Numerical

A company manufactures the consumer durable products and the company intends to develop an aggregate plan for six months starting from January through June. The following information is available.

Demand for working days.

Month	Jan	Feb	March	April	may	June
Demand	500	600	650	800	900	800
Working days	22	19	21	21	22	20

Cost Details-

1. Material- Rs.100/unit
2. Inventory carrying cost- Rs.10/unit/month
3. Cost of stock outs- Rs.20/unit/month
4. Cost of sub contracting- Rs.200/unit
5. Hiring and Training cost- Rs.50/worker
6. Labour hours required- Rs.4/unit
7. Lay off Costs- Rs.100/worker
8. Regular time Costs (For first 8hrs)- Rs.12.50/hour
9. Over time cost- Rs.18.75/hour
10. Beginning inventory- 200 units
11. Safety stock required- Nill

Numerical

Work out the cost of the following strategies-

1. Produce exactly to meet demand- vary the work force
2. Constant work force- vary inventory and allow shortages
3. Constant work force and use sub contracting

Solution:-

Strategy-1 Produce exactly to meet demand- vary the work force

Assumption- Opening work force equals the first month's requirements

Aggregate Production Planning requirements							
	Jan	Feb	March	April	May	June	Total
Beginning Inventory	200	0	0	0	0	0	
Forecasted Demand	500	600	650	800	900	800	
Production requirement (demand + safety stock- beginning inventory)	300	600	650	800	900	800	
Ending Inventory (beginning inventory + production requirement – demand forecast)	0	0	0	0	0	0	

Numerical

Strategy – Exact Production, Vary work force							
	Jan	Feb	March	April	May	June	Total
Production requirement	300	460	650	800	900	800	
Production Hrs. reqd. (Prod. Req x 4hrs/unit)	1200	2400	2600	3200	3600	3200	
Working days per month	22	19	21	21	22	20	
Hours/month/worker (working days x 8 hrs/day)	176	152	168	168	176	160	
No. of workers reqd.(Prod. Hrs reqd.÷ hrs/month/wrkr)	7	16	15	19	20	20	
Net wrkr hired (assume opening wrkr =1st month of 7)	0	9	0	4	1	0	
Hiring cost (wrkrs hired x Rs. 50)	0	450	0	200	50	0	700
Workers laid off	0	0	1	0	0	0	
Lay off cost (wrkrs laid off x Rs. 100)	0	0	100	0	0	0	100
Regular production cost(prod. Hrs.reqd. x 12.50 Rs./hr)	15000	30000	32500	40000	45000	40000	202500
Total							**203300**

Numerical

Strategy II – Constant work force, Vary Inventory and stock out							
	Jan	Feb	March	April	May	June	Total
Beginning inventory	200	140	-80	-310	-690	-1150	
Working days per month	22	19	21	21	22	20	
Produ.Hrs.availabl(working days/mthx8hrs/day x10wrkr)	1760	1520	1680	1680	1760	1600	
Actual production(Prod. Hrs. available÷4hrs/unit)	440	380	420	420	440	400	
Forecast demand	500	600	650	800	900	800	
Ending inventory (beginning inventory + actual)	140	-80	-310	-690	-1150	-1550	
Shortage cost(Unit short x Rs. 20/unit)	0	1600	6200	13800	23000	31000	75600
Units Excess (ending inventory – safety stock)	140	0	0	0	0	0	
Inventory cost (Unit excess x 10)	1400	0	0	0	0	0	0
Regular production cost (prod.hrs.Reqd. x 12.50 Rs./hrs)	22000	19000	21000	21000	22000	20000	125000
Total							**202000**

Numerical

Strategy – Exact Production, Vary work force							
	Jan	Feb	March	April	May	June	Total
Production requirement	300	460	650	800	900	800	
Working days per month	22	19	21	21	22	20	
Prod. hrs. availabl(working days x 8 hrs/day x 10 wrkrs)	1760	1520	1680	1680	1760	1600	
Actual production(Prod. Hrs. available÷4hrs/unit)	440	380	420	420	440	400	
Unit subcontracted (prod. Requirement- actual prod.)	0	220	230	380	460	400	
Subcontracting cost(Unit subcontracted x Rs. 100)	0	8000	23000	38000	46000	4000	155000
Regular production cost(prod. Hrs.reqd. x 12.50 Rs./hr)	22000	19000	21000	21000	22000	20000	125000
Total							**280000**

Numerical

Assume a constant work force of 10
600-140 = 460 units of beginning inventory in February.

