Forecasting

Source: Pearson Education Ltd. 2020. Chapter 4

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Outline

- What Is Forecasting?
- The Strategic Importance of Forecasting
- Seven Steps in the Forecasting System
- Forecasting Approaches
- Time-Series Forecasting

Learning Objectives

When you complete this chapter you should be able to :

+ ***Understand*** the three time horizons and which models apply for each

+ ***Explain*** when to use each of the four qualitative models

+ ***Apply*** the naive, moving-average, exponential smoothing, and trend methods

+ ***Compute*** three measures of forecast accuracy

What is Forecasting?

+ Process of predicting a future event

+ Underlying basis of all business decisions

    + Production

    + Inventory

    + Personnel

    + Facilities

Forecasting Time Horizons

1. *Short-range forecast*
   - Up to 1 year, generally less than 3 months
   - Purchasing, job scheduling, workforce levels, job assignments, production levels
2. *Medium-range forecast*
   - 3 months to 3 years
   - Sales and production planning, budgeting
3. *Long-range forecast*
   - 3^+ years
   - New product planning, facility location, capital expenditures, research and development

Distinguishing Differences

1. Medium/long range forecasts *deal with more comprehensive issues* and support management decisions regarding planning and products, plants and processes
2. Short-term forecasting usually *employs different methodologies* than longer-term forecasting
3. Short-term forecasts *tend to be more accurate* than longer-term forecasts

Types of Forecasts

1. **Economic forecasts**
   - Address business cycle – inflation rate, money supply, housing starts, etc.
2. **Technological forecasts**
   - Predict rate of technological progress
   - Impacts development of new products
3. **Demand forecasts**
   - Predict sales of existing products and services

Strategic Importance of Forecasting

- Supply Chain Management – Good supplier relations, advantages in product innovation, cost and speed to market
- Human Resources – Hiring, training, laying off workers
- Capacity – Capacity shortages can result in undependable delivery, loss of customers, loss of market share

Seven Steps in Forecasting

1. Determine the use of the forecast
2. Select the items to be forecasted
3. Determine the time horizon of the forecast
4. Select the forecasting model(s)
5. Gather the data needed to make the forecast
6. Make the forecast
7. Validate and implement the results

The Realities!

- Forecasts are seldom perfect, unpredictable outside factors may impact the forecast
- Most techniques assume an underlying stability in the system
- Product family and aggregated forecasts are more accurate than individual product forecasts

Forecasting Approaches

Qualitative Methods

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

Forecasting Approaches

Quantitative Methods

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

Overview of Qualitative Methods

1. **Jury of executive opinion**

   Pool opinions of high-level experts, sometimes augmented by statistical models

2. **Delphi method**

   Panel of experts, queried iteratively

Overview of Qualitative Methods

3. **Sales force composite**
   - Estimates from individual salespersons are reviewed for reasonableness, then aggregated
4. **Market Survey**
   - Ask the customer

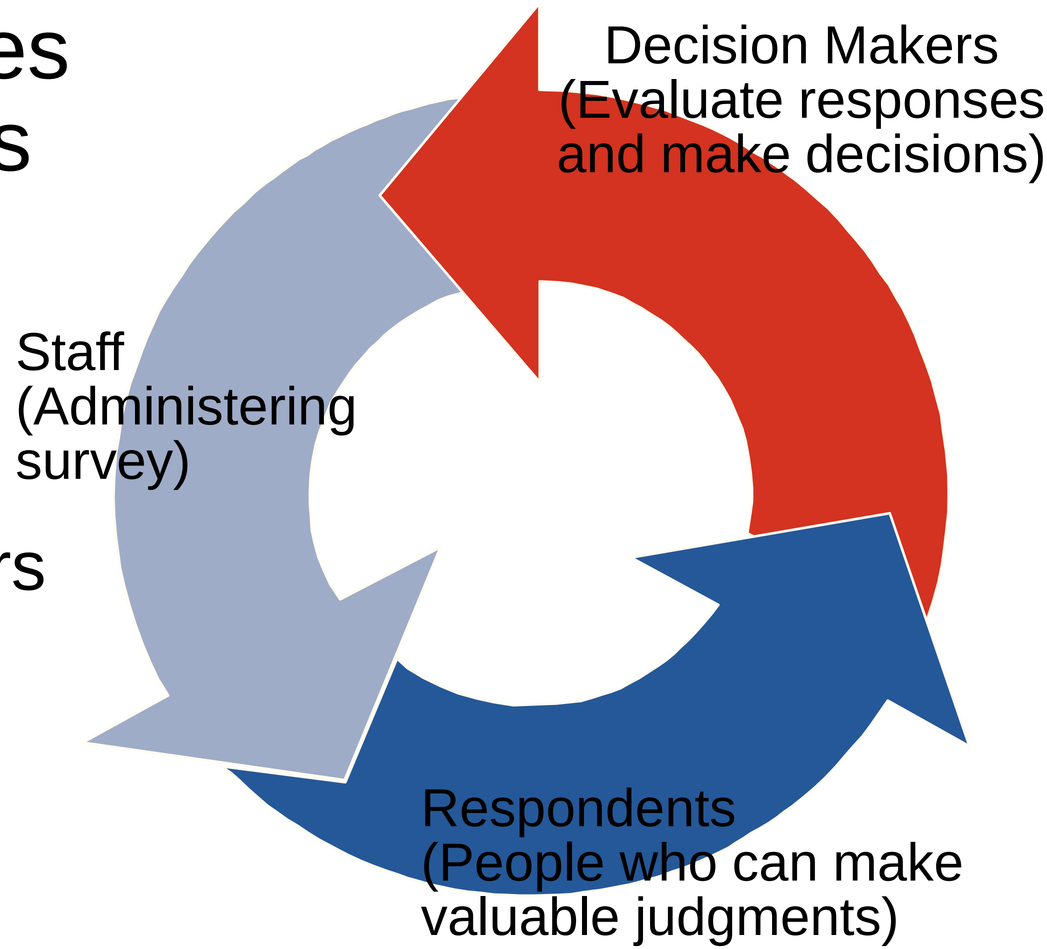
➔ Replaced by using **POS data** (point of sales)

