UNIVERSITY OF GONDAR

INSTITUTE OF TECHNOLOGY

DEPARTMENT OF INDUSTRIAL ENGINEERING

PRODUCTION PANNING AND CONTROL-II

COURSE CODE IEng 3112

TARGET GROUP 3rd YEAR INDUSTRIAL ENGINEERING REGULAR STUDENTS

Chapter 1

Forecasting Demand

Introduction

Demand management: Is the **supply chain management process** that **balances** the customers' **requirements** with the **capabilities** of the supply chain.

- With the right process in place, management can **match supply** with **demand** proactively and execute the plan with **minimal disruptions**. The process is not limited to forecasting.
- It includes harmonizing supply and demand, increasing flexibility, and reducing variability.
- A good demand management process can enable a company to be more proactive to anticipated demand, and more reactive to unanticipated demand.

Components of Demand

Six components of demand:

i. **Average demand**

ii. Trend: occurs when demand is increasing or decreasing over time as a result of some factor such as word of mouth, advertising, or changes in the population.

iii. Seasonal component: occurs with products and services that relate to certain months or time periods of the year.

Components of demand…..

iv. Cyclical components: similar to seasonal factors but have a much longer time period and are often harder to identify.

Cyclical factors include politics, economic conditions, war, and sociocultural influences.

v. Autocorrelation: occurs when the value of one data point is highly correlated with past values.

vi. Random variation: caused by chance events after all the other five components have been accounted for.

Forecasting

Forecasting is a process of estimating a future event by casting forward past data. The past data are

- Systematically combined in a predetermined way to obtain the estimate of the future.

Prediction is a process of estimating a future event based on subjective judgment rather than past data;

- Predicting is used to estimate the demand for new products where past data does not exists.

Common characteristics of forecasting

- Forecasts are rarely perfect because of randomness
- Forecasts are more accurate for groups than individuals

- Forecast accuracy decreases as time horizon increases

Importance of Forecasting

- To plan for the future by reducing uncertainty.
- To anticipate and manage change.
- To increase communication and integration of planning teams.
- To anticipate inventory and capacity demands and manage lead times.
- To project costs of operations into budgeting processes.
- To improve competitiveness and productivity through decreased costs and improved delivery and responsiveness to customer needs.

Importance of forecasting……

In general forecasting is used for;

Accounting	Cost /profit estimates
Finance	Cash flow and funds
Marketing	Pricing, promotion, Sales
Operations	Inventory, Schedules, MRP, workloads
Product/service design	New products launch
Human Resources	Hiring/recruiting/training

Elements of a good forecast

A properly prepared forecast should fulfill certain requirements:

1.The forecast should be **timely**. Usually, a certain amount of time is needed to respond to the information contained in a forecast. For example, capacity cannot be expanded overnight, nor can inventory levels be changed immediately. Hence, the forecasting horizon must cover the time necessary to implement possible changes.

2.The forecast should be **accurate**, and the degree of accuracy should be stated. This will enable users to plan for possible errors and will provide a basis for comparing alternative forecasts.

3.The forecast should be **reliable**, it should work consistently. A technique that sometimes provides a good forecast and sometimes a poor one will leave users with the uneasy feeling that they may get burned every time a new forecast is issued.

Elements of a good forecast……

4. The forecast should be expressed in **meaningful** units. Financial planners need to know how many dollars will be needed, production planners need to know how many units will be needed, and schedulers need to know what machines and skills will be required. The choice of units depends on user needs.

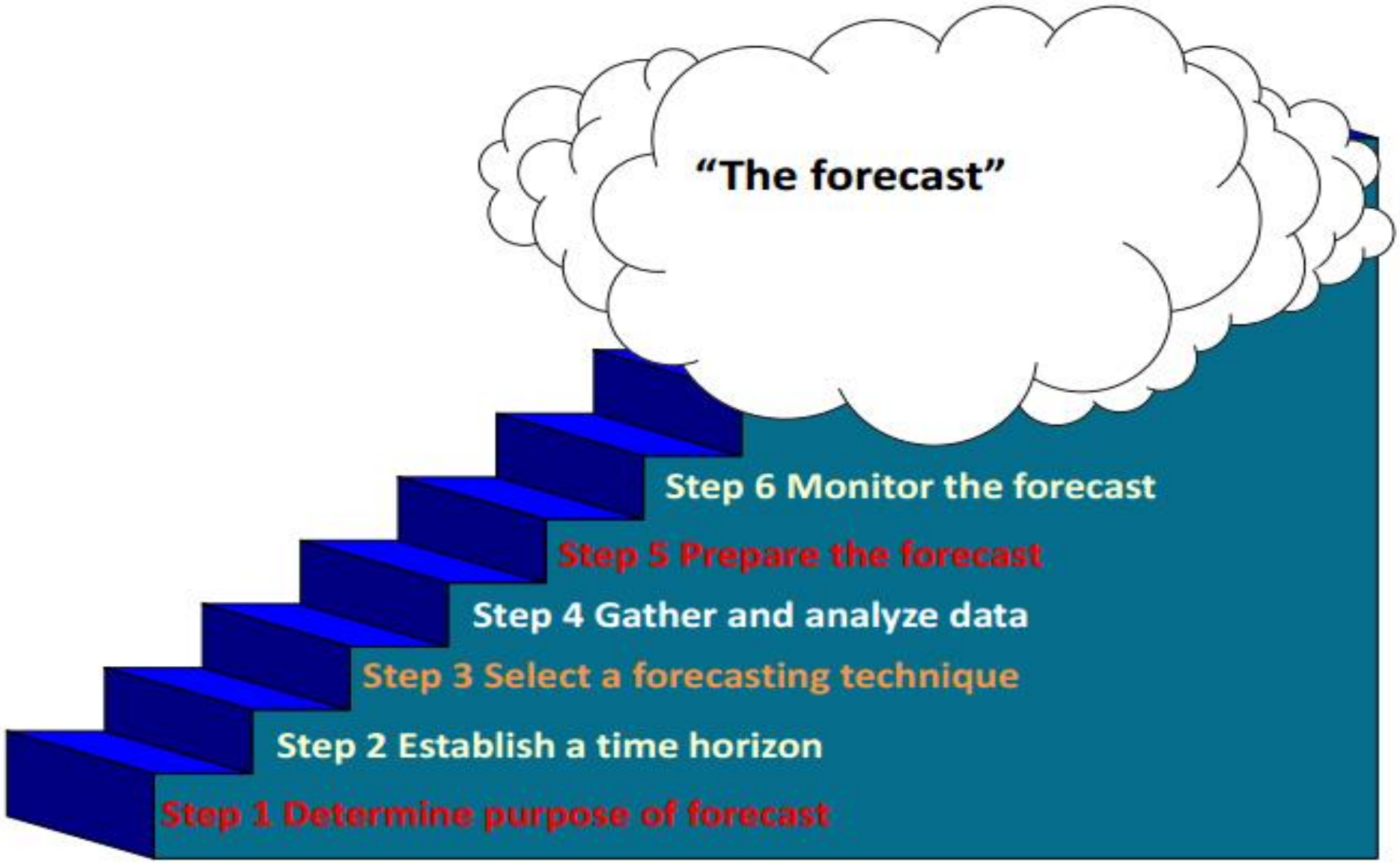
5. The forecast should be **in writing**. Although this will not guarantee that all concerned are using the same information, it will at least increase the likelihood of it. In addition, a written forecast will permit an objective basis for evaluating the forecast once actual results are in.

Elements of a good forecast……

6. The forecasting technique should be **simple to understand and use**. Users often lack confidence in forecasts based on sophisticated techniques; they do not understand either the circumstances in which the techniques are appropriate or the limitations of the techniques. Misuse of techniques is an obvious consequence. Not surprisingly, fairly simple forecasting techniques enjoy widespread popularity because users are more comfortable working with them.