Strategy – Exact Production, Vary work force							
PLAN	Hiring	Lay off	Subcontract	RT production	Shortage	Excess Inventory	Total Cost
PLAN-I Exact Production, Vary Work Force	700	100	-	202500	-	-	2033000
PLAN-II Constant Work Force, Vary Inventory and Shortages	-	-	-	125000	75600	1400	202000
PLAN – III Constant Work Force Subcontract	-	-	155000	125000	-	-	280000

Capacity Planning

Measurement of Capacity

- It is easy and simple to measure the capacity of the unit manufacturing homogenous tangible products which can be counted and can be expressed as number of units of output per period.
- For example, the capacity of a automobile unit can be expressed as number of vehicles produced per month.
- However it is difficult to express the capacities when the company manufactures multiple products and some of the products requiring common facilities and others specialized facilities.
- In such cases the capacity is expressed as man hours, machine hours or sometimes in terms of applicable resources.
- For example, a job shop can measure its capacity in machine hours and man hours.

Measures of Capacity

- ***Design capacity:***
  Designed capacity of a facility is the planned or engineered rate of output of goods or services under normal or full scale operating conditions.

  For example, the designed capacity of the cement plant is 100 TPD (Tonnes per day). Capacity of the sugar factory is 150 tonnes of sugarcane crushing per day.

Measures of Capacity

- ***System capacity:***
  System capacity is the maximum output of the specific product or product mix the system of workers and machines is capable of producing as an integrated whole
- System capacity is less than design capacity or at the most equal, because of the limitation of product mix, quality specification, breakdowns and some long range uncontrollable factors
- The actual is even less because of many factors affecting the output such as actual demand, downtime due to machine/equipment failure, unauthorized absenteeism, inefficiency of labor
- The system efficiency is expressed as ratio of actual measured output to the system capacity.
  System Efficiency (SE)=Actual output/System capacity

Capacity and Output Relationship

DESIGN CAPACITY

Reduced by long range effects, Product mix, Long range market conditions, Tight quality specifications, Imbalance in equipment or labour

SYSTEM CAPACITY

Reduced by short range effects, Actual demand, Inefficiency of workers, Machine inefficiencies, Scheduling, Planning and control.

ACTUAL OUTPUT

Cont..

- ***Licensed capacity:***
  Capacity licensed by the various regulatory agencies or government authorities. This is the limitation on the output exercised by the government.
- ***Installed capacity:***
  The capacity provided at the time of installation of the plant is called installed capacity.
- ***Rated capacity:***
  Capacity based on the highest production rate established by actual trials is referred to as rated capacity.

Factors influencing effective capacity

Effective capacity planning is dependent upon factors like

1. Forecast of Demand,
2. Production facility (layout, design, and location),
3. Product line or matrix,
4. Production technology,
5. Plant & Labour efficiency,
6. Human capital (job design, compensation),
7. Multiple shift operations,
8. Subcontracting,
9. Operational structure (scheduling, quality assurance) and
10. External structure (Management policy, safety regulations)

Long Range and Short Range Capacity Planning

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

Long Range Capacity Planning

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

Long Range Capacity Planning

- Following parameters will affect long range capacity decisions
  - ***Multiple products***
  - ***Phasing in capacity***
  - ***Phasing out capacity***

Multiple products

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

Long Range Capacity Planning

Phasing in capacity:

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

Long Range Capacity Planning

Phasing out capacity :

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

Short Range Capacity Planning

- Managers often use forecasts of product demand to estimate the short-term workload the facility must handle.
- Also looking ahead up to 12 months, anticipate output requirements for different products, and services.
- Managers then compare requirements with existing capacity and then take decisions as to when the capacity adjustments are needed.
- For short-term periods of up to one year, fundamental capacity is fixed and major facilities will not be changed.
- Many short-term adjustments for increasing or decreasing capacity are possible and its requirement depend upon the conversion process like whether it is capital intensive or labor intensive or whether product can be stored as inventory.
- Capital intensive processes depend on physical facilities, plant and equipment.
- Short-term capacity can be modified by operating these facilities more or less intensively than normal.
- In labor intensive processes short-term capacity can be changed by laying off or hiring people or by giving overtime to workers.
- The strategies for changing capacity also depend upon how long the product can be stored as inventory.