Jury of Executive Opinion

- Involves small group of high-level experts and managers
- Group estimates demand by working together
- Combines managerial experience with statistical models
- Relatively quick
- ‘Group-think’ disadvantage

Delphi Method

- Iterative group process, continues until consensus is reached
- Three types of participants
  - Decision makers
  - Staff
  - Respondents



Sales Force Composite

- Each salesperson projects his or her sales
- Combined at district and national levels
- Sales reps know customers' wants
- May be overly optimistic

Market Survey

- Ask customers about purchasing plans
- Useful for demand and product design and planning
- What consumers say and what they actually do may be different
- May be overly optimistic

Overview of Quantitative Approaches

1. Naive approach
2. Moving averages
3. Exponential smoothing
4. Trend projection
5. Linear regression

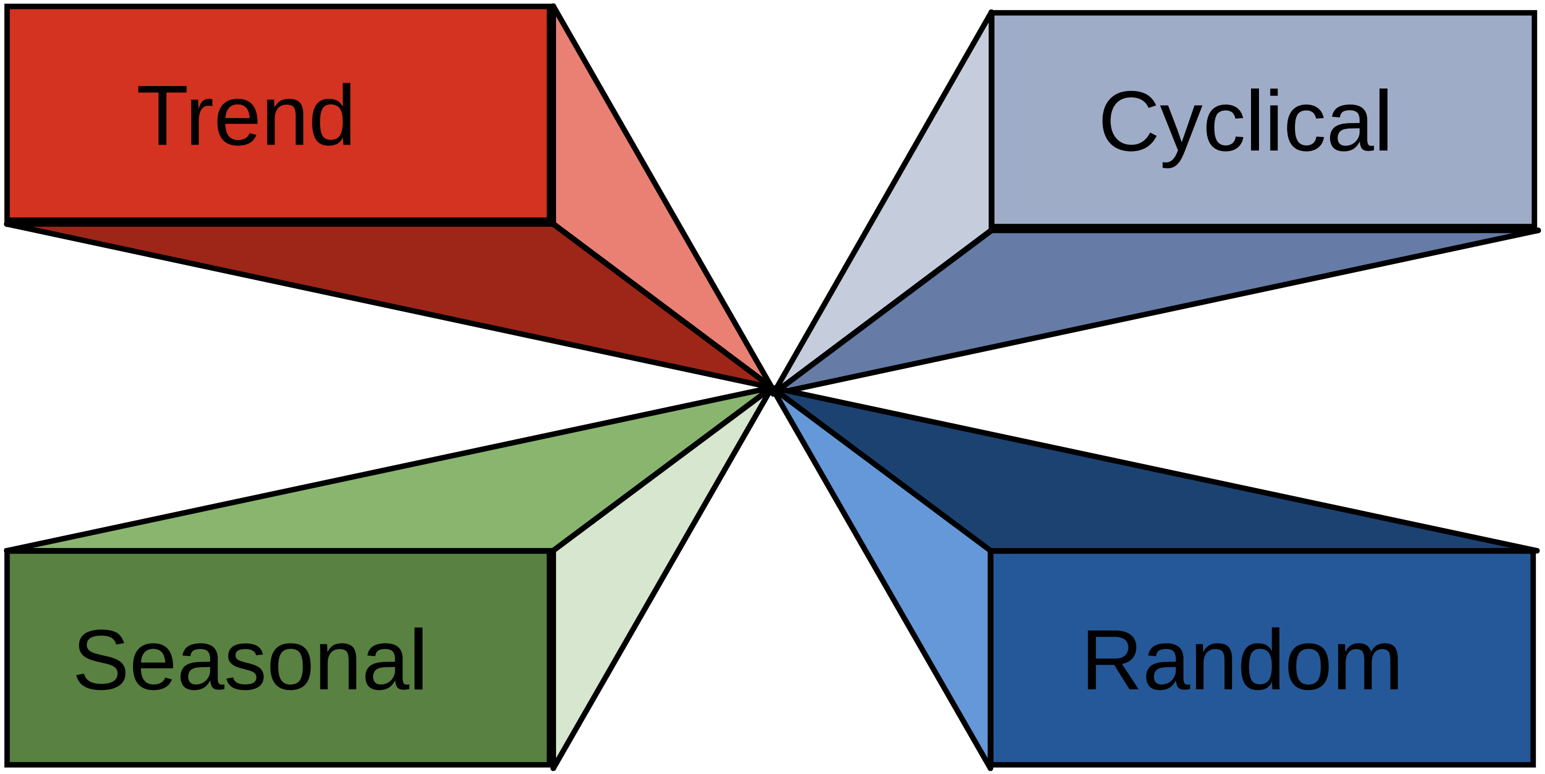
Items 1–4: Time-series models

Item 5: Associative model

Time-Series Forecasting

- 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

Time-Series Components



Components of Demand

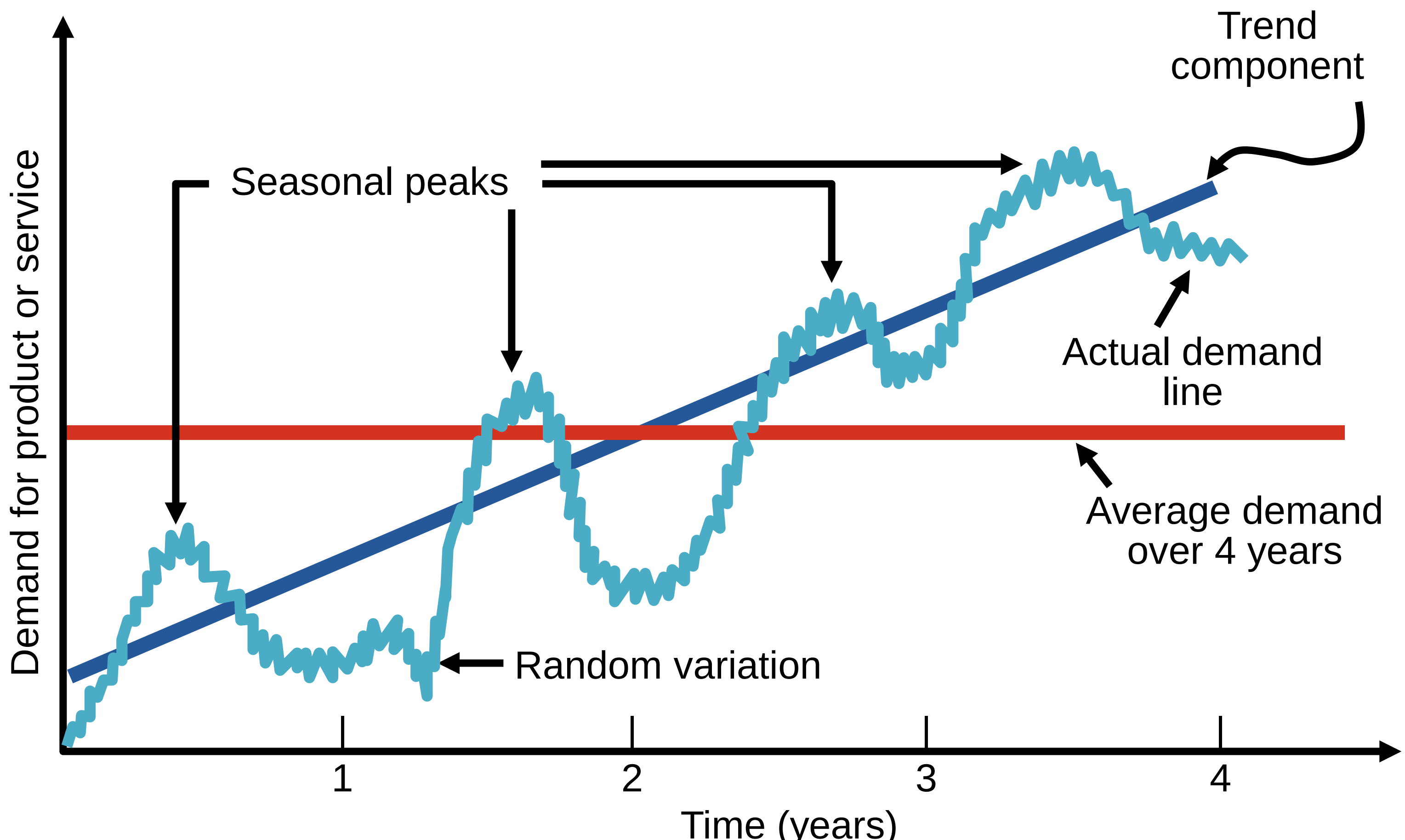
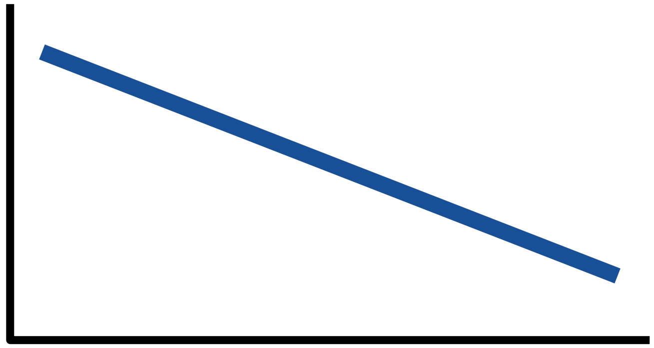


