REPUBLIC POLYTECHNIC

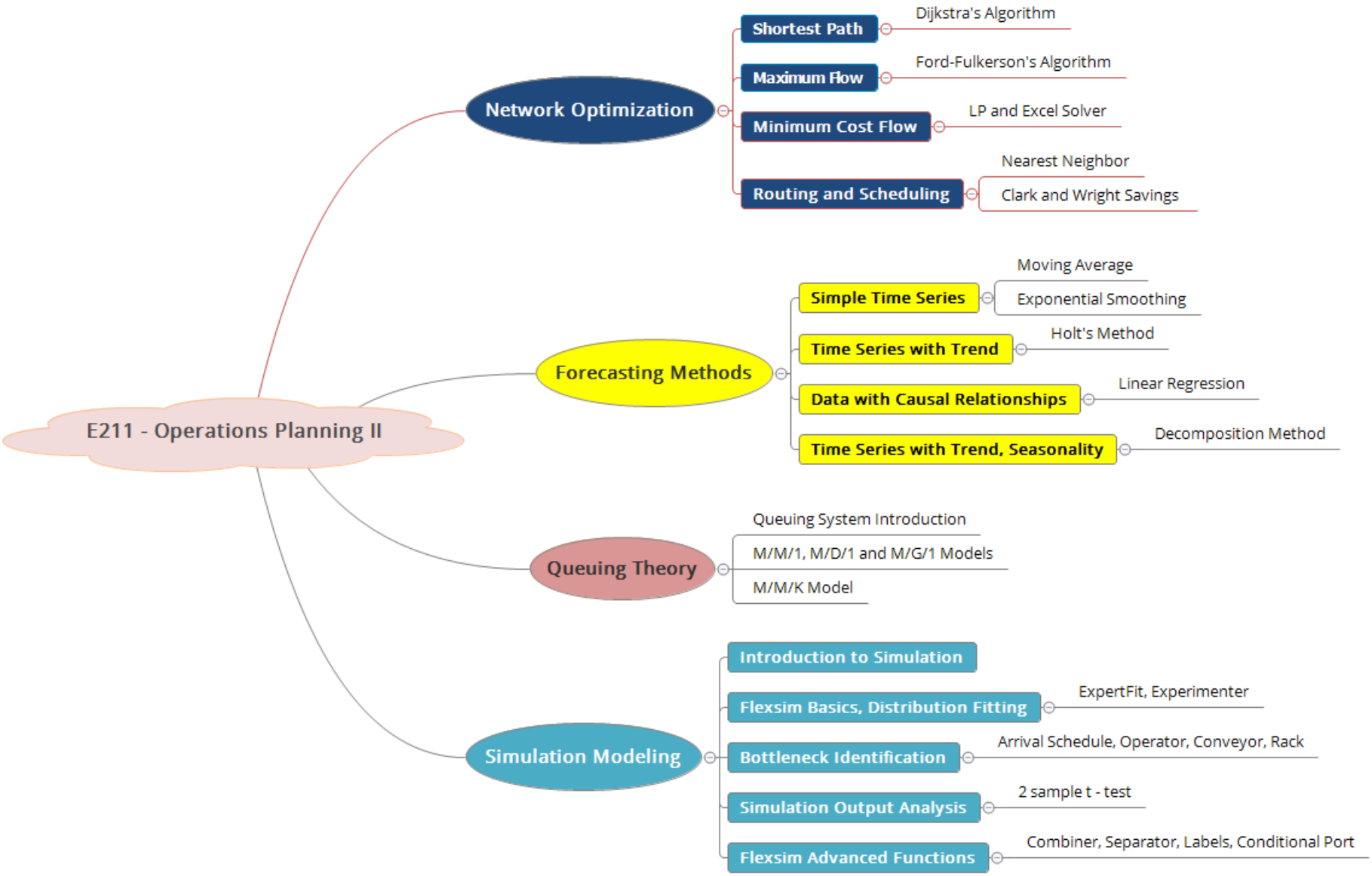
Problem 04

The Art of Forecasting (Part 1)

E211 – Operations Planning II

SCHOOL OF ENGINEERING

Module Coverage: E211 Topic Tree



Importance of Forecasting

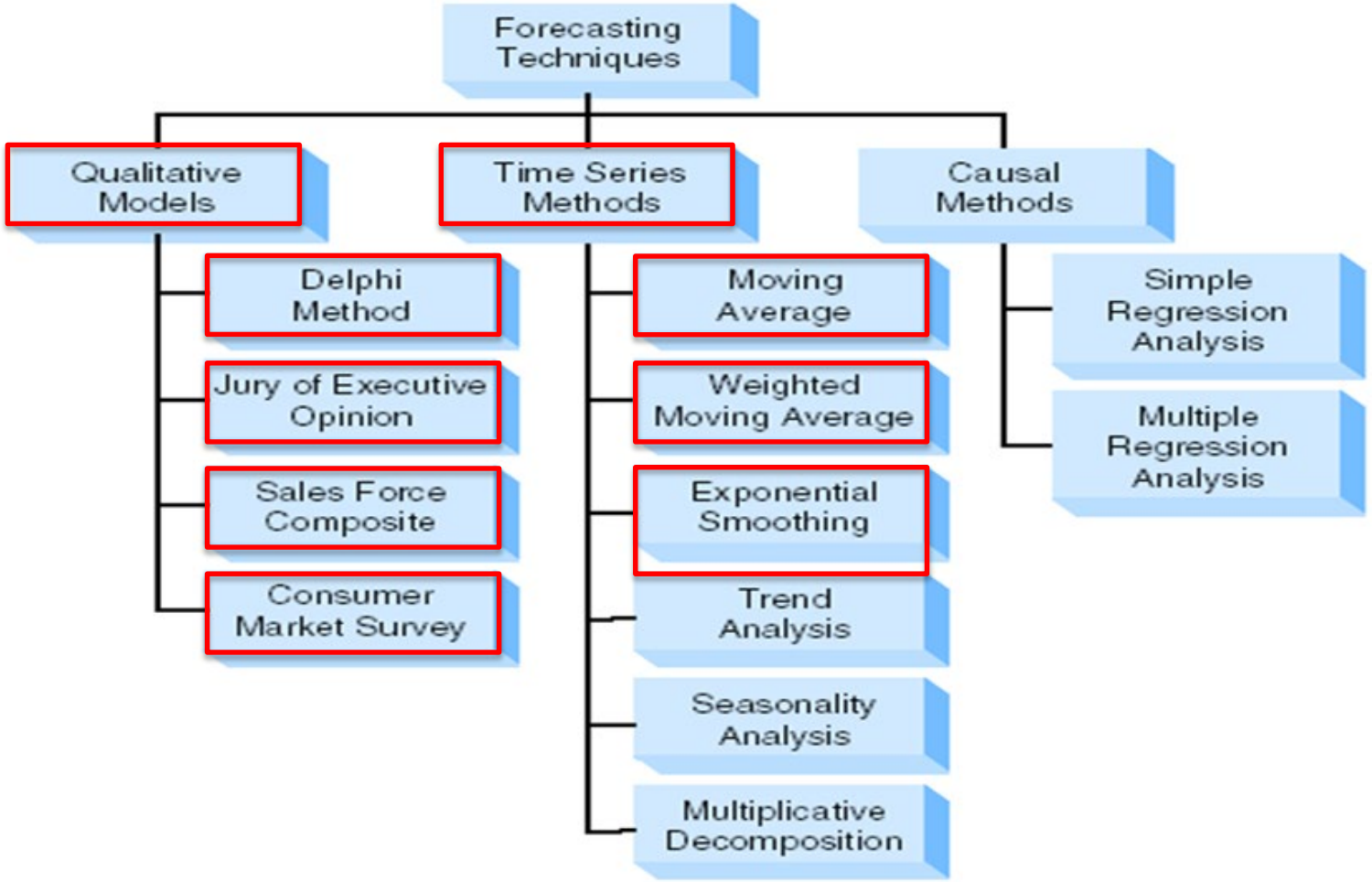
- Companies need to forecast product demand, technological changes and business cycles

