UNIT-II

FORECASTING

Demand forecasting is the process of making estimations about future customer demand over a defined period, using historical data and other information.

Purposes of forecasting:

Purposes of short-term forecasting

- Appropriate production scheduling.
- Reducing costs of purchasing raw materials.
- Determining appropriate price policy
- Setting sales targets and establishing controls and incentives.
- Evolving a suitable advertising and promotional campaign.
- Forecasting short term financial requirements.

Purposes of long-term forecasting

- Planning of a new unit or expansion of an existing unit.
- Planning long term financial requirements.
- Planning man-power requirements.

Stages in forecasting:

- **Setting the Objectives**: The purpose for which the demand forecasting is being done must be clear. Whether it is for short-term or long-term, the market share of the product, the market share of the organisation, competitors share, etc. By all these aspects, the objectives for forecasting are framed.

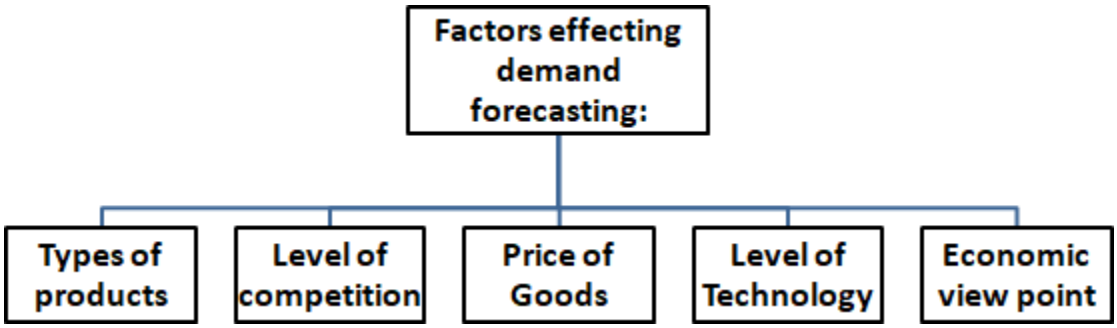
- **Determining the Time Perspective**: The defined objectives are supported by the period for which the forecasting is being done. The demand for a commodity varies with the change in its determinants over the period.
- There is a negligible change in price, income or other factors in the short run. But, the organisation may notice a considerable difference in these determinants over a long-term, affecting the demand of a commodity.

- **Selecting a Suitable Demand Forecasting Method**: Demand forecasting is based on specific evidence and is determined using a particular technique or method. The method of prediction must be selected wisely. It is dependant on the information available, the purpose of predicting and the period it is done for.

- **Collecting the Data**: Forecasting is based on past experiences and data. This data or information can be primary or secondary. Primary data comprises of the information directly collected by the analysts and researchers; whereas secondary data includes the physical evidence of the past performance, sales trend in the past years, financial reports, etc.

Estimating the Results: The data so collected is arranged in a systematic and meaningful manner. The past performance of a product in the market is analyzed on this basis. Accordingly, future sales prediction and demand estimation are done. The results so drew must be in a format which is easy to understand and apply by the management.

Factors effecting demand forecasting:



General Guiding Principles for Forecasting

1. Forecasts are more accurate for larger groups of items.
2. Forecasts are more accurate for shorter periods of time.
3. Every forecast should include an estimate of error.
4. Before applying any forecasting method, the total system should be understood.
5. Before applying any forecasting method, the method should be tested and evaluated.

Types of Forecasts by Time Horizon

1. Short-range forecast
2. Medium-range forecast
3. Long-range forecast

1. Short-range forecast

- It is usually up to 1 year, or generally less than 3 months
- It is required for current purchasing, job scheduling, workforce levels, job assignments, production levels
- It is concerned with capacity utilization of the firm
- Its accuracy will be more

2.Medium-range forecast

- It is usually one to 3 years
- It is required for Sales and production planning, budgeting
- It is useful for improving or increasing the existing capacity of the plant
- Its accuracy will be good

3.Long-range forecast

- It is usually more than 3 years such as 3 to 5 years.
- It is to consider the changes in the environments such as population, technology, competition in the market and financial policies of the government
- It is useful for new product planning, facility location, research and development
- Its accuracy will be less

Types of Forecasting Methods

1. Qualitative methods
2. Quantitative methods

Qualitative methods: These types of forecasting methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations

Quantitative methods: These types of forecasting methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations.