Figure 4.1

Trend Component

- Persistent, overall upward or downward pattern
- Changes due to population, technology, age, culture, etc.
- Typically several years duration



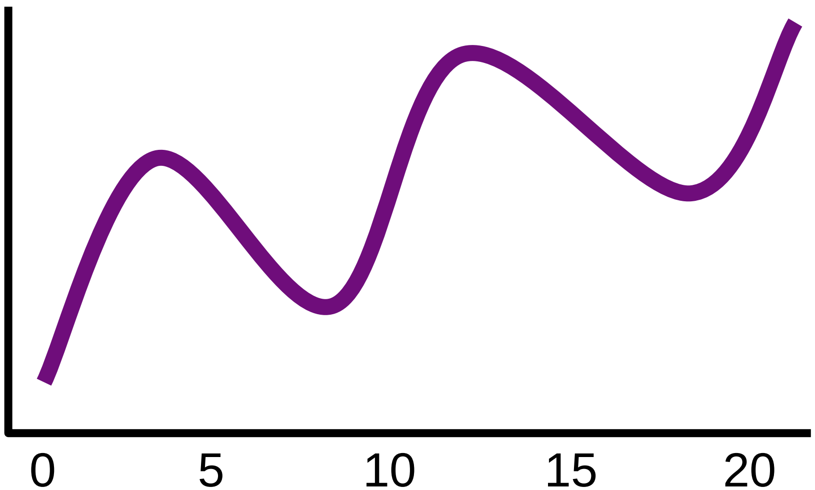
Seasonal Component

- Regular pattern of up and down fluctuations
- Due to weather, customs, etc.
- Occurs within a single year

PERIOD LENGTH	"SEASON" LENGTH	NUMBER OF "SEASONS" IN PATTERN
Week	Day	7
Month	Week	4 – 4.5
Month	Day	28 – 31
Year	Quarter	4
Year	Month	12
Year	Week	52

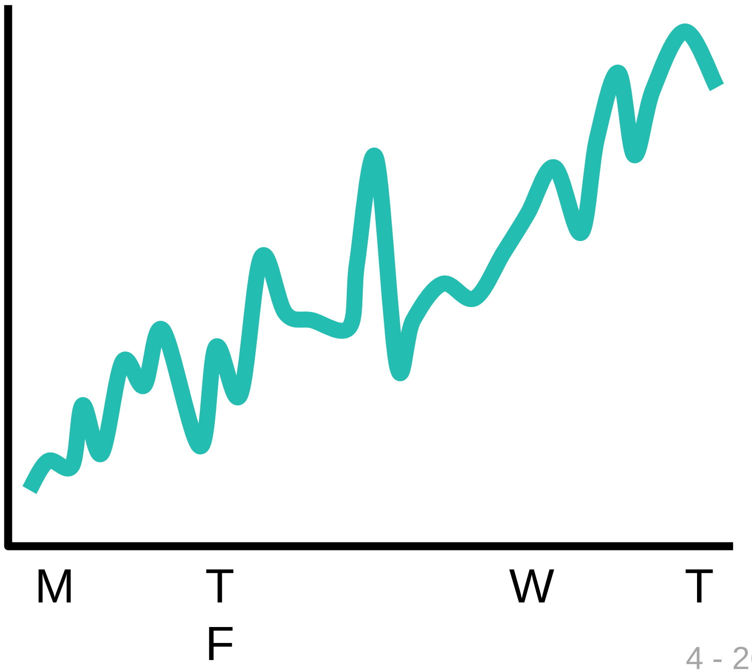
Cyclical Component

- Repeating up and down movements
- Affected by business cycle, political, and economic factors
- Multiple years duration
- Often causal or associative relationships



Random Component

- Erratic, unsystematic, ‘residual’ fluctuations
- Due to random variation or unforeseen events
- Short duration and nonrepeating