Short Range Capacity Planning

- The short-term capacity strategies are:
  - ***Inventories*****:** Stock of finished goods during slack periods to meet the demand during peak period.
  - ***Backlog:*** During peak periods, the willing customers are requested to wait and their orders are fulfilled after a peak demand period.
  - ***Employment level (hiring or firing)*****:** Hire additional employees during peak demand period and layoff employees as demand decreases.
  - ***Employee training:*** Develop multi-skilled employees through training so that they can be rotated among different jobs. The multi-skilling helps as an alternative to hiring employees.
  - ***Subcontracting*****:** During peak periods, hire the capacity of other firms temporarily to make the component parts or products.
  - ***Process design:*** Change job contents by redesigning the job.

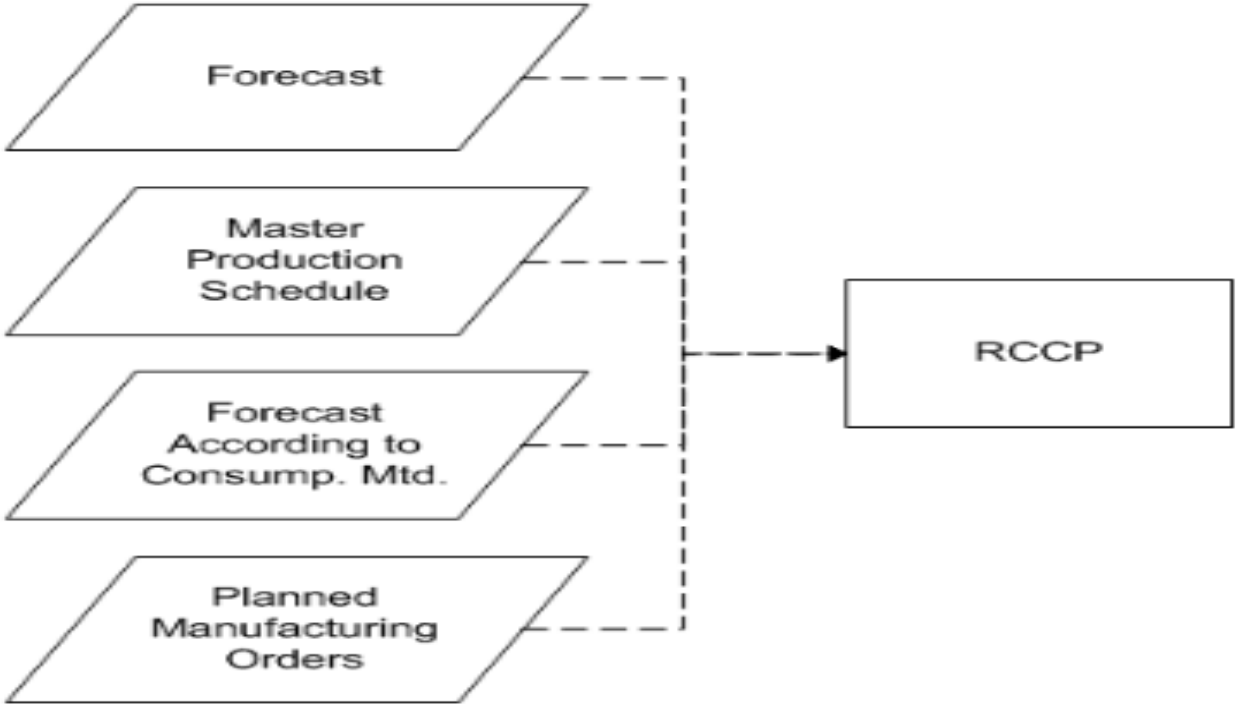
Rough cut capacity planning

- The main goal in rough-cut capacity planning is to identify where overloading or under-loading of production capacity occurs and revise the MPS as required.