	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 methods of forecasting.

These methods are used when

1. The time available is not enough for objectively determining the fore casts using quantitative methods

2. Historical data may not be available

Ex: In the launch of new innovative Product there is no data available from past experience on the sales

of the Product

3. The country facing economic and political turmoil

4. The available data may become redundant.

Types of Qualitative Forecasting Methods

i. Customer Surveys
ii. Sales Force Composites
iii. Jury of Executive Opinion
iv. The Delphi Method

i. Customer Surveys

- Only a few consumers are selected and their views on the probable demand are collected.
- Thus, it is a miniature form of Complete Enumeration Survey.
- The sample is considered to be a true representation of the entire population.
- This method is simple and cheaper.
- The results of survey can be obtained quickly and results are good.

ii. Sales Force Composites

- In this method sales persons are expected to estimate expected sales in their respective territories.
- The sales force, which has been selling the product to wholesalers / retailers / consumers over a period of time, is considered to know the product and the demand pattern very well.
- These method does not require intricate mathemathical calculations.
- This method 1s based on the first hand knowledge of the salesman.
- It is useful to forecast the sales of new products.

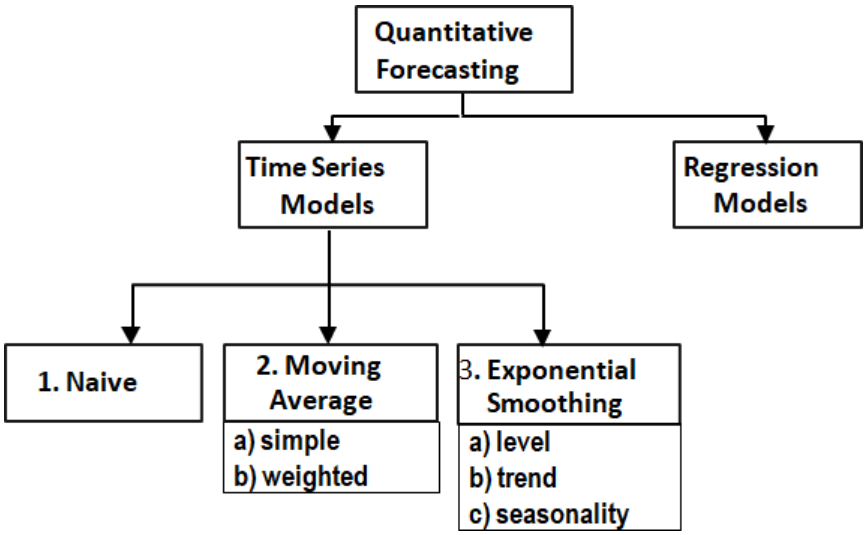
iii. Expert Opinion Method :

- This technique of forecasting demand seeks the views of experts on the likely level of
- demand in the future. They have a rich experience of the behaviour of demand.
- If the forecasting is based on the opinion of several experts, then it is known panel consensus.
- A specialized form of panel opinion is the Delphi Method. This method seeks the opinion of a group of experts through mail about the expected level of demand.
- The responses so received are analyzed by an independent body.

iv. The Delphi method

- Choose the experts to participate. There should be a variety of knowledgeable people in different areas.
- Through a questionnaire (or e-mail), obtain forecasts (and any premises or qualification captions for the forecasts) from all participants.
- Summarize the results and redistribute them to the participants along with appropriate new questions.
- Summarize again, refining forecasts and conditions, and again develop new questions.
- Repeat Step 4 if necessary. Distribute the final results to all participants.