Naive Approach

- Assumes demand in next period is the same as demand in most recent period
  - e.g., If January sales were 68, then February sales will be 68
- Sometimes cost effective and efficient
- Can be good starting point

Moving Averages

- MA is a series of arithmetic means
- Used if little or no trend
- Used often for smoothing
  - Provides overall impression of data over time

$$\text{Moving average} = \frac{\sum \text{demand in previous } n \text{ periods}}{n}$$

Moving Average Example

MONTH	ACTUAL SHED SALES	3-MONTH MOVING AVERAGE
January	**10**	
February	**12**	
March	**13**	
April	16	(**10** + **12** + **13**)/3 = 11 $^2/_3$
May	19	(12 + 13 + 16)/3 = 13 $^2/_3$
June	23	(13 + 16 + 19)/3 = 16
July	26	(16 + 19 + 23)/3 = 19 $^1/_3$
August	30	(19 + 23 + 26)/3 = 22 $^2/_3$
September	28	(23 + 26 + 30)/3 = 26 $^1/_3$
October	18	(26 + 30 + 28)/3 = 28
November	16	(30 + 28 + 18)/3 = 25 $^1/_3$
December	14	(28 + 18 + 16)/3 = 20 $^2/_3$

Weighted Moving Average

- Used when some trend might be present
  - Older data usually less important
- Weights based on experience and intuition

$$\text{Weighted moving average} = \frac{\sum \left((\text{Weight for period } n)(\text{Demand in period } n) \right)}{\sum \text{Weights}}$$

Weighted Moving Average

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	
June		
July		
August		
September		
October		
November		
December		

WEIGHTS APPLIED	PERIOD
3	Last month
2	Two months ago
1	Three months ago
6	Sum of the weights

Forecast for this month =

$$\frac{3 \times \text{Sales last mo.} + 2 \times \text{Sales 2 mos. ago} + 1 \times \text{Sales 3 mos. ago}}{\text{Sum of the weights}}$$

Weighted Moving Average

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	$[(3 \times 23) + (2 \times 19) + (16)]/6 = 20\ ^1/_2$
August	30	$[(3 \times 26) + (2 \times 23) + (19)]/6 = 23\ ^5/_6$
September	28	$[(3 \times 30) + (2 \times 26) + (23)]/6 = 27\ ^1/_2$
October	18	$[(3 \times 28) + (2 \times 30) + (26)]/6 = 28\ ^1/_3$
November	16	$[(3 \times 18) + (2 \times 28) + (30)]/6 = 23\ ^1/_3$
December	14	$[(3 \times 16) + (2 \times 18) + (28)]/6 = 18\ ^2/_3$

Potential Problems With Moving Average

1. Increasing n smooths the forecast but makes it less sensitive to changes
2. Does not forecast trends well
3. Requires extensive historical data