- Forecasting is important for all strategic and planning decisions in a supply chain

  - Forecasts of product demand, materials, labour, financing are important inputs to scheduling, acquiring resources, and determining resource requirements.

  - For example: if a company carries more inventory than needed, they're wasting resources; while if it carries less than needed, they're not able to satisfy the customer needs.

Types of Forecasts

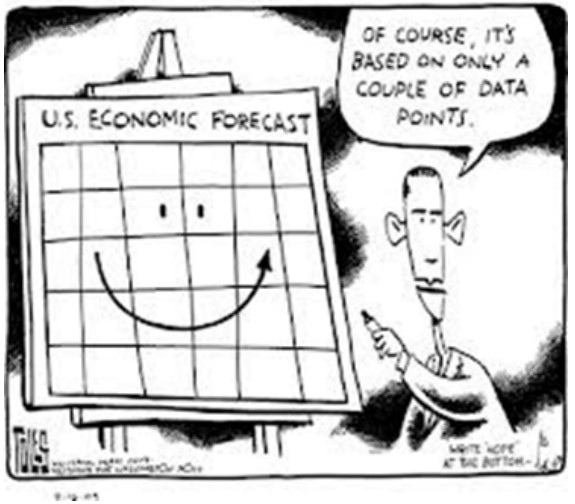


Forecasting Methods

- Qualitative Forecast
  - Subjective in nature
  - Expert judgment
    - Consensus Panel
    - Delphi Method
  - Grassroots Forecasting
  - Consumer Opinion

- Quantitative Forecast
  - Mathematical or simulation models
  - Causal forecasting
  - **Time Series**

(Today's focus)



Qualitative Forecasting

- Expert Judgment
  - Consensus Panel (focus group)
    - Bring experts together for discussion until consensus emerges
    - Problems with group dynamics may override forecast accuracy
  - Delphi Method
    - Coordinator requests/receives forecasts from experts (through emails, surveys)
    - Coordinator determines median response and the range of middle 50% of answers
    - Coordinator requests explanations from experts outside middle 50%
    - Median response, middle 50% range, and explanations sent to experts
    - Process repeated till consensus reached (time consuming)

Qualitative Forecasting

- Grassroots Forecasting/ Consulting Salesmen
  - Advantage
    - Provides a lot of detailed knowledge
  - Disadvantages
    - Conflict of Interest
    - Enthusiasm vs. Reality
- Consulting Consumers/ Market Research
  - Advantage
    - Well designed survey representative of consumer opinions
  - Disadvantages
    - May be costly and time consuming

Quantitative Forecasting

- Uses numerical values to generate the forecast
- Two types: Causal forecasting and Time-series forecasting
- Can be systematically modified and requires a large quantity of data
- Frequent updates are required
- Validation is difficult (how good/accurate is the model?)

Causal Forecasting

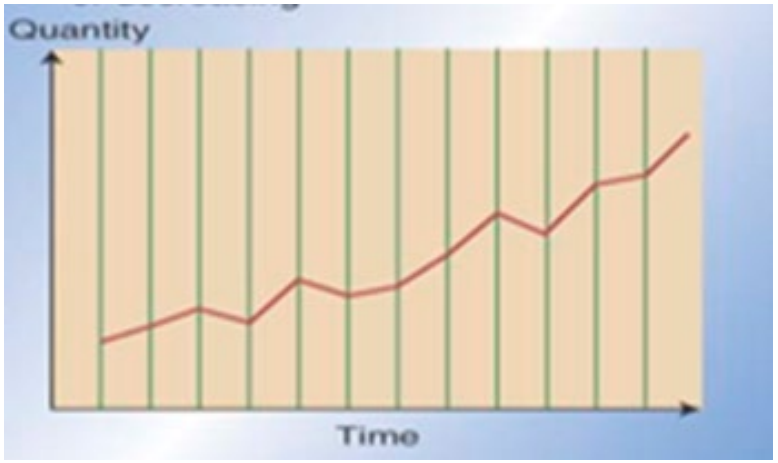
- Forecast of a variable of interest using one or more independent factors (variables).
  - For example, forecast of Sales Expense of Mobile Phone using Mobile Phone Monthly Sales.
- Relationship may not always be cause and effect
  - Example: Property prices can be predicted by growth in GDP.
- Curve Fitting
  - The independent variable must be known in advance or is more easily and reliably forecasted.
  - The independent variable provides information about the dependent variable.
  - Most common approach is Regression Analysis

Time-Series Forecasting

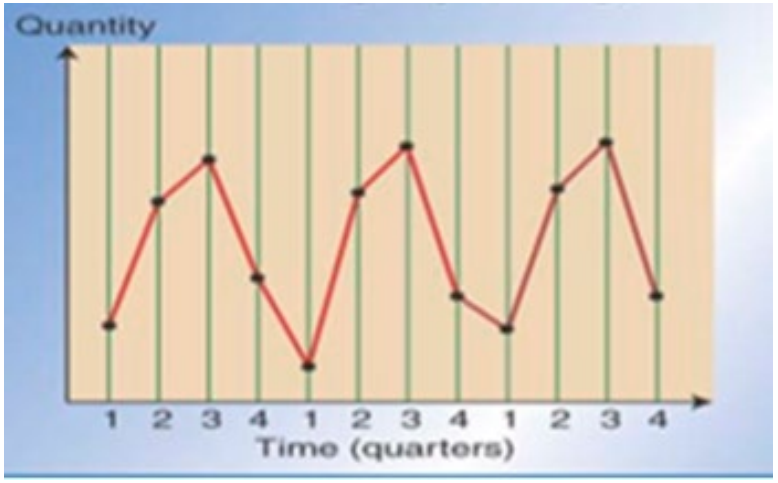
- Predicting the future from the historical data
- Based on a sequence of evenly spaced data points gathered sequentially in time (weekly, monthly, quarterly, etc.) known as time series
- Causal variables and qualitative factors are not considered