Quantitative Forecasting Methods



Demand patterns in forecasting

Time Series: The repeated observations of demand for a service or product in their order of occurrence.

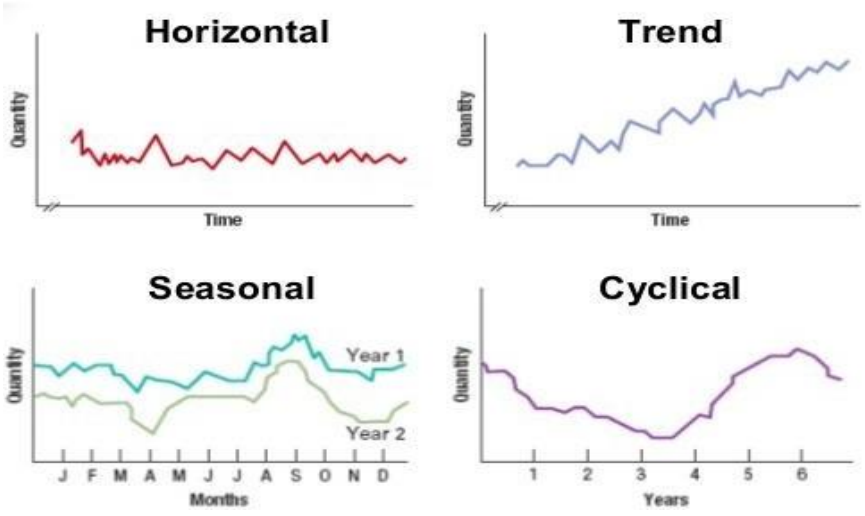
There are five basic patterns of most time series.

a. **Horizontal:** The fluctuation of data around a constant mean.

b. **Trend**: The systematic increase or decrease in the mean of the series over time.

c. **Seasonal** A repeatable pattem of increases or decreases in demand, depending on the time of day, week, month, or season.

d. **Cyclical:** The less predictable gradual increases or decreases over longer periods of time (years or decades).



1. Stationary (horizontal) demand pattern:

- No growth/decline trend, no seasonal variation.
- This demand pattern exists when the demand in the past do not have any increasing and decreasing trend i.e only random fluctuations are present around a Particular level of demand. The mean value does not change over a time
- Ex: Products with stable sales, number of defective items from a stable production processes
  Ex: Rice, vegetables, fruits, on petrol, Gas.
- The simple or weighted moving average method or simple exponential smoothing methods are suitable.

2. Seasonal demand pattern:

- No growth / decline trend, seasonal variation
- This pattern exists when the series fluctuations according to some seasonal factor the season may be months, quarters, weeks, etc.
- When there is no increasing or decreasing trend but there are seasonal variations .
  (similar crests and troughs in the curve at regular intervals of time).
- Ex: sale of refrigerators, sale of soft drinks, sale of wool items, etcThe simple moving average is suitable

3. Trend pattern :-

- Linear growth or decline, no seasonal variation.
- This pattern exists when there is no increase or decrease in the value of the demand over a time i.e increasing or decreasing trend with no seasonal variations.
- Ex: sales of many products, stock prices business and economic indicators
- Holt's double exponential smoothing more appropriate, ,

4. Cyclical pattern

- Linear growth/ decline trend, seasonal variation.
- This pattern exists when the length of a single cycle is longer than a year. The cycle does not repeat at constant intervals of time.
- i.e where there is an increasing or decreasing trend with seasonal variations
- Ex: prices of some metals, gross national product

Time Series Models

- Try to predict the future based on past data
- Assume that factors influencing the past will continue to influence the future

Naïve method:

- The forecast is equal to the actual value observed during the last period
- good for level patterns

$$F_{t+1} = D_t$$

Moving Average method:

- The average value over a set time period (e.g.: the last three weeks)
- Each new forecast drops the oldest data point & adds a new observation
- More responsive to a trend but still lags behind actual data

$$F_{t+1} = \sum D_t / n$$

Weighted Moving Average:

$$M_t = \frac{\sum_{t=1}^{n} W_t D_t}{\sum_{t=1}^{n} W_t}$$

- All weights must add to 100% or 1.00

e.g. **Wt=0 .5**, W_{t-1} **=0.3**, W_{t-2} **=0.2** (weights add to 1.0)

- Allows emphasizing one period over others; above indicates more weight on recent data (Wt=0.5)
- Differs from the simple moving average that weighs all periods equally - more responsive to trends
- ***Advantages of Moving Average Method***
  - Easily understood
  - Easily computed
  - Provides stable forecasts

- ***Disadvantages of Moving Average Method***
  - Requires saving lots of past data points: at least the N periods used in the moving average computation
  - Lags behind a trend
  - Ignores complex relationships in data

Exponential Smoothing method

- Assumes the most recent observations have the highest predictive value
  - gives more weight to recent time periods

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

F_{t+1} = Forecast value for time $t+1$

D_t = Actual value at time t

α = Smoothing constant

- Most frequently used time series method because of ease of use and minimal amount of data needed
- Need just three pieces of data to start:
  - Last period's forecast (**Ft**)
  - Last periods actual value (**Dt**)
  - Select value of smoothing coefficient'α' between 0 and 1.0
- If no last period forecast is available, average the last few periods or use naive method
- Higher 'α' values (e.g. 0.7 or 0 .8) may place too much weight on last period's random variation

Trend Adjusted Exponential Smoothing method

A trend in a time series is a systematic increase or decrease in the average of the series over time.

- Where a significant trend is present, exponential smoothing approaches must be modified; otherwise, the forecasts tend to be below or above the actual demand.

Trend-adjusted exponential smoothing method for incorporating a trend in an exponentially smoothed forecast.

- With this approach, the estimates for both the average and the trend are smoothed, requiring two smoothing constants. For each period, we calculate the average and the trend.

Regression Model

Simple Linear Regression Model

$y = a + bx$

where a = intercept

b = slope of the line

x = Independent variable

y = Dependent variable

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

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

- Solve for the y intercept

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

- Develop the equation for the trend line

Y=a + bX

FORECASTING QUANTITATIVE TECHNIQUES (PROBLEMS)

Time Series Models

- Try to predict the future based on past data
- Assume that factors influencing the past will continue to influence the future

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$$F_{t+1} = \sum D_t / n$$

Simple Moving Average

For Three period Moving Average

$$M_3 = \frac{\sum_{i=1}^{3} D_i}{3}$$

$F_4 = M_3$

$F_5 = M_4$

For Five period Moving Average

$F_6 = M_5$

$F_7 = M_6$

$$M_5 = \frac{\sum_{i=1}^{5} D_i}{5}$$

Where
n = number of periods taken to evaluate the moving average
Dt or Di = Actual demand in that period

Example 1: Forecast the order for the month of November by

i. Naive Approach
ii. a three period moving average .
iii. a five period moving average**.**

Month (*t*)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Order per month Dt	120	90	100	75	110	50	75	130	110	90

Solution:

i. Naive Approach

S. No.	**Month (*t*)**	**Order per month Dt**	**Forecast F_t**
1	Jan	120	
2	Feb	90	120
3	Mar	100	90
4	Apr	75	100
5	May	110	75
6	Jun	50	110
7	Jul	75	50
8	Aug	130	75
9	Sep	110	130
10	Oct	90	110
11	Nov		90

$F_2 = 120$ $\quad F_{t+1} = D_t$

$F_3 = 90$

$F_4 = 100$

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$F_{11} = 90$

Forecast the order for the month of November = 90

3- Months Moving Average (n=3)