7. The forecast should be **cost-effective**: The benefits should outweigh the costs.

Steps in the forecasting process



Types of Forecasts

Judgmental: uses subjective inputs

Time series: uses historical data assuming the future will be like the past

Associative models: uses explanatory variables to predict the future

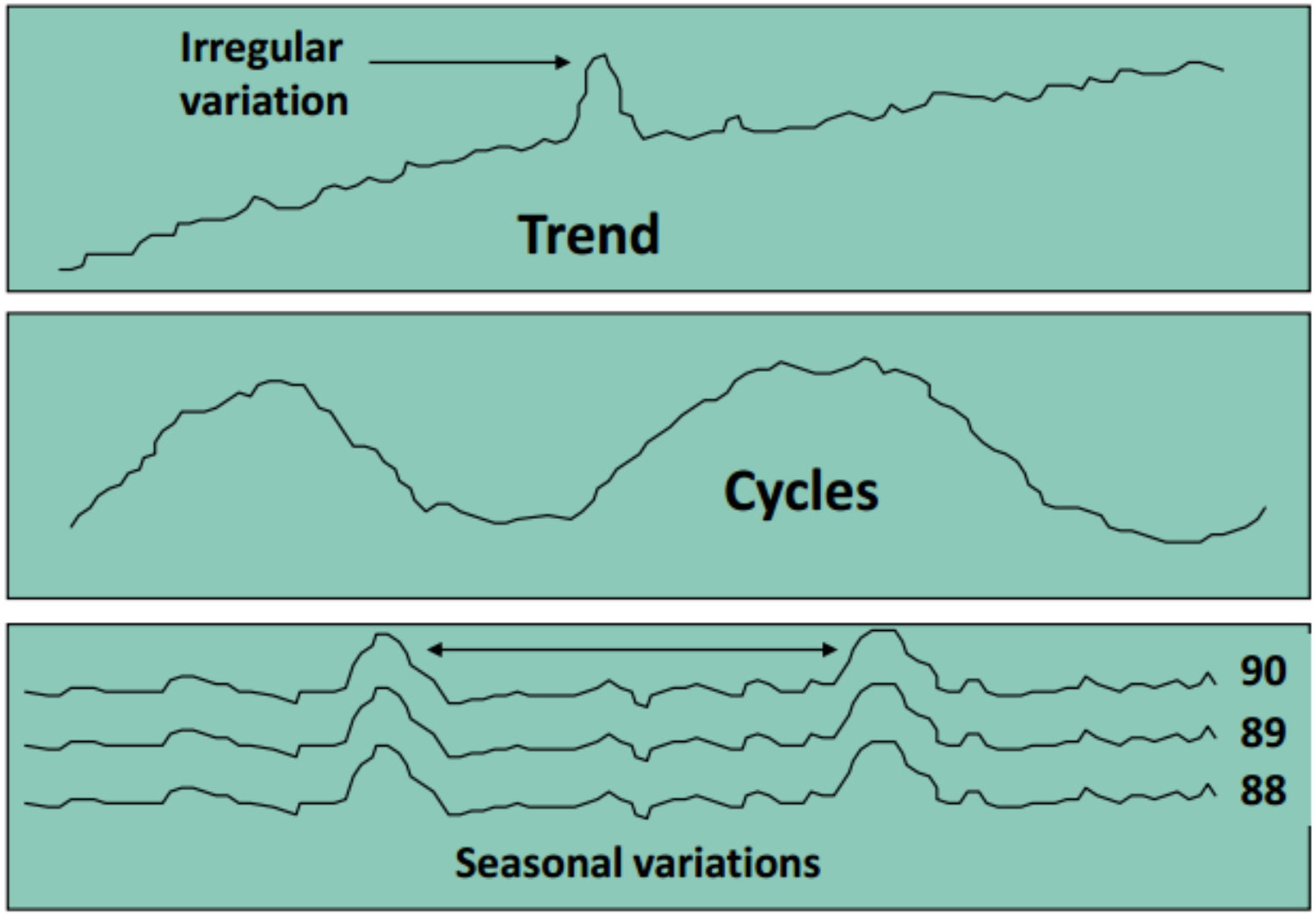
Judgmental Forecasts

- Executive opinions
- Sales force opinions
- Consumer surveys
- Outside opinion
- Delphi method
  - Opinions of managers and staff
  - Achieves a consensus forecast

Time Series Forecasts

- **Trend**: long-term movement in data
- **Seasonality**: short-term regular variations in data
- **Cycle**: wavelike variations of more than one year’s duration
- **Irregular variations:** caused by unusual circumstances
- **Random variations:** caused by chance

Forecast Variations



Types of forecasts by time horizon

- **Short-range forecast**

  ✓ Usually < 3 months

  • Job scheduling, worker assignments

- **Medium-range forecast**

  – 3 months to 2 years

  • Sales/production planning

- **Long-range forecast**

  – > 2 years

  • New product planning

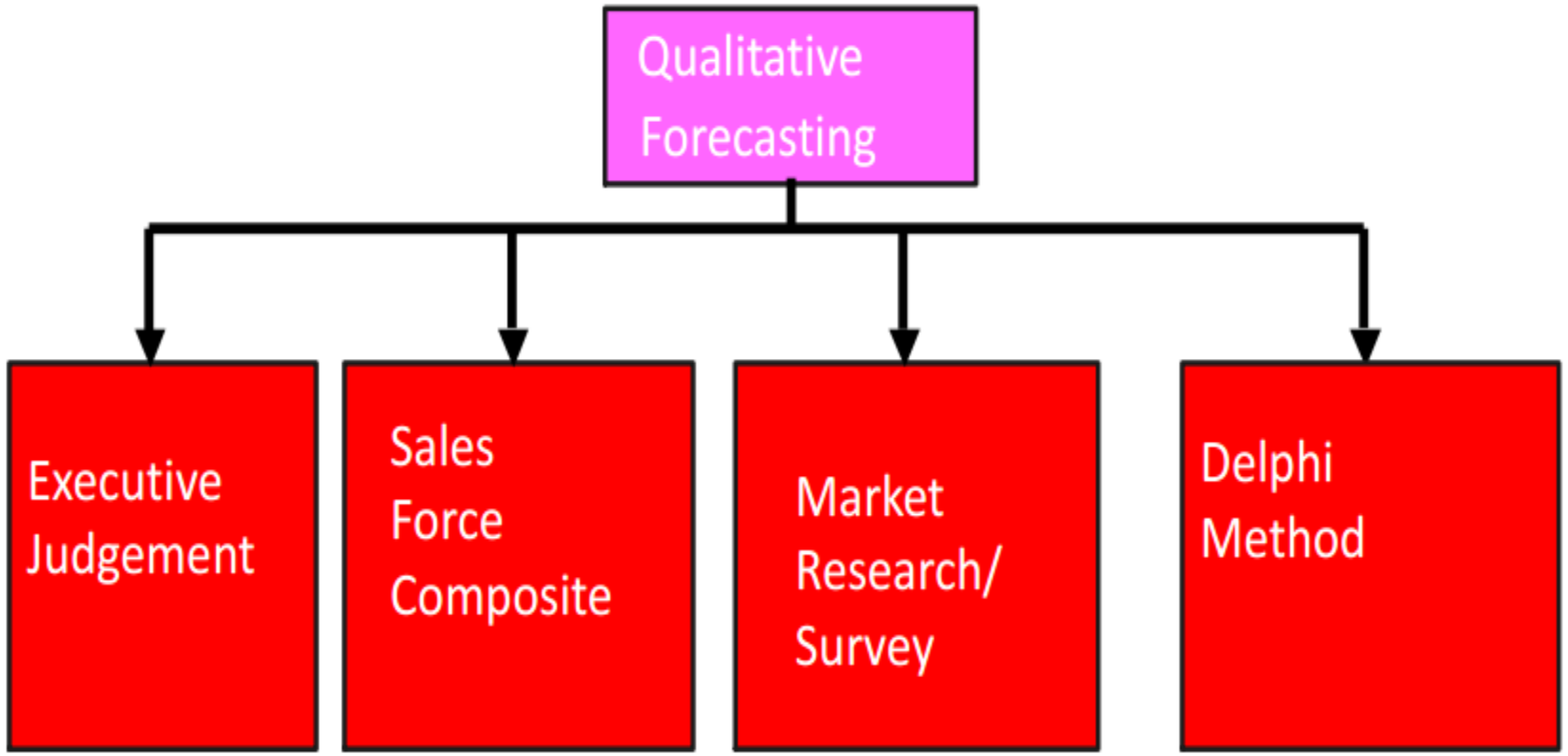
Detailed use of system

Design of system

Quantitative methods

Qualitative methods

Qualitative Forecasting Methods



Qualitative Methods….