Components of a Time Series

- **Trend** – gradual upward or downward movement of data over time

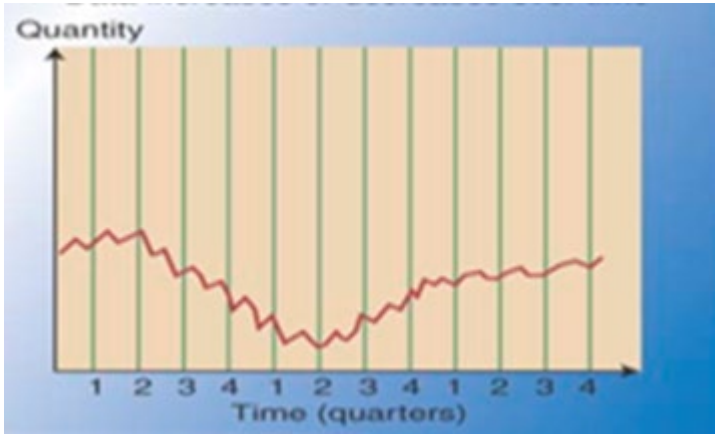


- **Seasonality** – pattern repeats itself after a period of time (e.g. sales of winter clothing)

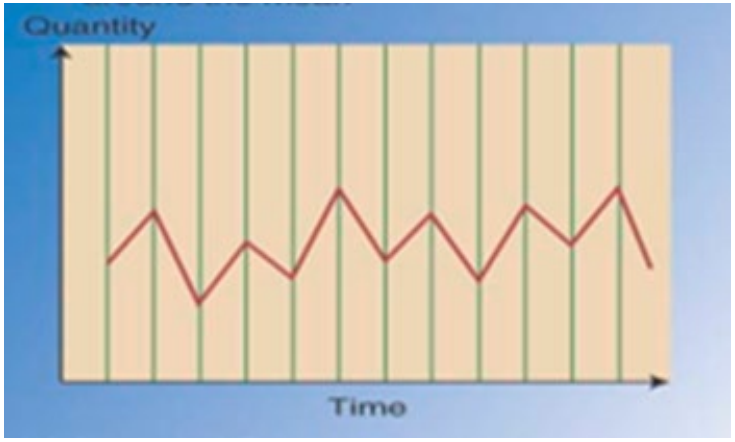


Components of a Time Series

- **Cyclicity** – cyclical fluctuation, unpredictable pattern due to economic or business climate (usually few years)



- **Random** – Irregular variations, due to chance or unusual situations with no discernible patterns



General Models

- **Additive model:**
  - $Y_t = T_t + C_t + S_t + I_t$
- **Multiplicative model:** (will be covered in P06)
  - $Y_t = T_t * C_t * S_t * I_t$

where

Y_t: The observed value of the time series at time t

T_t: The trend component in time t

C_t: The cyclical component in time t.

S_t: The seasonal component in time t.

I_t : The irregular component in time t.

Time Series Forecasting Methods

- Moving Average (MA)
- Weighted Moving Average (WMA)
- Simple Exponential Smoothing (SES)

(will be covered today)

- Trend-adjusted exponential smoothing (Holt's method), will be covered in P05.

Moving Average

- Simple method to spot underlying trend
- Provides quick forecast based on average of most recent N set of data

$$F_t = \frac{A_{t-N} + A_{t-N+1} + \ldots\ldots + A_{t-1}}{N}$$

Where F_t is the forecast in period t

N is the number of most recent periods used in the forecast.

A_{t-N} = previous N period's actual demand

Moving Average

- Uses the *N* most recent data points to predict
- Possible to use weights to place more emphasis on recent data
- May require extensive records of past data
- Will lag (*N*+1)/2 periods if trend is present
- What '*N*' should be chosen?
  - Small '*N*' makes level very responsive to the last observed demand point
  - Large '*N*' makes level less responsive, smoother

Weighted Moving Average

$$F_t = \frac{W_1 A_{t-N} + W_2 A_{t-N+1} + \ldots\ldots + W_N A_{t-1}}{\sum_{i=1}^{N} W_i}$$

where W_i's are the individual weights.

- Greater weights may be placed on more recent data to improve the responsiveness of forecast to changes
- Exponential Smoothing method is a special form of weighted *MA*

e-Learning Video
https://drive.google.com/file/d/0BzDXcAvKVLAbQ3BWOVEwd1N5WjA/view?pli=1

Exponential Smoothing

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

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

  where,

  F_t = forecast for period t

  F_{t-1} = forecast for period t-1

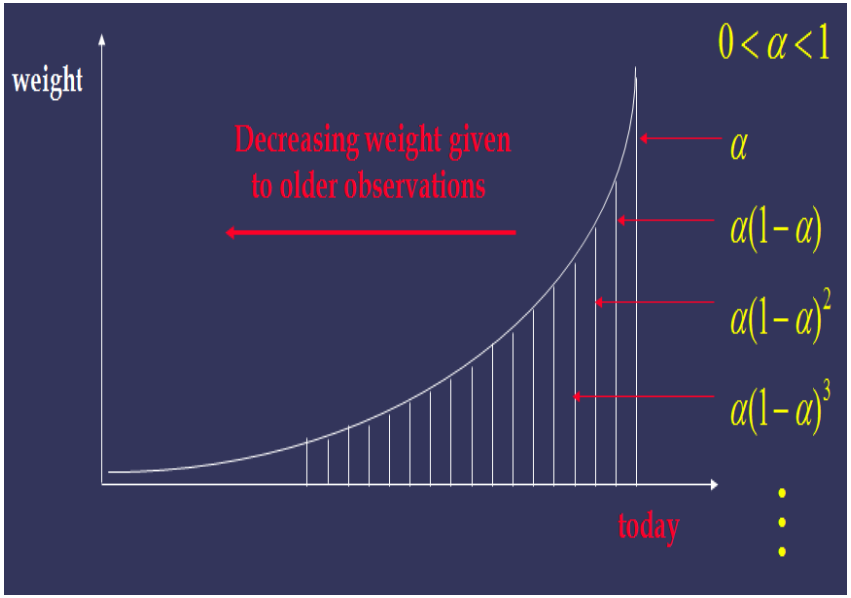
  α, (alpha) = smoothing constant ($0 \le \alpha \le 1$)

  A_{t-1} = actual demand for period t-1

- After expanding the F_t formula,

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

- Question: Do you notice that Exponential Smoothing method is a special form of weighted Moving Average Method?