S.No.	Month (*t*)	Order per month Dt	Moving Average Mt	Forecast F_t	Error (Dt - Ft)
1	Jan	120	------	------	------
2	Feb	90	------	------	------
3	Mar	100	103	------	------
4	Apr	75	88	103	-28
5	May	110	95	88	22
6	Jun	50	78	95	-45
7	Jul	75	78	78	-3
8	Aug	130	85	78	52
9	Sep	110	105	85	25
10	Oct	90	110	105	-15
11	Nov	------	------	**110**	------

$M_3 = (D_1+D_2+D_3)\ /3$

$= (120+90+100)\ /3$

$= 103$

$$M_3 = \frac{\sum_{i=1}^{3} D_i}{3}$$

$F_4 = M_3 = 103$

$M_4 = 88$

$.F_5 = M_4 = 88$

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$.M_{10} = 110$

$F_{11} = M_{10} = 110$

Forecast the order for the month of November = 110

5- Months Moving Average (n=5)

S.No.	Month (*t*)	Order per month Dt	Moving Average Mt	Forecast F_t	Error (Dt - Ft)
1	Jan	120	------	------	------
2	Feb	90	------	------	------
3	Mar	100	------	------	------
4	Apr	75	------	------	------
5	May	110	99	------	------
6	Jun	50	85	99	-49
7	Jul	75	82	85	-10
8	Aug	130	88	82	48
9	Sep	110	95	88	22
10	Oct	90	91	95	-5
11	Nov	------	-----	**91**	------

$M_5 = (D_1 + D_2 + D_3 + D_4 + D_5) / 5$

$= (120+90+100+75+110)/5$

$= 99$

$$M_5 = \frac{\sum_{i=1}^{5} D_i}{5}$$

$F_6 = M_5 = 99$

$M_6 = 85$

$F_7 = M_6 = 85$

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$M_{10} = (50+75+130+110+90)/5$

$= 91$

$F_{11} = M_{10} = 91$

Forecast the order for the month of November = 91

Example 2 : During the past ten weeks, sales of cases of Comfort brand headache medicine at Robert's Drugs have been as follows. Forecast the sales for period 11 using

i) a three period moving average .
ii) a five period moving average.

Week	1	2	3	4	5	6	7	8	9	10
Sales	110	115	125	120	125	120	130	115	110	130

Solution:

i) 3 Period Moving Average (n=3)

Week (*t*)	Actual Demand Dt	Moving Average Mt	Forecast F_t	Error (Dt - Ft)
1	110	------	------	------
2	115	------	------	------
3	125	117	------	------
4	120	120	117	3
5	125	123	120	5
6	120	122	123	-3
7	130	125	122	8
8	115	122	125	-10
9	110	118	122	-12
10	130	118	118	12
11	------	------	**118**	------

$M_3 = (D_1+D_2+D_3)/3$

$= (110+115+125)/3$

$= 117$

$$M_3 = \frac{\sum_{i=1}^{3} D_i}{3}$$

$F_4 = M_3 = 117$

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$M_{10} = 118$

$F_{11} = M_{10} = 118$

Sales for the week 11 = 118

ii) 5 Period Moving Average (n=5)

Week (*t*)	Actual Demand Dt	Moving Average Mt	Forecast F_t	Error (Dt - Ft)
1	110	------	------	------
2	115	------	------	------
3	125	------	------	------
4	120	------	------	------
5	125	124	------	------
6	120	122	124	-4
7	130	120	122	8
8	115	121	120	-5
9	110	121	121	-11
10	130	118	121	9
11	------	------	**118**	-----

$M_5 = (D_1 + D_2 + D_3 + D_4 + D_5) / 5$

$= (110+115+125+120+125)/5$

$= 124$

$$M_5 = \frac{\sum_{i=1}^{5} D_i}{5}$$

$F_6 = M_5 = 124$

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$M_{10} = 118$

$F_{11} = M_{10} = 118$

Sales for the week 11 = 118

Weighted Moving Average:

$$M_t = \frac{\sum_{t=1}^{n} W_t D_t}{\sum_{t=1}^{n} W_t}$$

Three period Weighted moving average

$$M_3 = \frac{W_1 D_1 + W_2 D_2 + W_3 D_3}{W_1 + W_2 + W_3}$$

$F_4 = M_3$

$F_5 = M_4$

Example 3: Use a 3 period weighted moving average to forecast the sales for week 11 giving a weight of 0.6 to the most recent period, 0.3 to the second most recent period, and 0.1 to the third most recent period