- Overloading means that too much production of products has been planned in the facility and insufficient capacity exists to produce planned quantities of products required in MPS.

- Under-loading means that not enough production of products has been planned to fully load the facility.

Rough cut capacity planning



Rough cut capacity planning

- Rough cut capacity planning (RCCP) is the process of verifying if organization have sufficient capacity available to meet the requirements of master production schedule across a specific period.
- RCCP is a long-term technique that marketing and production departments will use to stabilize the capacity available and what is required, so organization can make changes to production schedule or available capacity.
- Traditionally, many manufacturers would adopt Master Resource Planning (MRP-II) software to pull off their rough cut capacity planning, as it's a Production Management Software that gives the tools for:
- — Production planning and scheduling;
- — Raw material and finished goods inventory management; and
- — Calculating manufacturing costs.

Rough cut capacity planning

- When organization working out rough cut capacity planning, it can be done at two levels:
- **Routing-Based RCCP**
- Routing-based rough cut capacity planning shows resource availability. For this, organization is going to look into the required and available **capacity in hours per week per resource**.
- **Rate-Based RCCP**
- This is where organization measure rough cut capacity by production lines. For this, organization will need to figure out required and available **capacity per week per production line**.
- So, to quickly summarize, rough cut capacity planning will look into how much need to produce, how much are organization able to produce, and how can find a balance between the two.

Rough cut capacity planning

Benefits-

It's worth reiterating that rough cut capacity planning allows to understand how much supply are going to need to meet demand, but also give a schedule that is flexible (as things happen on the shop floor which disrupts production).

But, other benefits of rough cut capacity planning includes:

- **Improved Project Management**
- Understanding all operations and outstanding job operations means , organization can improve project management.
- For example, one can see which operations should start by a specific date, and which jobs can start later because they have a short turnaround.
- Essentially, organization team will be able to easily prioritize operations by their start date.

Rough cut capacity planning

- **Better Resource Management**
- Rough cut capacity planning allows to understand the total number of hours of work for each week by each manufacturing process.
- For example, knowing how much work is passing through a workstation can help to determine if too much or not enough workloads are being processed, which will allow to adjust the capacity by:
- — Changing the number of shifts;
- — Changing the number of workstations in operation; or
- — Passing operations onto a contract manufacturer.

Rough cut capacity planning

- **Improved Manufacturing Lead Time**
- The transparency offered by rough cut capacity planning allows manufacturers to easily identify areas along their production lines that are being overworked or are prone to other issues such as a bottleneck in production.
- With this overview, it's easy to see an area of concern and make important business decisions immediately to address the problem, which is going to:
- — Reduce your manufacturing lead time;
- — Reduce costs; and
- — Improve customer satisfaction by finishing projects on-time.
- The benefits of rough cut capacity planning are numerous. But, to pull off RCCP, organization needs to develop proper planning and forecasting

UNIVERSITY NUMERICAL

The following data gives the sales of the company for the various years. Fit the straight line and forecast the sales for the year 2018 and 2019. [Tabulate the calculations] (Dec.17)

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Sales ('000)	13	20	20	28	30	32	33	38	43

SOLUTION

Year	Sales (y)	Deviation (x)	x^2	xy
1	13	-4	16	-52
2	20	-3	9	-60
3	20	-2	4	-40
4	28	-1	1	-28
5	30	0	0	0
6	32	1	1	32
7	33	2	4	66
8	38	3	9	114
9	43	4	16	172
	$\sum y=257$	**$\sum x = 0$**	**$\sum x^2 = 60$**	**$\sum xy = 204$**

CONT..

- a= 28.56
- b=3.4
- Y= 28.56 + 3.4x
- Forecast for 2018, y_{18}= 45560
- Forecast for 2019, y_{19}= 49000