Briefly, the qualitative methods are:

- Executive Judgment: *Opinion of a group of high level experts or managers is pooled.*
- Sales Force Composite: *Each regional salesperson provides his/her sales estimates*. Those forecasts are then reviewed to make sure they are realistic. All regional forecasts are then pooled at the district and national levels to obtain an overall forecast.
- Market Research/Survey: Petitions input from customers pertaining to their future purchasing plans. It involves the use of questionnaires, consumer panels and tests of new products and services.

Forecasting technique cont…

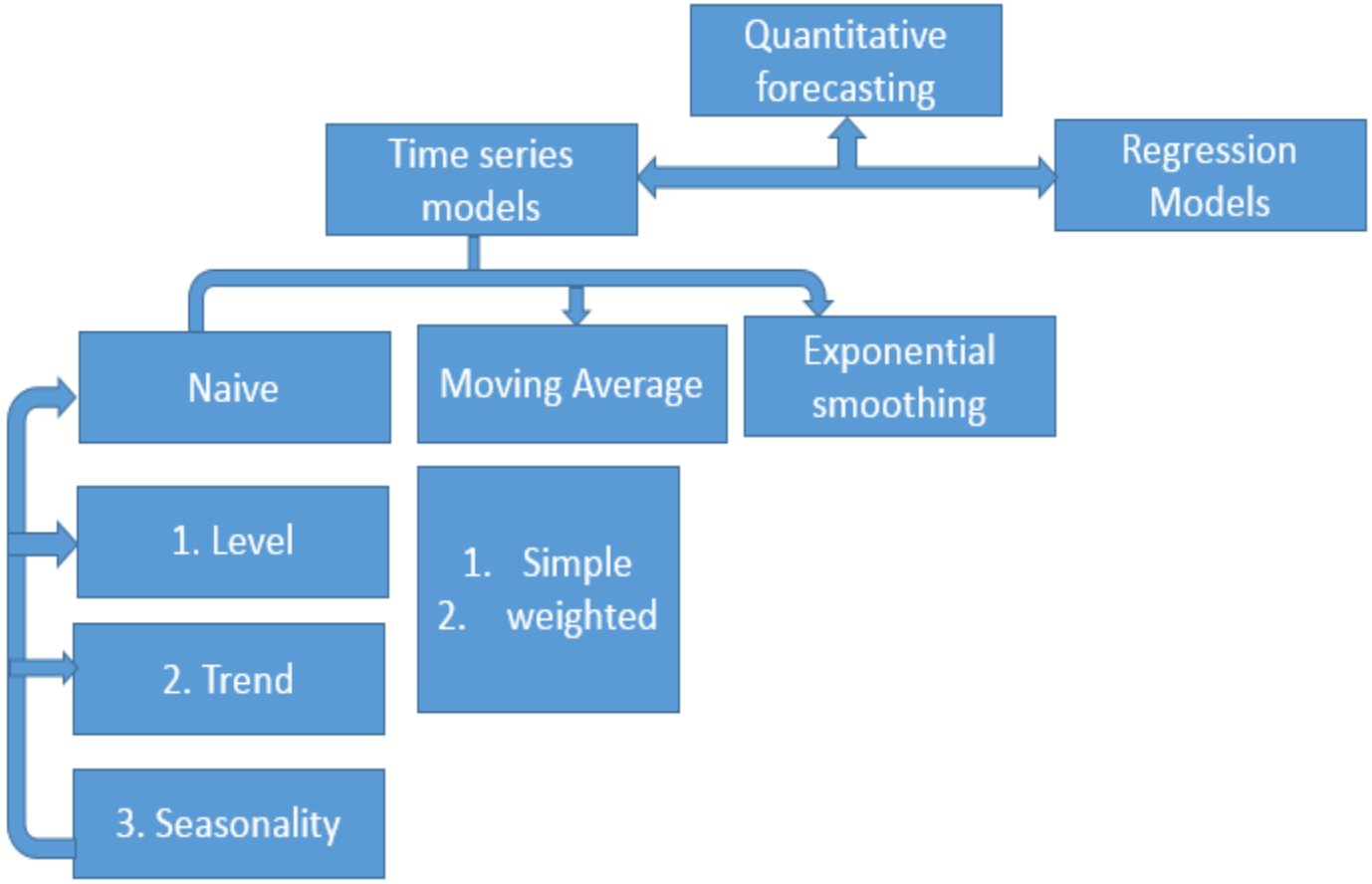
- **Delphi Method**: An iterative process in which managers and staff complete a series of questionnaires, each developed from the previous one, to achieve a harmony forecast. The Delphi method has been applied to a variety of situations, not all of which involve forecasting.
  - ✓As a forecasting tool, it is useful for technological forecasting, that is, for assessing changes in technology and their impact on an organization. Often the goal is to predict when a certain event will occur.
  - ✓ For the most part, these are long-term, single-time forecasts, which usually have very little hard information to go by or data that are costly to obtain, so the problem does not lend itself to analytical techniques. Rather, judgments of experts or others who possess sufficient knowledge to make predictions are used.

Delphi method.….

Typically, the procedure consists of the following steps:

- Each expert in the group makes his/her own forecasts in form of statements
- The coordinator collects all group statements and summarizes them
- The coordinator provides this summary and gives another set of questions to each group member including feedback as to the input of other experts.
- The above steps are repeated until a consensus is reached.

Quantitative Forecasting Methods



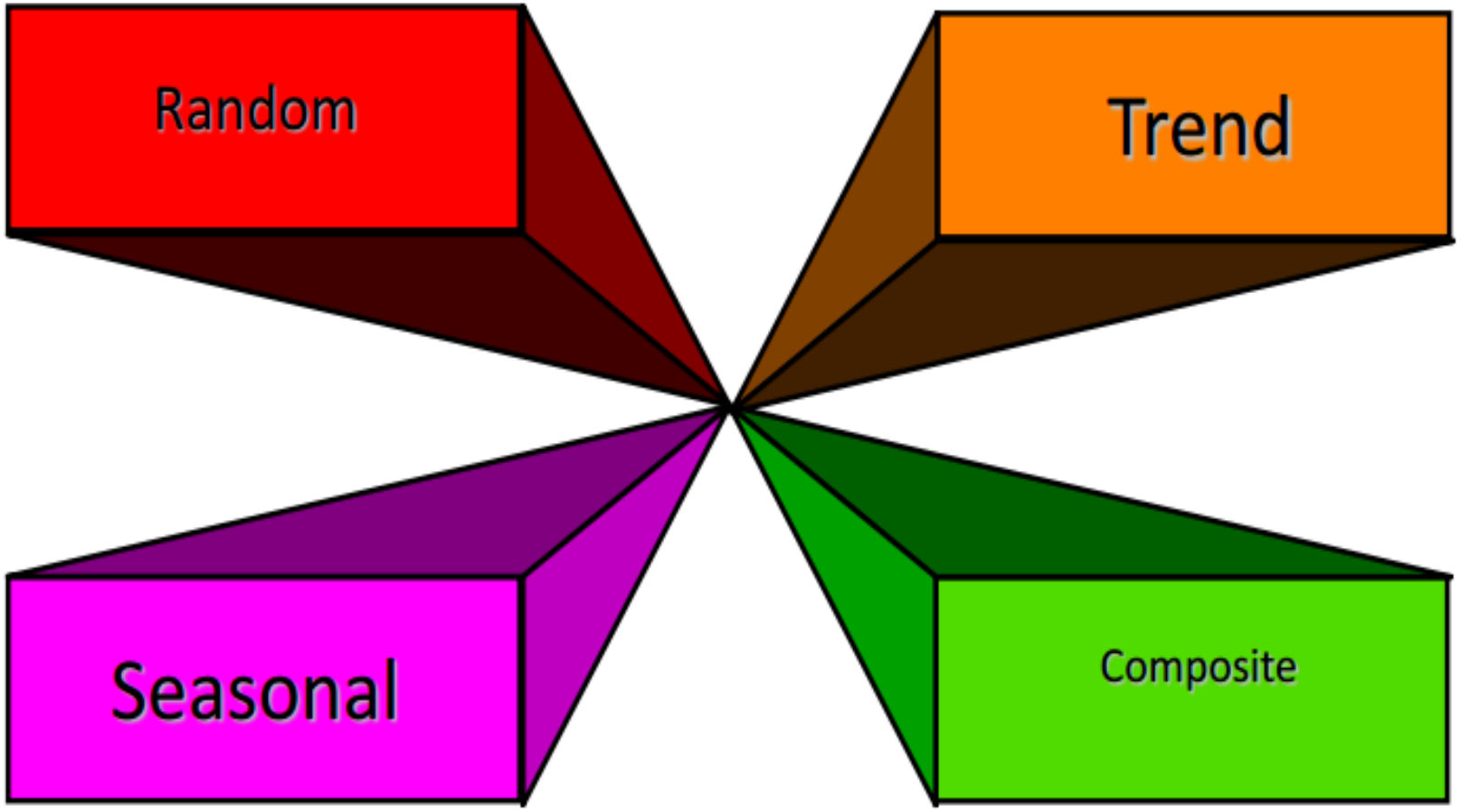
Quantitative Forecasting Methods

- Rely on data and analytical techniques.