Week	1	2	3	4	5	6	7	8	9	10
Sales	110	115	125	120	125	120	130	115	110	130

Solution:

Week (*t*)	**Actual Demand Dt**	**Weighted Moving Average Mt**	**Forecast F_t**	**Error (Dt - Ft)**
1	110	------	------	------
2	115	------	------	------
3	125	121	------	------
4	120	121	121	-1
5	125	124	121	4
6	120	122	124	-4
7	130	127	122	8
8	115	120	127	-12
9	110	114	120	-10
10	130	123	114	17
11	------	------	**123**	-----

W1 =0.1, W2= 0.3 and W3=0.6

$$M_3 = \frac{W_1 D_1 + W_2 D_2 + W_3 D_3}{W_1 + W_2 + W_3}$$

$$M_{3=} \frac{0.1\text{x}110 + 0.3\text{x}115 + 0.6\text{x}125}{0.1 + 0.3 + 0.6}$$

= 121

$F_4 = M_3 = 121$

$F_5 = M_4 = 121$

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$F_{11} = M_{10} = 123$

Sales for the week 11 = 123

Exponential Smoothing method

- Assumes the most recent observations have the highest predictive value
  - gives more weight to recent time periods

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

F_{t+1} = Forecast value for time $t+1$

D_t = Actual value at time t

α = Smoothing constant

Example 4 : Using the exponential smoothing technique, compute the forecasts from the following data (time series) under the situations when **α = 0.1 and 0.6.** Compute the forecast for the 10th period?

Month	1	2	3	4	5	6	7	8	9
Demand	820	775	680	655	750	802	798	689	775

Solution:

Assume $F_1=D_1$

Week	Demand	Forecast a=0.1	Forecast a=0.6
1	820	820.00	820.00
2	775	820.00	820.00
3	680	815.50	793.00
4	655	801.95	725.20
5	750	787.26	683.08
6	802	783.53	723.23
7	798	785.38	770.49
8	689	786.64	787.00
9	775	776.88	728.20
10		776.69	756.28

$$\mathbf{F_{t+1} = F_t + a(D_t - F_t)}$$

For **a=0.1**

$F_2 = F_1 + a(D_1 - F_1)$

$=820+0.1(820-820)$

$=820.00$

$F_3 = F_2 + a\,(D_2 - F_2)$

$=820+0.1\,(775-820)$

$= 815.5$

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$F_{10} = F_9 + a\,(D_9 - F_9)$

$= 776.88+0.1\,(775-776.88)$

$= \mathbf{776.69}$

Forecast for the 10th period when a is 0.1 =776.69

For **a=0.6**

$F_2 = F_1 + a(D_1 - F_1)$

$=820+0.6(820-820)$

$=820.00$

$F_3 = F_2 + a\,(D_2 - F_2)$

$=820+0.6\,(775-820)$

$= 793$

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$F_{10} = F_9 + a\,(D_9 - F_9)$

$= 728+0.6\,(775-728)$

$= \mathbf{756.28}$

Forecast for the 10th period when a is 0.6 =756.28

Example 5 : Using the exponential smoothing technique, Compute the forecasts from the following data (time series) under the situations when **α = 0.3 and 0.6.** Compute the forecast for the month of july ? Assume F1=100.00

Month	January	February	March	April	May	June
Demand	120	90	101	91	115	83

Solution:

S.No.	Month	Demand	Forecast a = 0.3	Forecast a = 0.6
1	January	120	100.00	100.00
2	February	90	106.00	112.00
3	March	101	101.20	98.80
4	April	91	101.14	100.12
5	May	115	98.10	94.65
6	June	83	103.17	106.86
7	July		97.12	92.54

$$F_{t+1} = F_t + a(D_t - F_t)$$

For **a = 0.3 and** Assuming F1=100.00

$F_2 = F_1 + a(D_1 - F_1)$

$=100+0.3(120-100)$

$=106.00$

$F_3 = F_2 + a(D_2 - F_2)$

$=106+0.3(90-106)$

$=101.2$

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$F_7 = F_6 + a(D_6 - F_6)$

$= 103.17+0.3(83-103.17)$

$=$ **97.12**

Forecast for the month of july when a is 0.3 =97.12

For **a = 0.6 and** Assuming F1=100.00

$F_2 = F_1 + a(D_1 - F_1)$

=100+0.6(120-100)

=112.00

$F_3 = F_2 + a(D_2 - F_2)$

=112+0.6(90-112)

= 98.8

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$F_7 = F_6 + a(D_6 - F_6)$

= 106.86+0.6(83-106.86)

= **92.54**

Forecast for the month of july when a is 0.3 = 92.54

Linear 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 = Dependent variable (forecast for X)
X = Independent variable
a = value of y at X = 0 (Y intercept)
b = slope of the line

- Solve for the slope of the line

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

- Solve for the y intercept

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

- Develop the equation for the trend line **Y=a + bX**

Example 6: A maker of golf shirts has been tracking the relationship between sales and advertising dollars. Use linear regression to find out what sales might be if the company invested $53,000 in advertising next year.

Sales $	130	151	150	158
Adv.$	32	52	50	55

Solution:

S.No.	Adv.$ (X)	Sales $ (Y)	XY	X^2
1	32	130	4160	2304
2	52	151	7852	2704
3	50	150	7500	2500
4	55	158	8690	3025
5	53			
Tot	189	589	28202	9253

$$\bar{X} = \frac{189}{4} = 47.25$$

$$\bar{Y} = \frac{589}{4} = 147.25$$

$$b = \frac{\sum XY - n\bar{X}\bar{Y}}{\sum X^2 - n\bar{X}^2}$$

$$b = \frac{28202 - 4(47.25)(147.25)}{9253 - 4(47.25)^2} = 1.15$$

$$a = \bar{Y} - b\bar{X} = 147.25 - 1.15(47.25)$$
$$a = 92.9$$

$$Y = a + bX$$
$$= 92.9 + 1.15X$$
$$Y = 92.9 + 1.15(53)$$
$$= 153.85$$

Correlation Coefficient:

- Correlation coefficient **(r)** measures the direction and strength of the linear relationship between two variables. The closer the r value is to 1.0 the better the regression line fits the data points.

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2} * \sqrt{n(\sum Y^2) - (Y)^2}}$$

$$r = \frac{4(28{,}202) - 189(589)}{\sqrt{4(9253) - (189)^2} * \sqrt{4(87{,}165) - (589)^2}} = .982$$

$$r^2 = (.982)^2 = .964$$

Coefficient of determination ($\mathbf{r^2}$) measures the amount of variation in the dependent variable about its mean that is explained by the regression line. Values of ($\mathbf{r^2}$) close to 1.0 are desirable

Example 7: A firm believes that its annual profit depends on its expenditures for research. The information for the preceding six years is given below. Estimate the profit when expenditure is 6 units.