Exponential Smoothing

- Widely used method for short-term forecasting
- Requires little record keeping of past data
- Choice of smoothing constant depends on whether underlying average is likely to change
- Will lag by 1/α periods if trend is present
- Choice of α: Use the exponent to smooth the randomness in the data.
  - If α is chosen to be small, response to change is slow, with resultant smooth estimators.
  - If α is chosen to be large, response to change is fast, with resultant large variability in the output.

Forecasting Errors

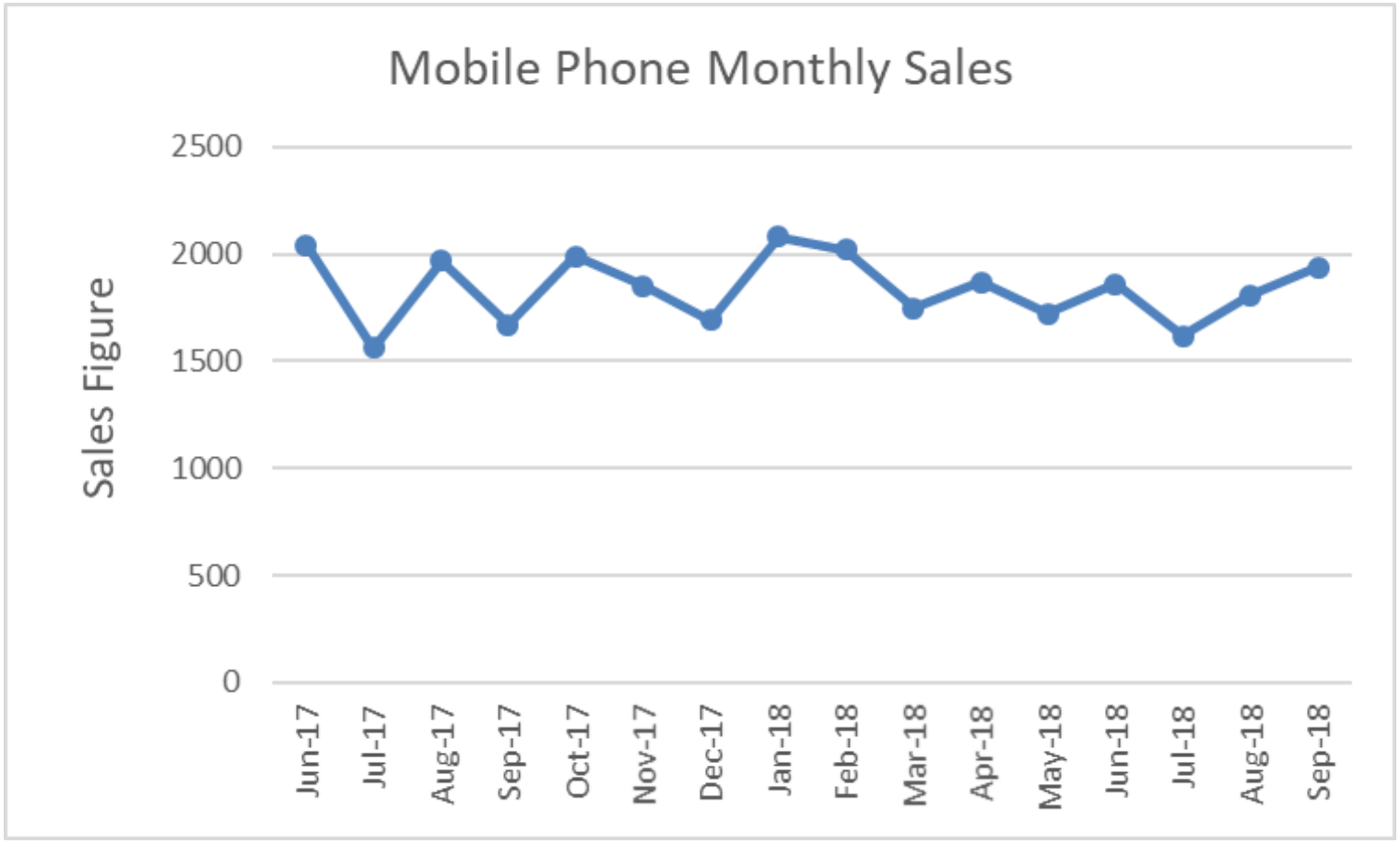
- Forecast will always deviate from the actual demand. Forecasting Error is the difference between the forecast and the actual demand.
- Some measures of forecasting error

Mean absolute deviation (MAD)	$MAD = \frac{1}{n}\sum_{t=1}^{n} \lvert A_t - F_t \rvert$
Mean absolute percent error (MAPE)	$MAPE = \frac{1}{n}\sum_{t=1}^{n} \frac{\lvert A_t - F_t \rvert}{A_t} \times 100\%$
Mean square error (MSE)	$MSE = \frac{1}{n}\sum_{t=1}^{n} (A_t - F_t)^2$

where *n* is the total number of periods for which both actual and forecasted values exist.

P04 Suggested Solution

Mobile Phone Monthly Sales



The Mobile Phone Monthly Sales data exhibit random up and down fluctuations.

Mobile Phone Monthly Sales: Moving Average Solution

Period	Sales (No. of Units)	MA, 3 Period	MA, 5 Period
1	2040		
2	1560		
3	1970		
4	1670	1856.67	
5	1990	1733.33	
6	1850	1876.67	1846.00
7	1690	1836.67	1808.00
8	2080	1843.33	1834.00
9	2020	1873.33	1856.00
10	1750	1930.00	1926.00
11	1870	1950.00	1878.00
12	1720	1880.00	1882.00
13	1860	1780.00	1888.00
14	1620	1816.67	1844.00
15	1810	1733.33	1764.00
16	1940	1763.33	1776.00