- It includes :
- **Time-Series Methods**: it conducts a statistical analysis of past data to develop forecasts for the future. Assumes the future will follow same patterns as the past.
- **Causal Method:**
  - Explores cause-and-effect relationships
  - Uses leading indicators to predict the future
  - E.g. housing starts and appliance sales

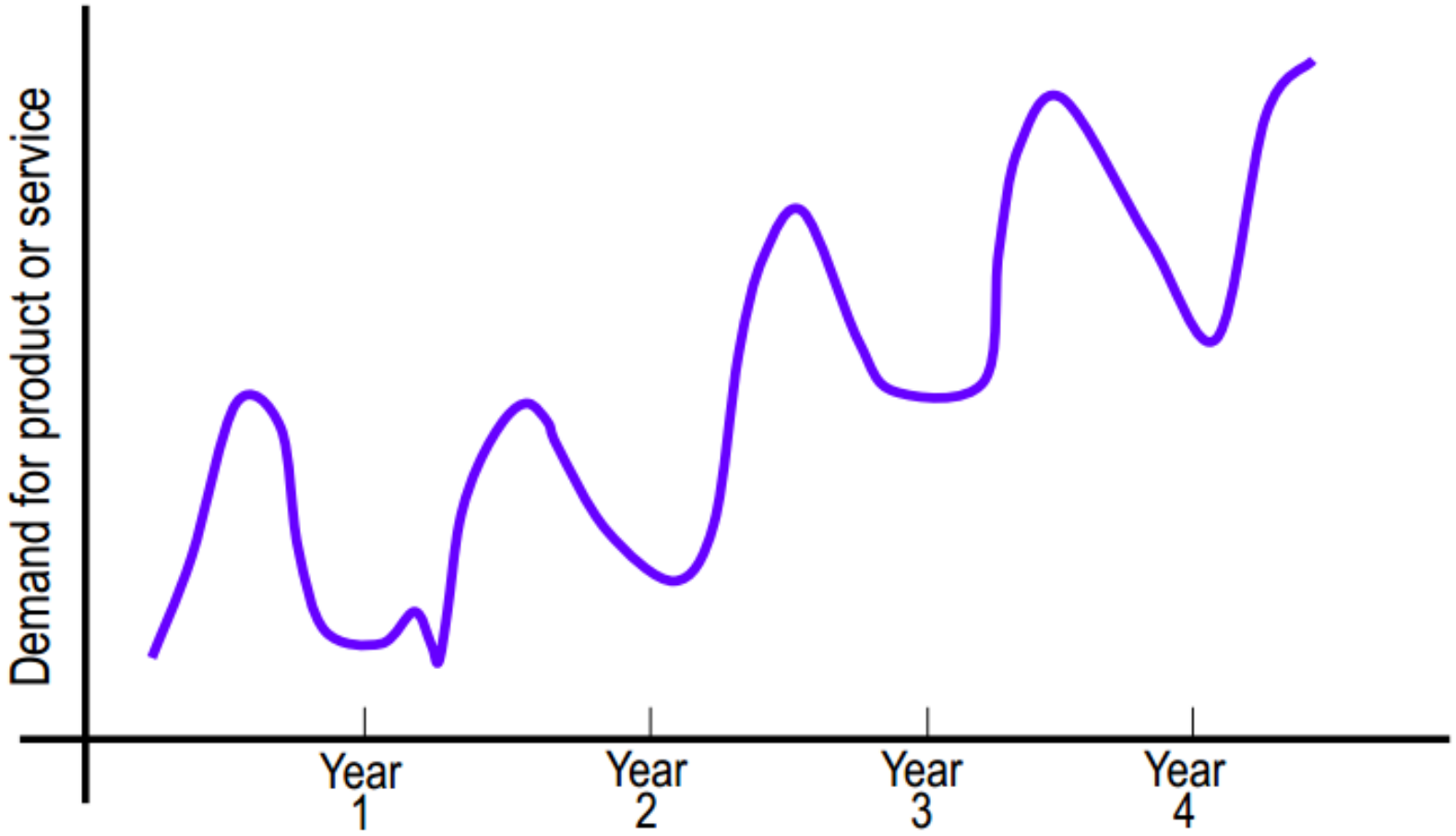
Quantitative Forecasting Methods

Time Series Models: Components



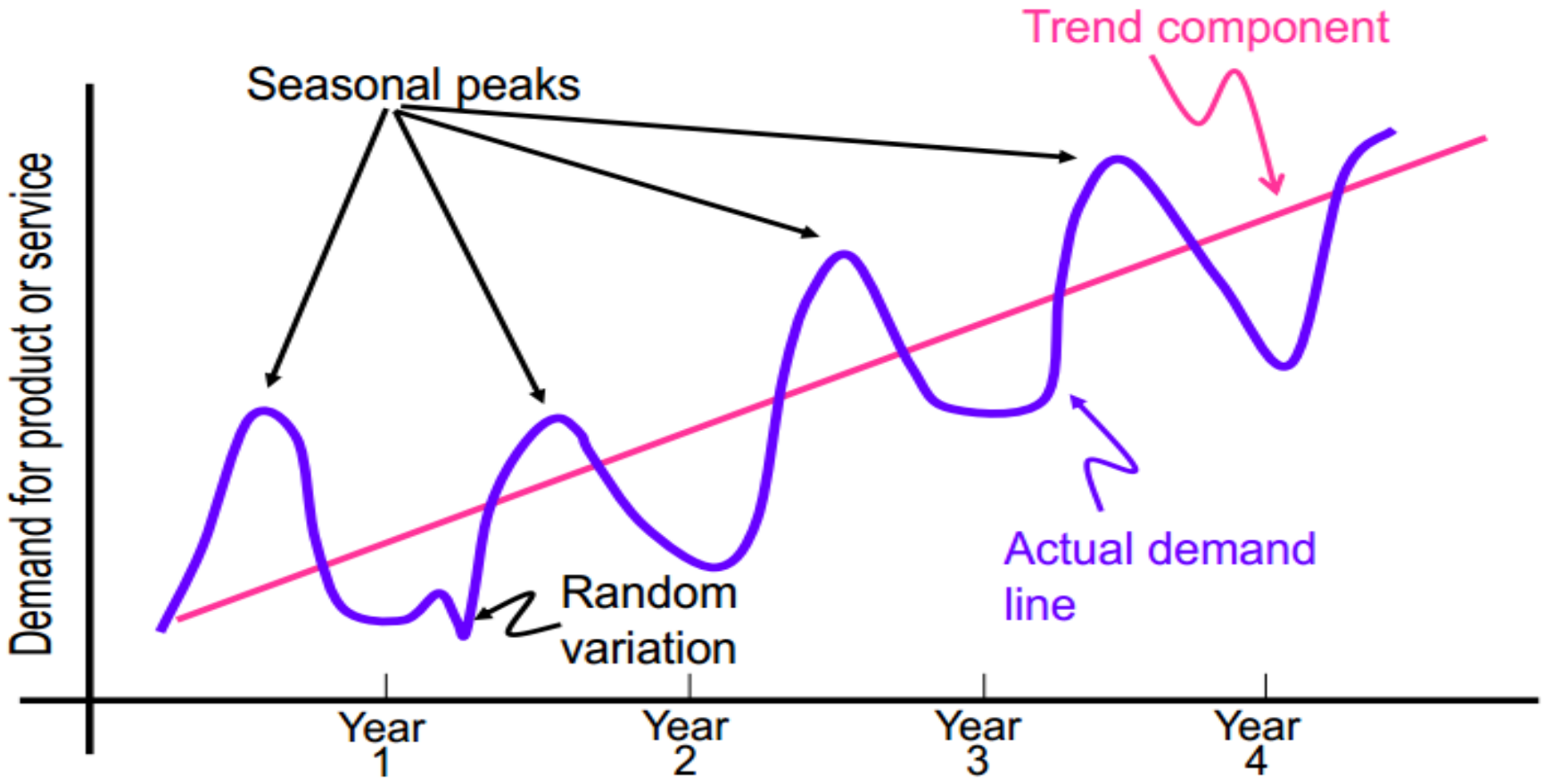
Quantitative Forecasting Methods

Product Demand over Time



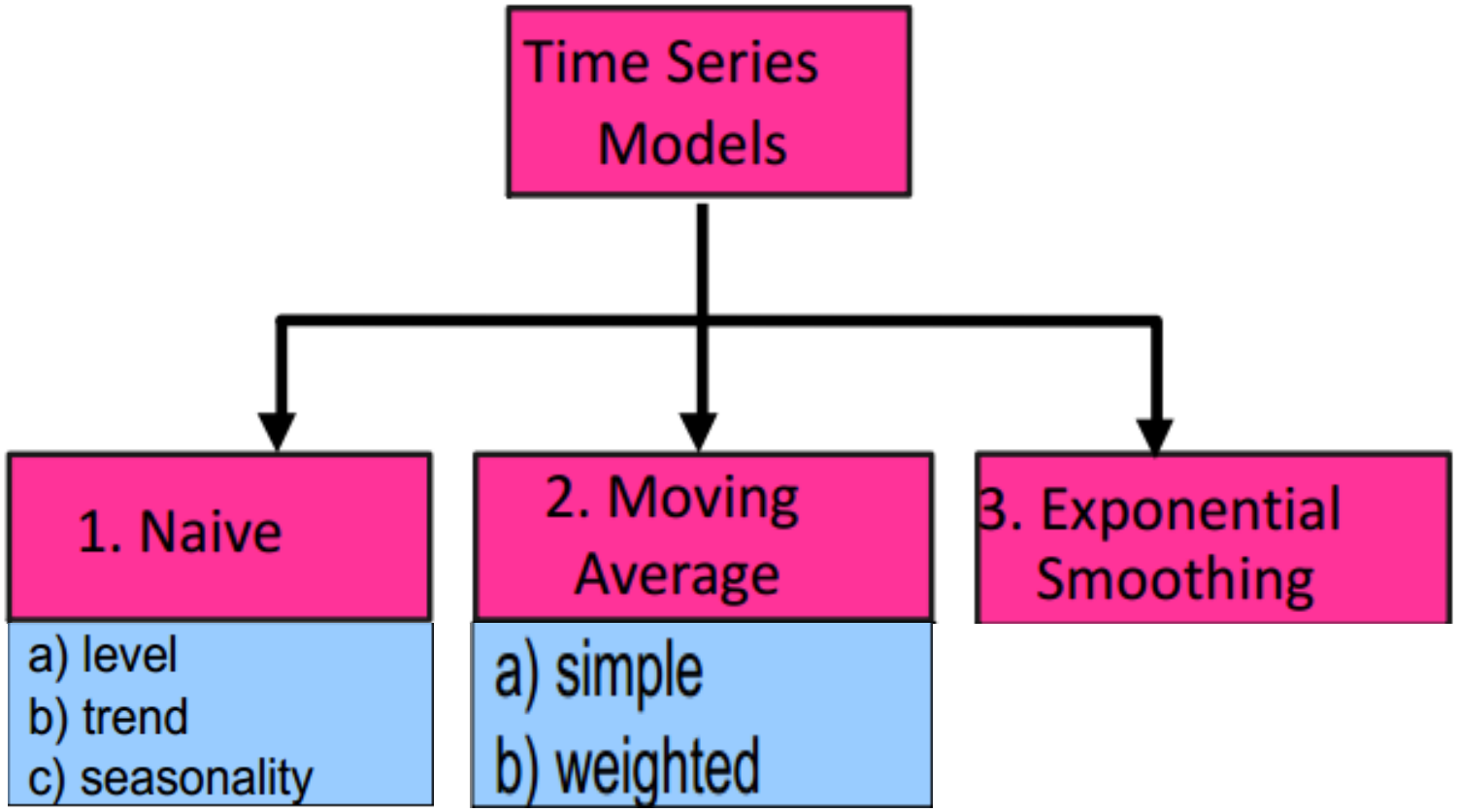
Quantitative Forecasting Methods

Product Demand over Time