Graph of Moving Averages

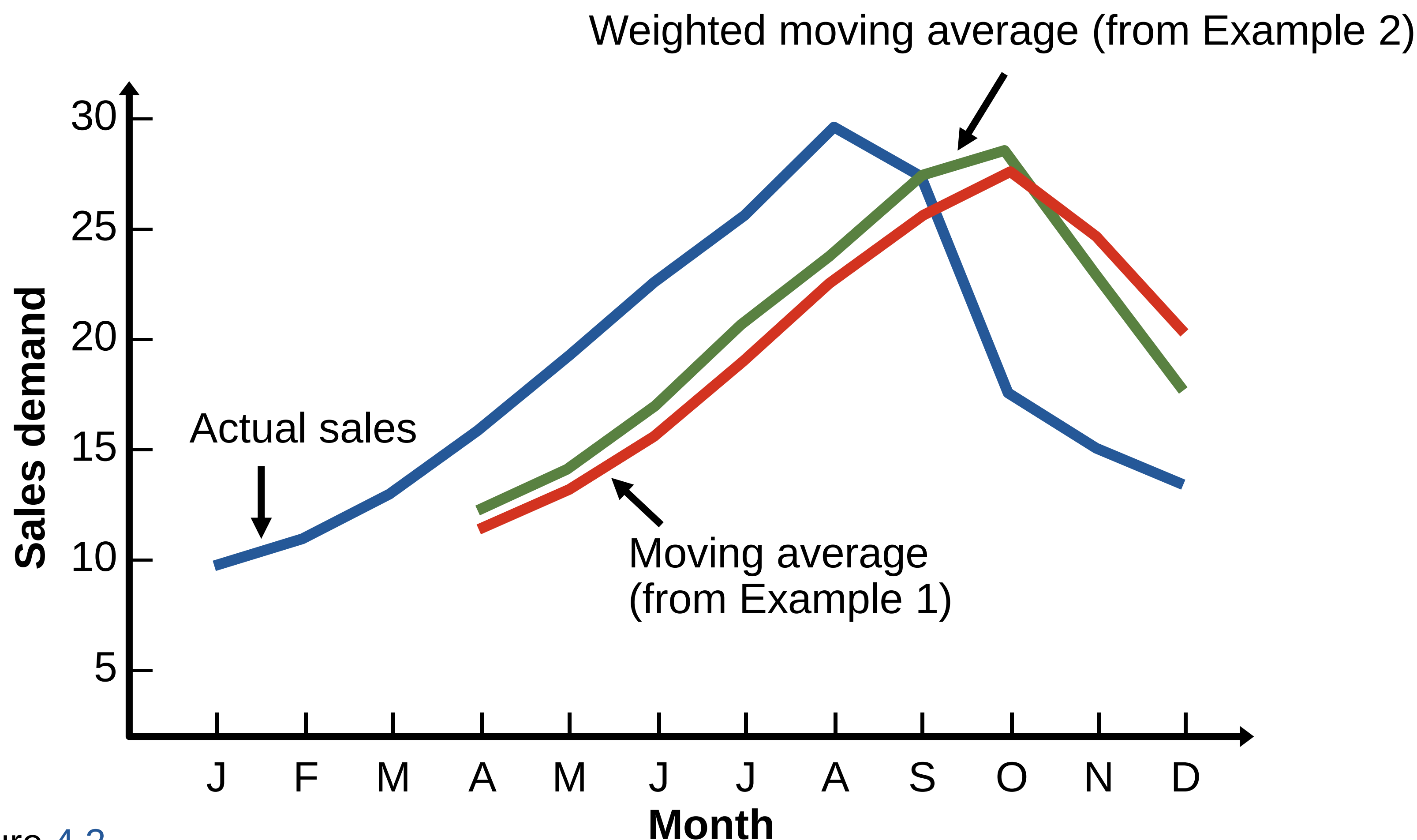


Figure 4.2

Exponential Smoothing

- Form of weighted moving average
  - Weights decline exponentially
  - Most recent data weighted most
- Requires smoothing constant (α)
  - Ranges from 0 to 1
  - Subjectively chosen
- Involves little record keeping of past data

Exponential Smoothing

New forecast = Last period's forecast
+ α (Last period's actual demand
– Last period's forecast)

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

where F_t = new forecast
F_{t-1} = previous period's forecast
α = smoothing (or weighting) constant ($0 \le \alpha \le 1$)
A_{t-1} = previous period's actual demand

Exponential Smoothing Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

Exponential Smoothing Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

New forecast = 142 + .2(153 – 142)

Exponential Smoothing Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant $\alpha = .20$

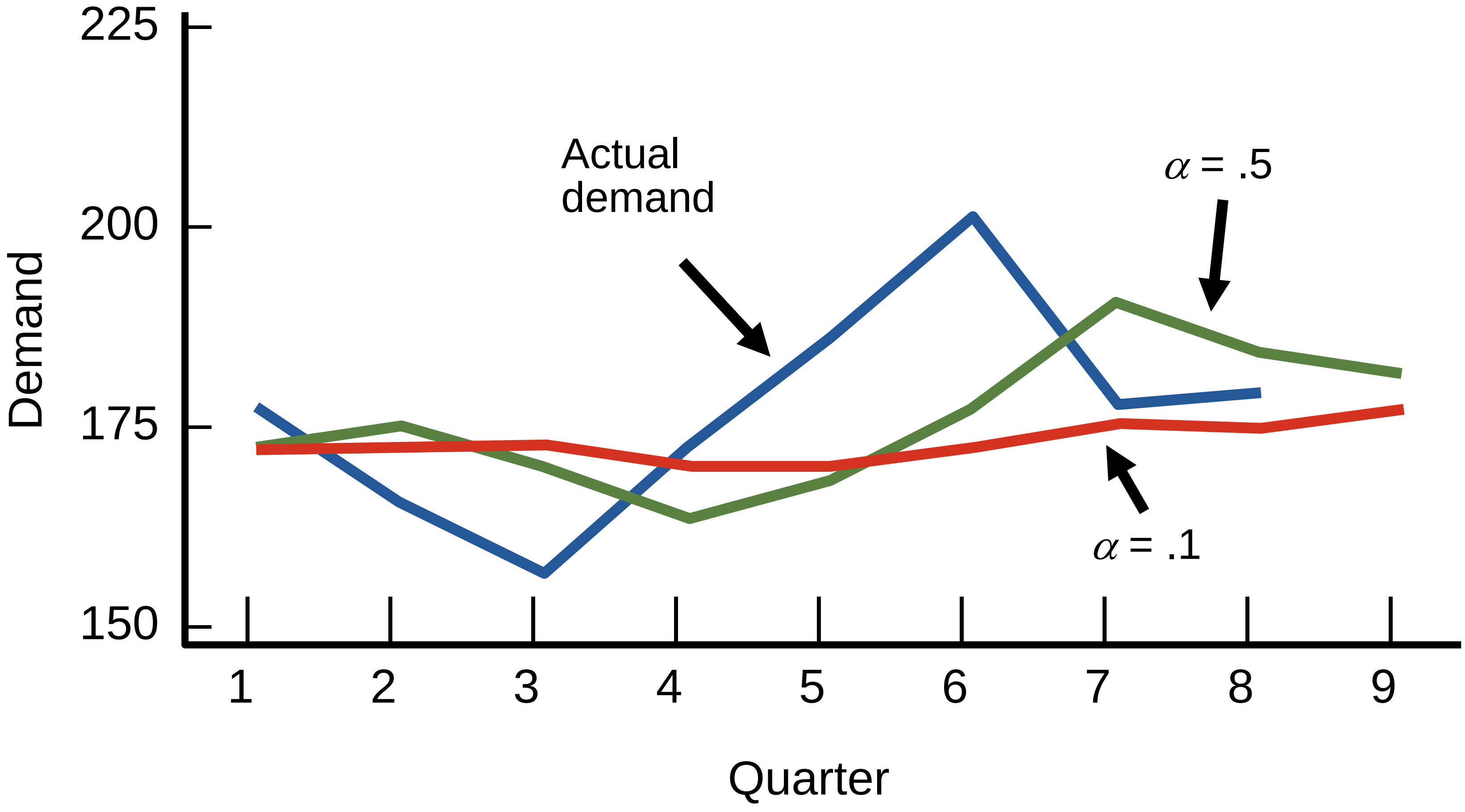
New forecast $= 142 + .2(153 – 142)$
$= 142 + 2.2$
$= 144.2 \approx 144$ cars