$F_5 = \frac{1560+1970+1670}{3}$

$F_9 = \frac{1670+1990+1850+1690+2080}{5}$

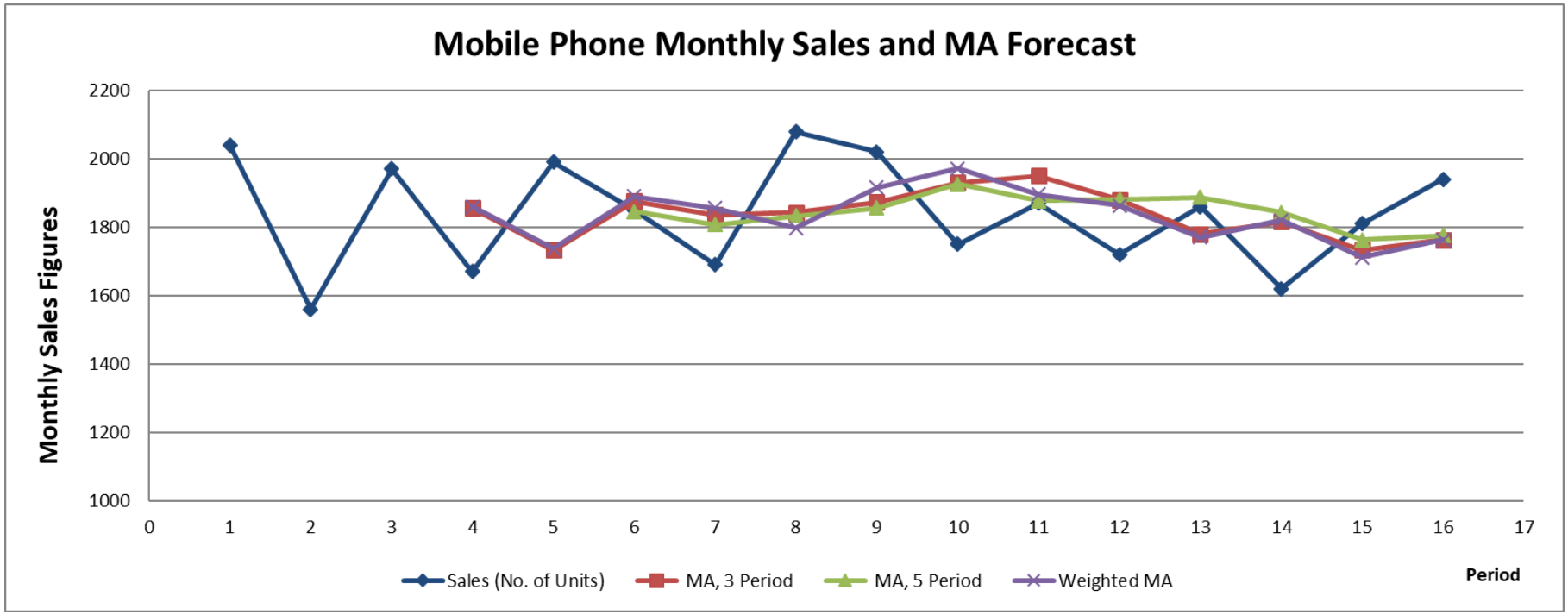
Mobile Phone Monthly Sales: Weighted Moving Average

Period	Sales (No. of Units)	Weighted MA
1	2040	
2	1560	
3	1970	
4	1670	1861.00
5	1990	1738.00
6	1850	1890.00
7	1690	1856.00
8	2080	1798.00
9	2020	1917.00
10	1750	1972.00
11	1870	1897.00
12	1720	1864.00
13	1860	1771.00
14	1620	1820.00
15	1810	1712.00
16	1940	1763.00

Weights assigned:
5 (most recent), 3, 2 (least recent)

$$F_7 = \frac{1670*2+1990*3+1850*5}{2+3+5}$$

Mobile Phone Monthly Sales: Moving Average Solution



- Moving average forecast begins on the N+1 period (for 3 month MA, first forecast on 4th month)
- As N increases, the forecasted values become less responsive to changes in the actual data and graph becomes more smoothed.

Mobile Phone Monthly Sales: Simple Exponential Smoothing

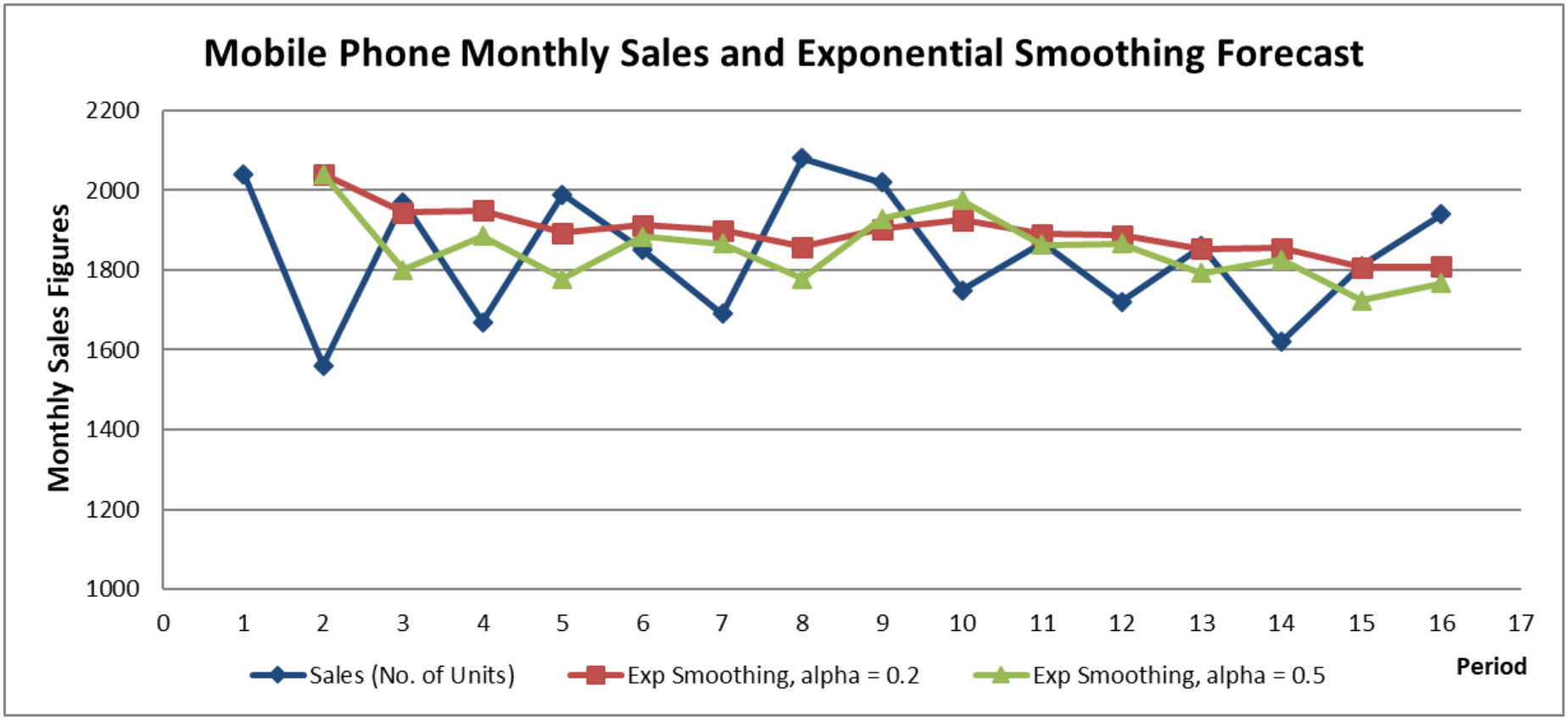
Period	Sales (No. of Units)	Exp Smoothing, alpha = 0.2	Exp Smoothing, alpha = 0.5
1	2040		
2	1560	2040.00	2040.00
3	1970	1944.00	1800.00
4	1670	1949.20	1885.00
5	1990	1893.36	1777.50
6	1850	1912.69	1883.75
7	1690	1900.15	1866.88
8	2080	1858.12	1778.44
9	2020	1902.50	1929.22
10	1750	1926.00	1974.61
11	1870	1890.80	1862.30
12	1720	1886.64	1866.15
13	1860	1853.31	1793.08
14	1620	1854.65	1826.54
15	1810	1807.72	1723.27
16	1940	1808.17	1766.63