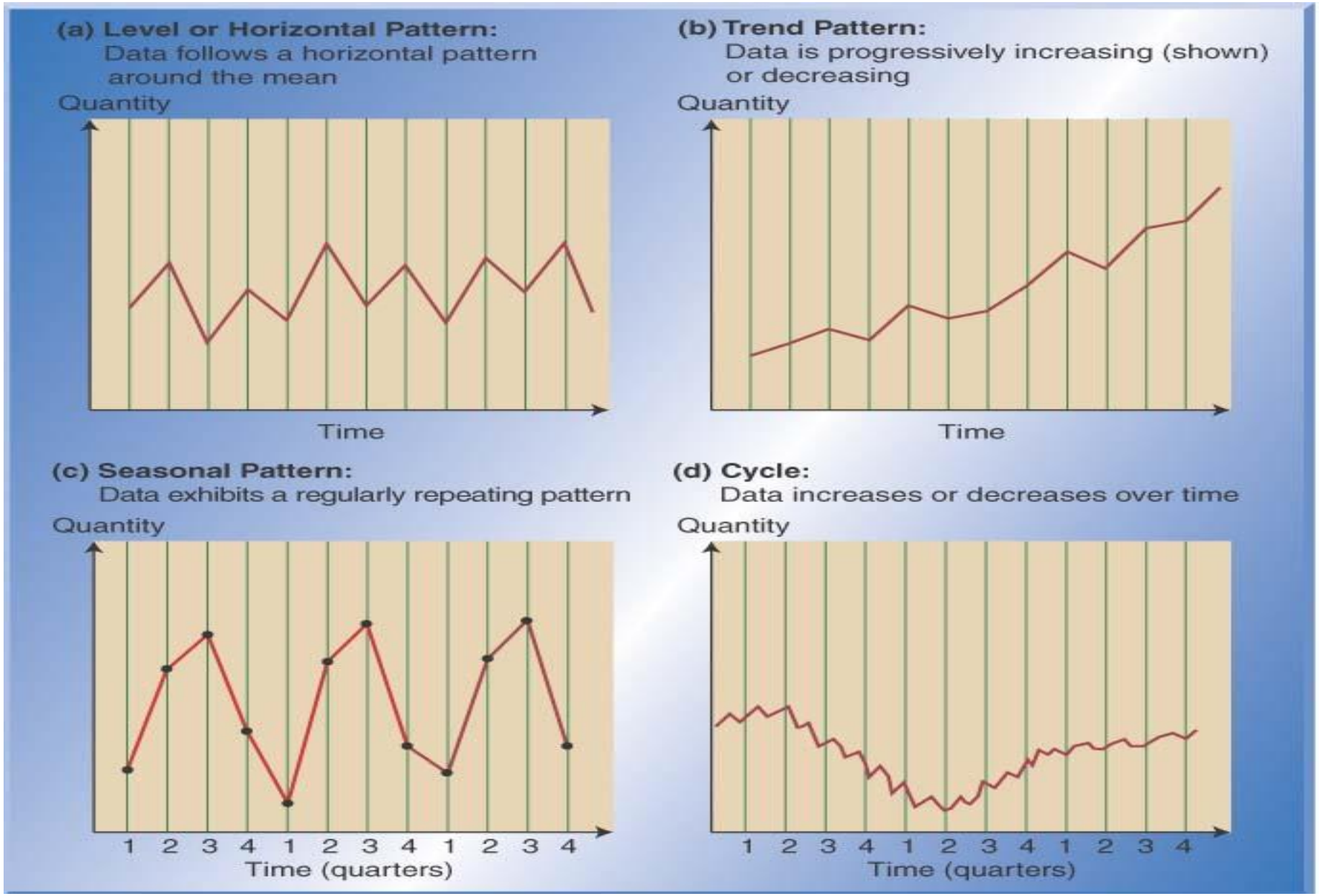
Now let's look at some time series approaches to forecasting…

Quantitative Forecasting Methods



Quantitative forecasting methods

- Time series patterns



Quantitative Forecasting Methods……

1. Naïve approach:

- Assumes demand in next period is the same as demand in most recent period
- Next period forecast = Last Period's actual ----- $F_{t+1} = A_t$
- Simple to use
- Sometimes cost effective and efficient
- Quick and easy to prepare
- Data analysis is nonexistent
- Easily understandable
- Cannot provide high accuracy

e.g. If the sales forecast for the month May were 48, then June sales will be 48.