Effect of Smoothing Constants

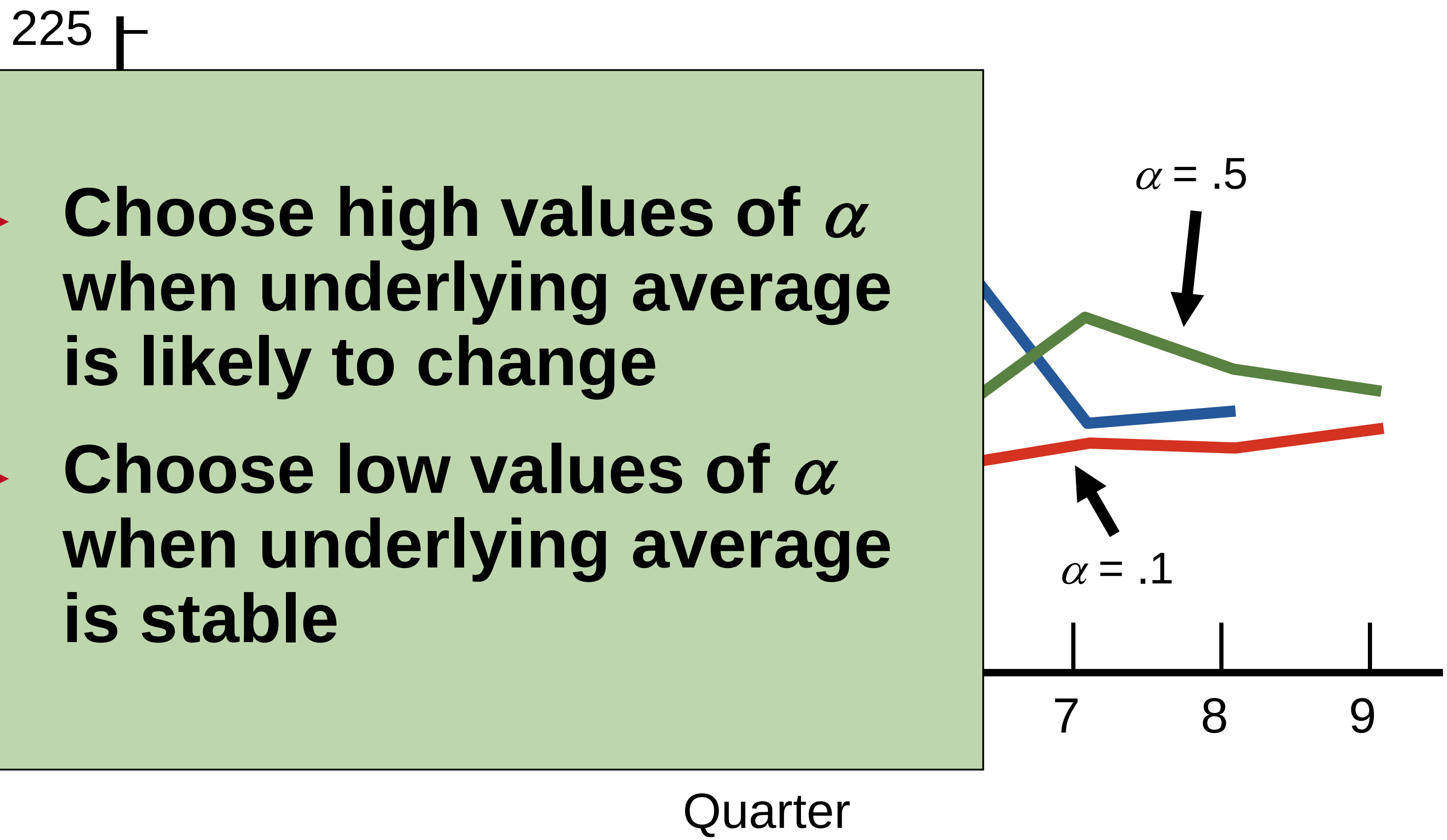
- Smoothing constant generally $.05 \leq \alpha \leq .50$
- As α increases, older values become less significant