F_3 = 0.2*1560+(1-0.2)*2040

Recall:

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

Mobile Phone Monthly Sales: Simple Exponential Smoothing Solution



For the smoothing constant α,

- When α = 0.2 (compared with 0.5), response to change is slower, with resultant smooth estimators.
- When α = 0.5 (compared with 0.2), response to change is faster, with resultant large variability in the output.

Mobile Phone Monthly Sales: Forecasting Errors for Moving Average and Exponential Smoothing Methods

Forecasting methods	Measures of forecasting error		
	MAD	MAPE	MSE
MA (3-Period)	150.00	8.19%	26694.87
MA (5-Period)	121.82	6.67%	21691.64
Weighted MA (3-Period)	153.15	8.38%	29144.38
Exp Smoothing, (alpha = 0.2)	148.86	8.57%	37410.80
Exp Smoothing, (alpha = 0.5)	172.83	9.74%	42591.33

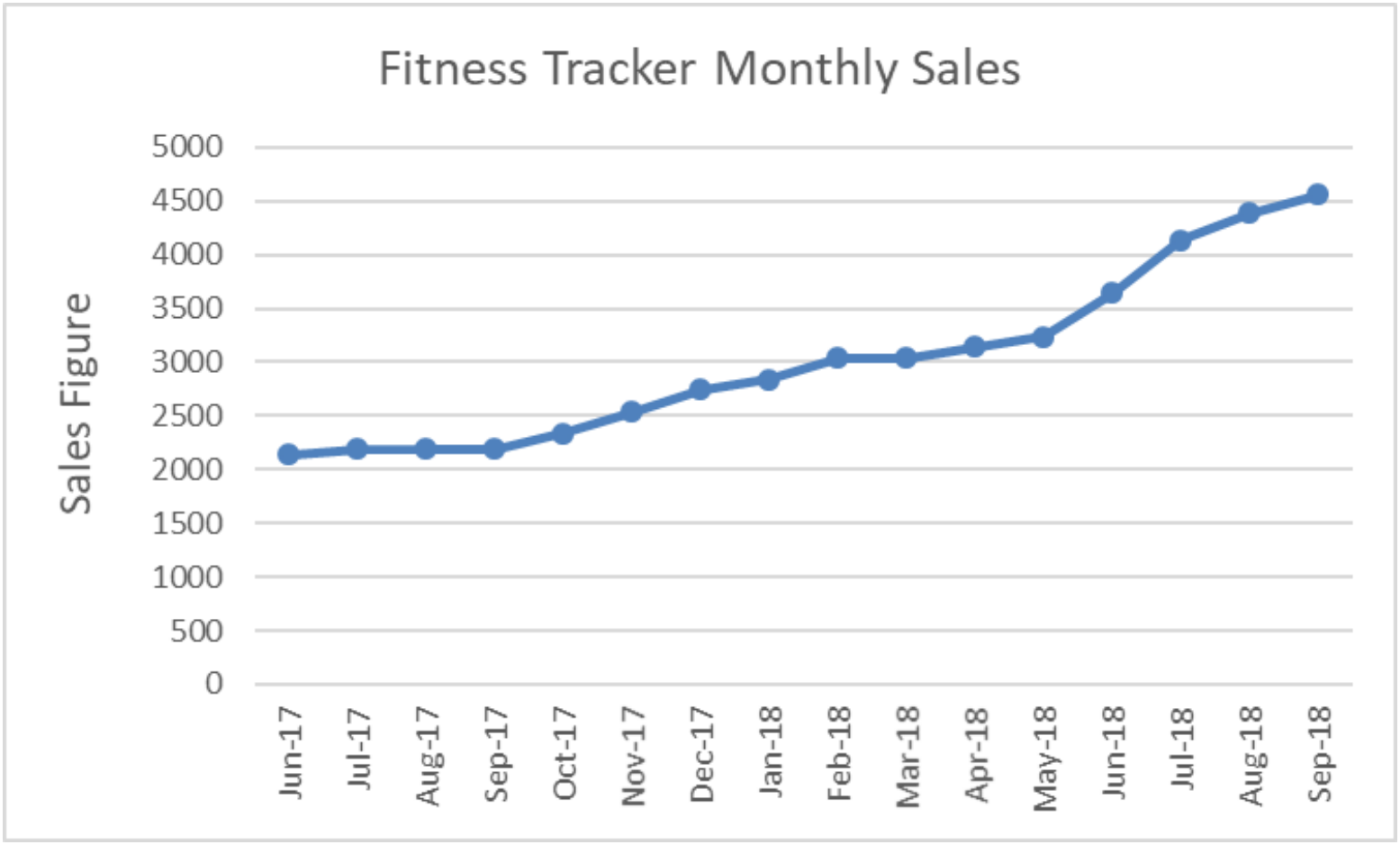
- For the Mobile Phone Monthly Sales data, Moving Average (5-period) provides the most accurate forecasts from June 2017 to current as its forecasting error is the smallest.
- We can use Moving Average (5-period) to do forecast for the mobile phone sales in Oct-18:

$$F_{17} = \frac{1720+1860+1620+1810+1940}{5}$$

$$= 1790$$

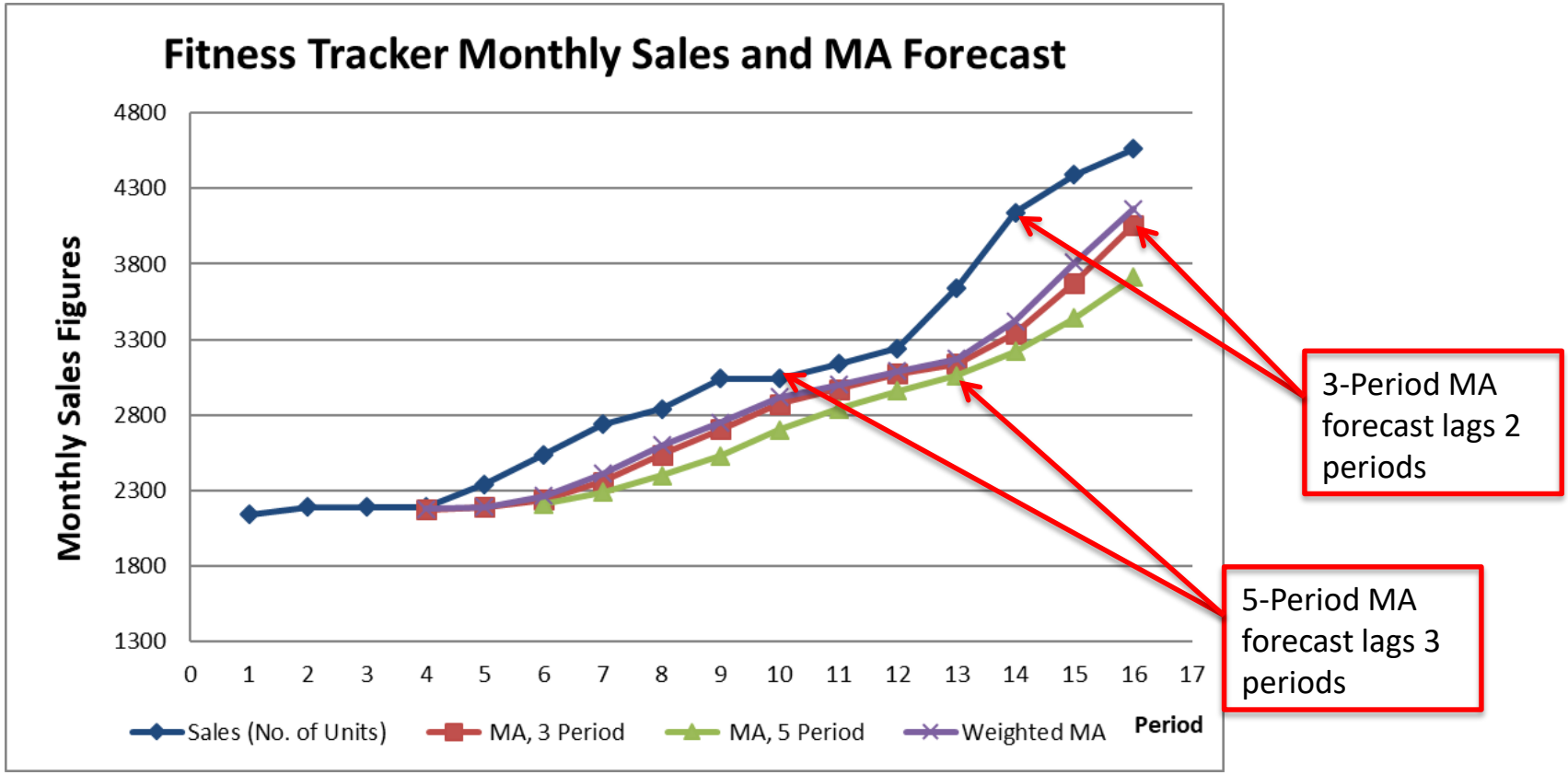
Period	Sales (No. of Units)	MA, 3 Period	MA, 5 Period
1	2040		
2	1560		
3	1970		
4	1670	1856.67	
5	1990	1733.33	
6	1850	1876.67	1846.00
7	1690	1836.67	1808.00
8	2080	1843.33	1834.00
9	2020	1873.33	1856.00
10	1750	1930.00	1926.00
11	1870	1950.00	1878.00
12	1720	1880.00	1882.00
13	1860	1780.00	1888.00
14	1620	1816.67	1844.00
15	1810	1733.33	1764.00
16	1940	1763.33	1776.00
		1790.00	1790.00

Fitness Tracker Monthly Sales



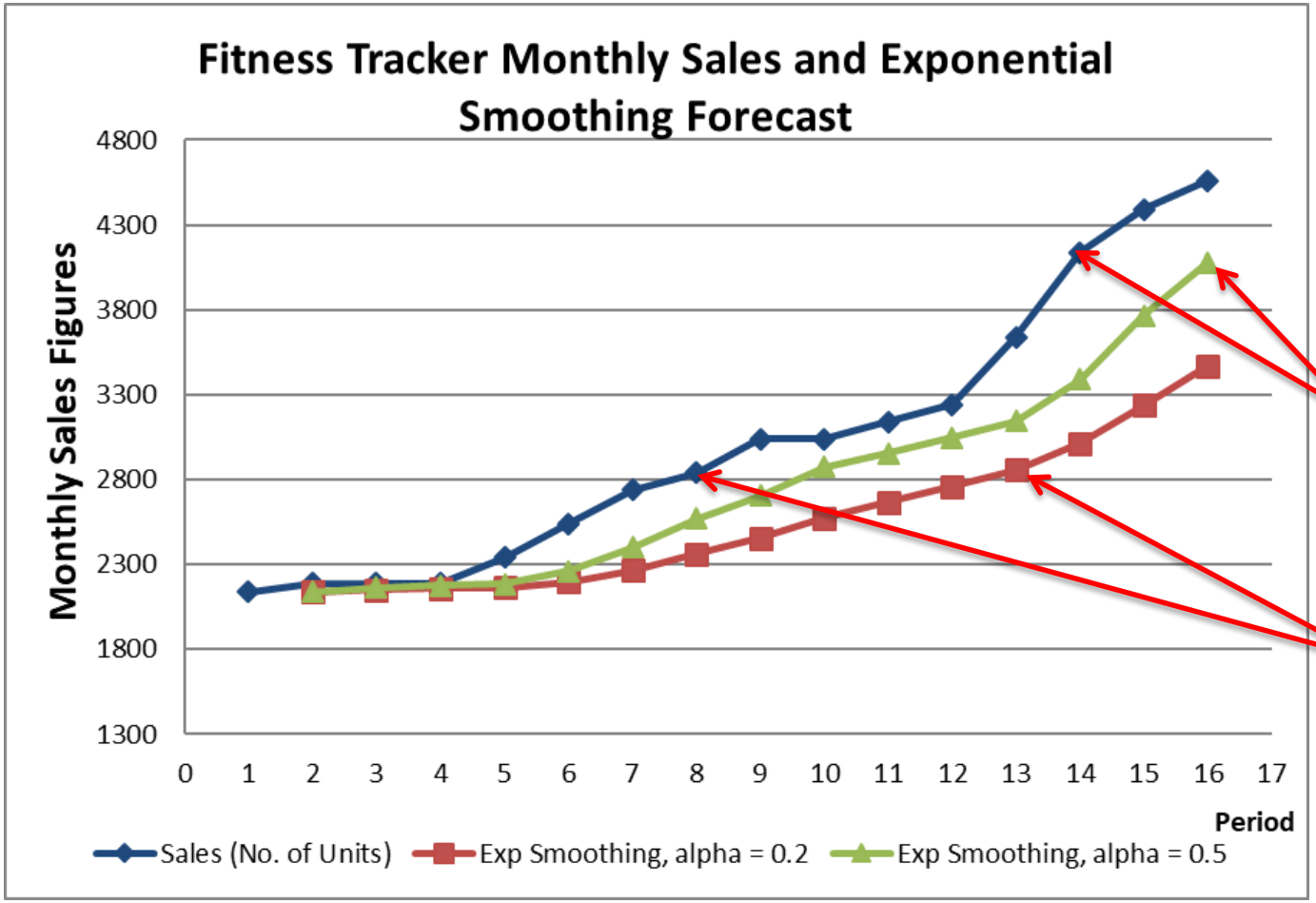
The fitness tracker sales data exhibit an upward trend. Will moving average and simple exponential smoothing methods be suitable to do forecast for this set of data?