Quantitative forecasting methods……

2. Simple moving average

- Assumes an average is a good estimator of future behavior
  - – Used if little or no trend
  - – Used for smoothing
- A smaller N makes the forecast more responsive.
- A larger N makes the forecast more stable.

Quantitative forecasting methods……

- The moving average method uses the last t periods in order to predict demand in period $t+1$.
- There can be two types of moving average methods : **simple moving** average and **weighted moving** average
- The moving average method assumption is that the most accurate prediction of future demand in a simple (linear) combination of past demand.

Quantitative Forecasting Methods……

2.a simple moving average: A technique that averages a number of recent actual values, updated as new values become available.

- In the simple moving average models the forecast value is given by;

$$F_{t+1} = \frac{A_t + A_{t-1} + A_{t-2} + \ldots + A_{t-n+1}}{n}$$

t	is the current period.
F_{t+1}	is the forecast for next period
n	is the forecasting horizon (how far back we look),
A	is the actual sales figure from each period.

Quantitative Forecasting Methods……

Example1: apply a 3-month moving average forecast for the following orders.

Months	Demand(y)	Forecast
January	120	
February	90	
March	100	
April	75	
May	110	
June	50	
July	75	
August	130	
September	110	
October	90	
November	?	

Quantitative Forecasting Methods……

Example1: apply a 3-month moving average forecast for the following orders.

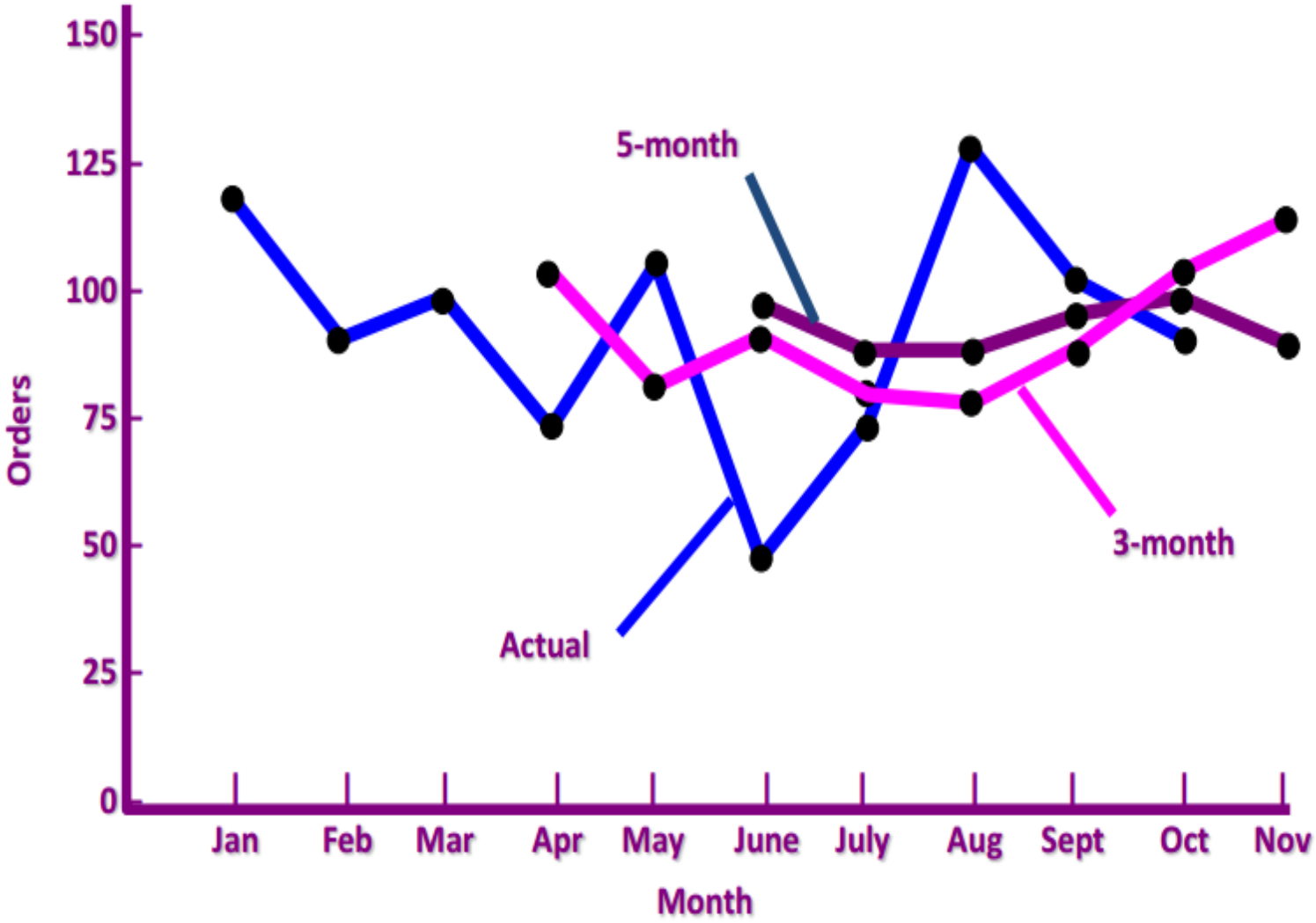
Months	Demand(y)	Forecast
January	120	-
February	90	-
March	100	-
April	75	103.33
May	110	88.33
June	50	95
July	75	78.33
August	130	78.33
September	110	85
October	90	105
November	?	110

What if the forecasting period is 5 months moving average?

What you observed?

Quantitative forecasting methods……

Smoothing effect



In general

- ✓ 5 month average smooth's data more;
- ✓ 3 month average more responsive.

Quantitative Forecasting Methods……

2.b Weighted Moving Average: it is similar to a moving average, except that it assigns more weight to the most recent values in a time series.

- Gives more emphasis to recent data
- Weights decrease for older data
- The sum of all weights equals 1.

$$F_{t+1} = w_1 A_t + w_2 A_{t-1} + w_3 A_{t-2} + \ldots + w_n A_{t-n+1}$$

where;
W_t=Weight for the period t, A_t = Actual value in period t,
$W_{n=}$ weight for the period t-n+1, and
$A_{t-n+1=}$ Actual value in period t-n+1,

Quantitative Forecasting Methods……

Example2: Forecast for month 5?

Month 1	Month 2	Month3	Month 4	Month 5
100	90	105	95	?

- Take 40 percent of the actual sales for the most recent month, 30 percent of two months ago, 20 percent of three months ago, and10 percent of four months ago.

Quantitative Forecasting Methods……

- The forecast for month 5 would be :

$$F5 = 0.40(95) + 0.30(105) + 0.20(90) + 0.10(100)$$

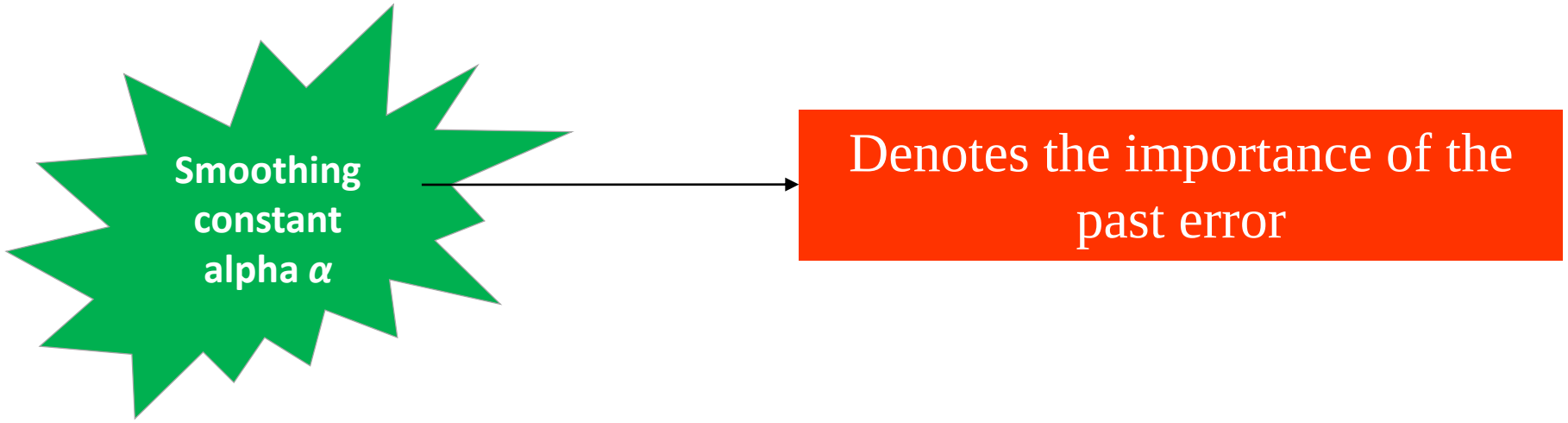
$$= 38 + 31.5 + 18 + 10$$

$$= 97.5$$

Quantitative Forecasting Methods……

3.Exponential Smoothing: This method is suitable for forecasting data with no clear trend or seasonal pattern.