Year	1	2	3	4	5	6
Expenditure for research	2	3	5	4	11	5
Annual profit	20	25	34	30	40	31

Solution:

Year	Expenditure for research X	Annual profit Y	XY	X^2
1	2	20	40	4
2	3	25	75	9
3	5	34	170	25
4	4	30	120	16
5	11	40	440	121
6	5	31	155	25
7	6	?		
Total	30	180	1000	200

$$\bar{X} = \frac{30}{6} = 5$$

$$\bar{Y} = \frac{180}{6} = 30$$

$$b = \frac{\sum XY - n\bar{X}\bar{Y}}{\sum X^2 - n\bar{X}^2}$$

$$b = \frac{1000 - 6 \text{ x } 5 \text{ x } 30}{200 - 6 \text{ x } (5)^2} = 2$$

$$a = \bar{Y} - b\bar{X} = 30 - 2 \text{ x } 5$$

$$a = 20$$

$$Y = a + bX$$

$$= 20 + 2X$$

$$Y = 20 + 2 \text{ x } 6$$

$$= 32$$

Measuring Forecast Error

- Forecasts are never perfect
- Need to know how much we should rely on our chosen forecasting method

Measuring Forecast Error

$$E_t = D_t - F_t$$

- Note that over-forecasts = negative errors and under-forecasts = positive errors

Measuring Forecasting Accuracy

i) Mean Absolute Deviation (MAD)

Measures the total error in a forecast without regard to sign

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

ii) Cumulative Forecast Error (CFE)

Measures any bias in the forecast

$$CFE = \sum (\text{actual} - \text{forecast})$$

iii) Mean Square Error (MSE)

Penalizes larger errors

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

iv) Root Mean Squared Error (RMSE)

$$RMSE = \sqrt{MSE}$$

v) Mean Absolute Percentage Error (MAPE)

$$MAPE = \frac{\sum_{t=1}^{n} |D_t - F_t|}{D_t} X100$$

vi) Mean forecast error (MFE)

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

vii) Tracking Signal

Measures if your model is working

$$TS = \frac{CFE}{MAD}$$

Example 8: Determine the Mean Absolute Deviation (MAD), Mean Square Error (MSE), Mean Absolute Percentage Error (MAPE), Mean forecast Error (MFE) for the following Data

Period	1	2	3	4	5
Demand	150	160	165	175	180
Forecast	165	165	165	165	165

Solution:

Period	**Demand D_t**	**Forecast F_t**	**Error $(D_t - F_t)$**	**Absolute deviation $\lvert D_t - F_t \rvert$**	**Squared Error $(D_t - F_t)^2$**	**Percentage Error $(D_t - F_t) * 100/D_t$**	**Absolute Percentage Error $\lvert D_t - F_t \rvert * 100/\lvert D_t \rvert$**
1	150	165	-15	15	225	-10	10
2	160	165	-5	5	25	-3.125	3.125
3	165	165	0	0	0	0	0
4	175	165	10	10	100	5.71	5.71
5	180	165	15	15	225	8.33	8.33
TOTAL			5	45	**575**		27.165

$$MAD = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n} = \frac{45}{5} = 9$$

$$MSE = \frac{\sum_{t=1}^{n} (D_t - F_t)^2}{n} = \frac{575}{5} = 115$$

$$MAPE = \frac{1}{n} \sum_{t=1}^{n} \frac{|D_t - F_t|}{D_t} X100 = \frac{27.165}{5} = 5.433\%$$

$$MFE = \frac{\sum_{t=1}^{n} (D_t - F_t)}{n} = \frac{+5}{5} = +1$$

Example 9: Determine the MAD, MSE and RMSE values for the given forecast values in the table below?

Month	1	2	3	4	5
Sales	220	250	210	300	325
Forecast	N/A	255	205	320	315

Solution:

Month	**Sales** D_t	**Forecast** F_t	**Error** $(D_t - F_t)$	**Absolute deviation** $\lvert D_t - F_t \rvert$	**Squared Error** $(D_t - F_t)^2$
1	220	N/A	---	---	----
2	250	255	-5	5	25
3	210	205	5	5	25
4	300	320	-20	20	400
5	325	315	10	10	100
TOTAL				**40**	**550**

$$MAD = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n} = \frac{40}{4} = 10$$

$$MSE = \frac{\sum_{t=1}^{n} (D_t - F_t)^2}{n} = \frac{550}{4} = 137.5$$

$$RMSE = \sqrt{MSE} = \sqrt{137.5} = 11.73$$