Fitness Tracker Monthly Sales: Forecasting using MA Methods



- In the Fitness Tracker Monthly Sales data, there is an obvious upward trend. When trend is present,
  - Forecast from Moving Average method will lag by (N+1)/2 periods.
    - ✓ 3-Period MA will lag about 2 periods.
    - ✓ 5-Period MA will lab about 3 periods.

Fitness Tracker Monthly Sales: Simple Exponential Smoothing Solution



When α = 0.5, SES forecast lags 2 periods

When α = 0.2, SES forecast lags 5 periods

- Smaller alpha shows that response to change is slower as compared to larger alpha
- Simple Exponential Smoothing method will lag by 1/α periods.
- For example, when α = 0.5, the forecasted value will lag about 2 periods compared with the actual data.

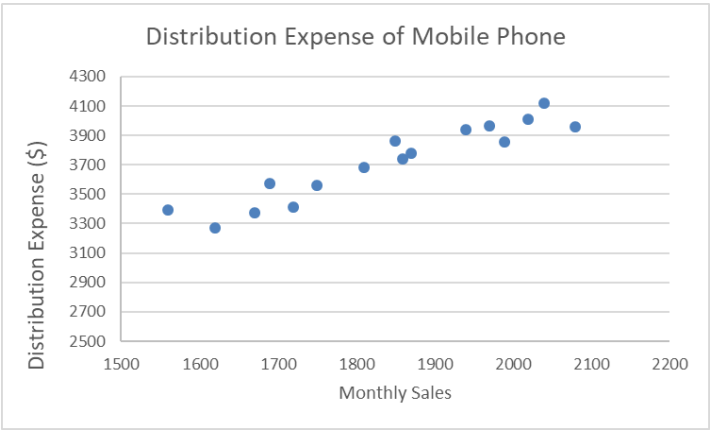
Fitness Tracker Monthly Sales: Forecasting Errors using MA and SES Methods

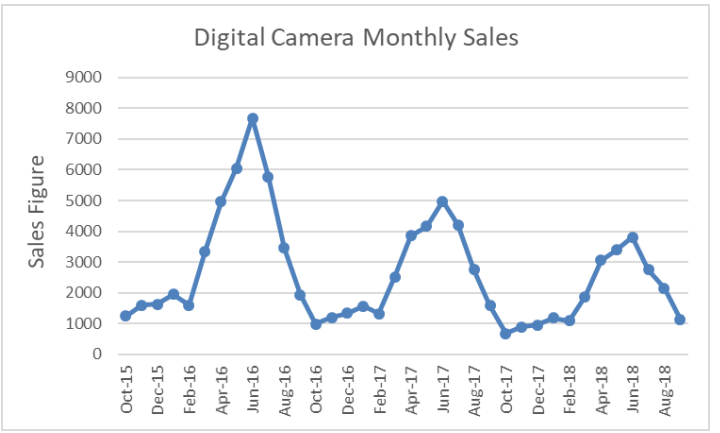
Forecasting methods	Measures of forecasting error		
	MAD	MAPE	MSE
MA (3-Period)	346.41	10.07%	169317.09
MA (5-Period)	540.91	15.41%	350627.27
Weighted MA (3-Period)	297.69	8.69%	125926.92
Exp Smoothing, (alpha = 0.2)	515.83	14.91%	400384.09
Exp Smoothing, (alpha = 0.5)	290.53	8.55%	128689.60

- Exponential Smoothing ($\alpha = 0.5$) is the best among the forecasting methods as it has the lowest forecasting errors in terms of MAD and MAPE.
- However, the forecasting errors are still quite large, and the forecasted values tend to lag due to the presence of trend in the data set.
- Are there other forecasting methods that can more effectively handle trend in a data set? What are they?

How about Distribution Expense of Mobile Phone and Digital Camera Monthly Sales?

- Are the forecasting methods learned today suitable for forecasting the Distribution Expense of Mobile Phone and Digital Camera Monthly Sales?
- Both Moving Average and Simple Exponential Smoothing methods are not suitable to be used, because
  - Mobile Phone Distribution Expense is highly correlated with the Mobile Phone Monthly Sales.
  - Trend and seasonality components are present in the Digital Camera Monthly Sales data.
- Need to explore other forecasting methods that can handle
  - Causal forecasting
  - Trend and seasonality





Conclusion

- Qualitative forecasting methods are based on subjective opinions of consumers or experts whereas quantitative forecasting methods use past data to predict future values.
- Moving average, weighted moving average and simple exponential smoothing are simple-to-use methods in time-series forecasting. They are used to provide forecast for the next time period when there are only random fluctuations in the data set.
- Measures of forecasting errors should be used to compare and select the appropriate forecasting methods.

Learning Objectives

- Introduce forecasting and simple time series analysis based on historical data.
- Explain qualitative and quantitative forecasting methods.
- Apply simple time series analysis methods (Moving Average and Simple Exponential Smoothing) to derive the forecast for cases where the linear relationship between the two factors could not be determined.
- Evaluate the forecasting models using forecasting error calculations.

Overview of E211 Operations Planning II Module