- Prediction of the future depends mostly on the most recent observation, and on the error for the latest forecast.



Quantitative Forecasting Methods……

- The most recent occurrences are more indicative of the future than those in the more distant past.
- If this premise is valid – “that the importance of data diminishes as the past becomes more distant”- then exponential smoothing may be the most logical and easiest method to use.

Quantitative forecasting methods……

New Forecast = Old Forecast + a proportion of the forecast error

The simplest formula is

New forecast = Old forecast + α (Latest Observation – Old Forecast)

where α (alpha) is the smoothing constant.

Or more mathematically,

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

i.e $$F_t = \alpha A_{t-1} + (1- \alpha) F_{t-1}$$

Where

F_t = The exponentially smoothed forecast for period t

F_{t-1} = The exponentially smoothed forecast made for the prior period

A_{t-1} = The actual demand in the prior period

α = The desired response rate, or smoothing constant

Quantitative Forecasting Methods……

NB: if we are not given the forecast value for the first period assume forecasted value is equals to the actual value.

Example3: for the following demand data calculate the forecasted demand, for the month of June at $\alpha=0.1$

Months	Demand(y)	Forecasted
January	1325	1370
February	1353	
March	1305	
April	1275	
May	1210	
June	?	

What is the forecast at $\alpha=0.8$ and compare the result!

Quantitative Forecasting Methods……

NB: if we are not given the forecast value for the first period assume forecasted value is equals to the actual value.

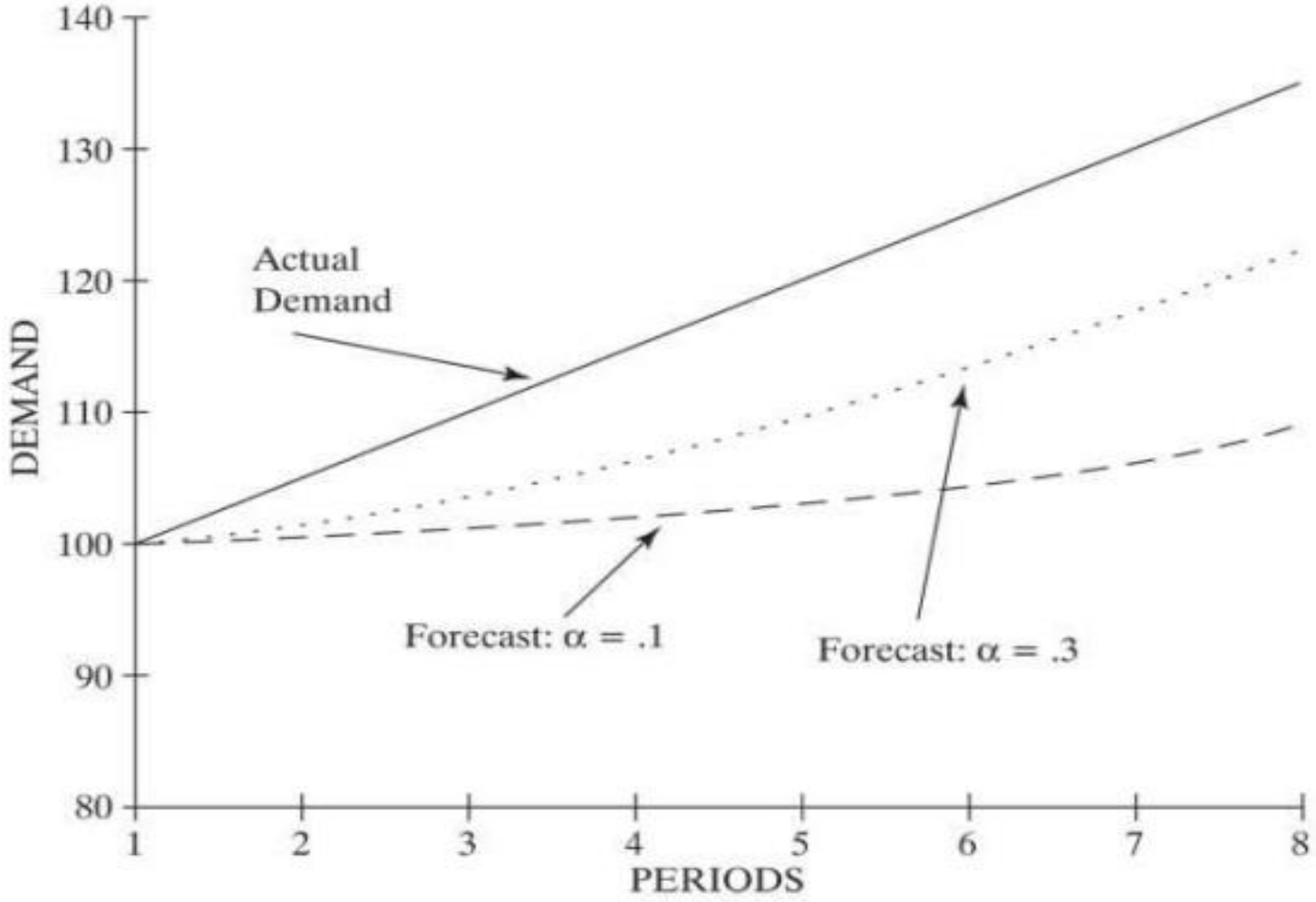
Example3: for the following Bottled water demand data calculate the forecasted demand, for the month of June at $\alpha=0.1$

Months	Demand(y)	Forecasted
January	1325	1370
February	1353	1365.5
March	1305	1364.25
April	1275	1358.33
May	1210	1350
June	?	1336

What is the forecast at $\alpha=0.8$ and compare the result!

Quantitative Forecasting Methods……

Impact of The Value of α



Quantitative Forecasting Methods……

Choosing appropriate Value of ɑ

- If real demand is **stable**: small ɑ
- If real demand is rapidly increasing or decreasing: large ɑ to try to keep up with the change.

Quantitative Forecasting Methods……

Exponential smoothing with trend

FIT: Forecast including trend

δ: Trend smoothing constant

$$FIT_t = F_t + T_t$$

$$F_t = FIT_{t-1} + \alpha(A_{t-1} - FIT_{t-1})$$

$$T_t = T_{t-1} + \delta(F_t - FIT_{t-1})$$

The idea is that the two effects are decoupled,

(F is the forecast without trend and T is the trend component)

Quantitative Forecasting Methods……

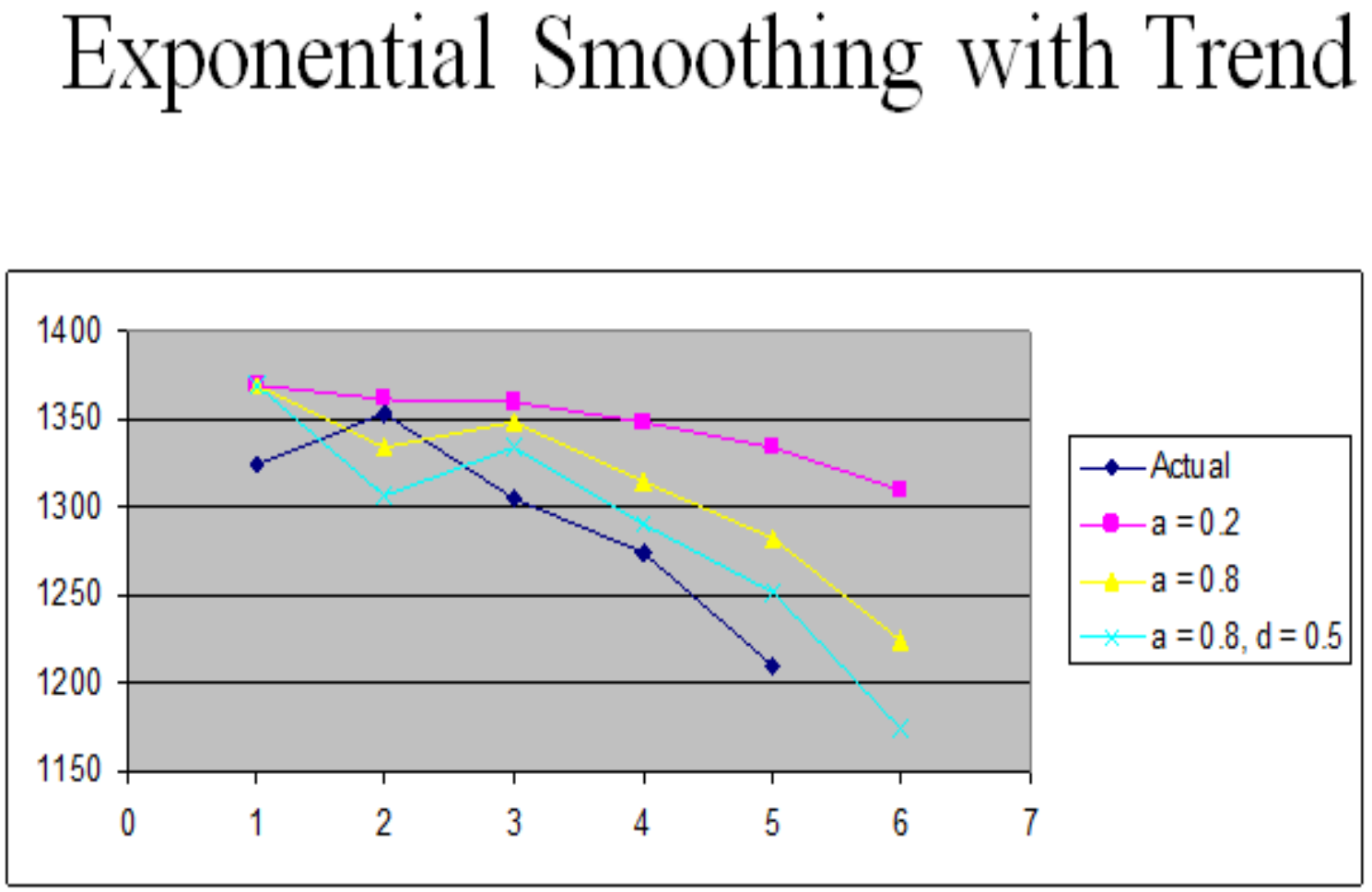
Again use previous Example (bottled water)

	A_t	F_t	T_t	FIT_t
Jan	*1325*	*1380*	*-10*	*1370*
Feb	*1353*	*1334*	*-28*	*1306*
Mar	*1305*	*1344*	*-9*	*1334*
Apr	*1275*	*1311*	*-21*	*1290*
May	*1210*	*1278*	*-27*	*1251*
Jun		*1218*	*-43*	*1175*

$\alpha = 0.8$

$\delta = 0.5$

Quantitative Forecasting Methods……



Quantitative Forecasting Methods……

- Causal Method
  - ➢ Causal models establish a cause-and-effect relationship between independent and dependent variables.
  - ➢ A common tool of causal modeling is linear regression:

$$Y = a + bx$$

Quantitative Forecasting Methods……

4. Linear Regression Analysis

❖Useful for long term forecasting of major occurrences and aggregate planning.

e.g. very useful for product families.

❖Used for both time series forecasting and causal forecasting.

❖ Time series forecasting: If dependent variable changes as a result of time

❖ Casual forecasting: If one variable changes because of change in another variable.

Quantitative Forecasting Methods……

- 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

Linear Regression Analysis.....

Example: The demand for a product for the last five periods is given below. Using a linear trend equation, find the forecasted demand for 6^{th} and 7^{th} period.

t Week	t^2	y Sales	ty
1	1	150	150
2	4	157	314
3	9	162	486
4	16	166	664
5	25	177	885
$\Sigma t = 15$ $(\Sigma t)^2 = 225$	$\Sigma t^2 = 55$	$\Sigma y = 812$	$\Sigma ty = 2499$

Linear Regression Analysis.....

$$b = \frac{5\,(2499) - 15(812)}{5(55) - 225} = \frac{12495-12180}{275-225} = 6.3$$

$$a = \frac{812 - (6.3)15}{10} = 143.5$$

$$y = 143.5 + 6.3t$$

$$F_6 = a + b(t) = 143.5 + 6.3(6) = 181.3$$

$$F_7 = a + b(t) = 143.5 + 6.3(7) = 187.6$$

Measures of Forecast Error

- A good forecast has a small error
- Forecasts are never perfect.
- Need to know how much we should rely on our chosen forecasting method.
- Measuring forecast error:

$$\mathbf{E_t = A_t - F_t}$$

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

Measuring Error…

a. MAD = Mean Absolute Deviation

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

($|A_t - F_t|$ = e_t)

b. MSE = Mean Squared Error

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

c. RMSE = Root Mean Squared Error

$$RMSE = \sqrt{MSE}$$

- Ideal values =0 (i.e., no forecasting error)

Measuring Error…

Example: find the forecast error for the given data

t	A_t	F_t	e_t	$\|e_t\|$	e_t^2
Jan	120	100	20	20	400
Feb	90	106	-16	16	256
Mar	101	102	-1	1	1
April	91	101	-10	10	100
May	115	98	17	17	289
June	83	103	-20	20	400
			-10	84	1,446

1. Mean Absolute Deviation (MAD)

$$MAD = \frac{\sum_1^n |e_t|}{n} \quad \frac{84}{6} = 14$$

2a. Mean Squared Error (MSE)

$$MSE = \frac{\sum_1^n (e_t)^2}{n} \quad \frac{1,446}{6} = 241$$

2b. Root Mean Squared Error (RMSE)

$$RMSE = \sqrt{MSE}$$

RMSE = SQRT(241) =15.52

- An accurate forecasting system will have small MAD, MSE and RMSE; ideally equal to zero.
- A large error may indicate that either the forecasting method used or the parameters such as α used in the method are wrong.

Measuring Error cont…

- The tracking signal is a measure of how often our estimations have been above or below the actual value. It is used to decide when to re-evaluate using a model.
- Good tracking signal has low values

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

Where;

CFE=Cumulative sum of forecast error

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

If TS > 4 or < -4, *investigate!*

Measuring Error cont…

Example: bottled water

Month	Actual	Forecast
Jan	*1,325*	*1,370*
Feb	*1,353*	*1,361*
Mar	*1,305*	*1,359*
Apr	*1,275*	*1,349*
May	*1,210*	*1,334*
Jun	*1,195*	*1,309*

Exponential Smoothing
($\alpha = 0.2$)

Month	Actual	Forecast
Jan	*1,325*	*1370*
Feb	*1,353*	*1306*
Mar	*1,305*	*1334*
Apr	*1,275*	*1290*
May	*1,210*	*1251*
Jun	*1,195*	*1175*

Forecasting with trend
($\alpha = 0.8$)
($\delta = 0.5$)

Question: Which one is better?

Measuring Error cont…

Bottled water : compare MAD and TS

	MAD	TS
Exponential Smoothing	70	- 6.0
Forecast Including Trend	33	- 2.0

We observe that FIT performs a lot better than ES

Application of Forecasting

- Forecasts are vital to every business organization and for every significant management decision.
  - **Sales Forecasting :** Any company in selling goods needs to forecast the demand for those goods.
  - **Forecasting Economic Trends** : forecasting economic trends on a regional, national, or even international level.
  - **Forecasting Staffing Needs:**
  - **Forecasting in education environment :**
  - **Ministry of Petroleum :**
  - **Department of Technology:**