	WEIGHT ASSIGNED TO				
SMOOTHING CONSTANT	MOST RECENT PERIOD (α)	2^{ND} MOST RECENT PERIOD $\alpha(1-\alpha)$	3^{RD} MOST RECENT PERIOD $\alpha(1-\alpha)^2$	4^{th} MOST RECENT PERIOD $\alpha(1-\alpha)^3$	5^{th} MOST RECENT PERIOD $\alpha(1-\alpha)^4$
$\alpha = .1$	.1	.09	.081	.073	.066
$\alpha = .5$	.5	.25	.125	.063	.031

Impact of Different α



Impact of Different α



- **Choose high values of α when underlying average is likely to change**
- **Choose low values of α when underlying average is stable**

Selecting the Smoothing Constant

The objective is to obtain the most accurate forecast no matter the technique

We generally do this by selecting the model that gives us the lowest forecast error according to one of three preferred measures:

- Mean Absolute Deviation (MAD)
- Mean Squared Error (MSE)
- Mean Absolute Percent Error (MAPE)

Common Measures of Error

Mean Absolute Deviation (MAD)

$$\text{MAD} = \frac{\sum \left| \text{Actual} - \text{Forecast} \right|}{n}$$

Determining the MAD

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH $\alpha = .10$	FORECAST WITH $\alpha = .50$
1	180	175	175
2	168	175.50 = 175.00 + .10(180 – 175)	177.50
3	159	174.75 = 175.50 + .10(168 – 175.50)	172.75
4	175	173.18 = 174.75 + .10(159 – 174.75)	165.88
5	190	173.36 = 173.18 + .10(175 – 173.18)	170.44
6	205	175.02 = 173.36 + .10(190 – 173.36)	180.22
7	180	178.02 = 175.02 + .10(205 – 175.02)	192.61
8	182	178.22 = 178.02 + .10(180 – 178.02)	186.30
9	?	178.59 = 178.22 + .10(182 – 178.22)	184.15

Determining the MAD

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH $\alpha = .10$	ABSOLUTE DEVIATION FOR $\alpha = .10$	FORECAST WITH $\alpha = .50$	ABSOLUTE DEVIATION FOR $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.50	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
	Sum of absolute deviations:		82.45		98.62
	MAD = $\dfrac{\Sigma\lvert\text{Deviations}\rvert}{n}$		10.31		12.33

Common Measures of Error

Mean Squared Error (MSE)

$$\text{MSE} = \frac{\sum \left(\text{Forecast errors}\right)^2}{n}$$

Determining the MSE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR $\alpha = .10$	$(\text{ERROR})^2$
1	180	175	$5^2 = 25$
2	168	175.50	$(-7.5)^2 = 56.25$
3	159	174.75	$(-15.75)^2 = 248.06$
4	175	173.18	$(1.82)^2 = 3.31$
5	190	173.36	$(16.64)^2 = 276.89$
6	205	175.02	$(29.98)^2 = 898.80$
7	180	178.02	$(1.98)^2 = 3.92$
8	182	178.22	$(3.78)^2 = 14.29$
			Sum of errors squared = 1,526.52

$$\text{MSE} = \frac{\sum (\text{Forecast errors})^2}{n} = 1{,}526.52 / 8 = 190.8$$

Common Measures of Error

Mean Absolute Percent Error (MAPE)

$$\text{MAPE} = \frac{\sum_{i=1}^{n} 100 \left| \text{Actual}_i - \text{Forecast}_i \right| / \text{Actual}_i}{n}$$

Determining the MAPE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR $\alpha = .10$	ABSOLUTE PERCENT ERROR 100(|ERROR|/ACTUAL)
1	180	175.00	100(5/180) = 2.78%
2	168	175.50	100(7.5/168) = 4.46%
3	159	174.75	100(15.75/159) = 9.90%
4	175	173.18	100(1.82/175) = 1.05%
5	190	173.36	100(16.64/190) = 8.76%
6	205	175.02	100(29.98/205) = 14.62%
7	180	178.02	100(1.98/180) = 1.10%
8	182	178.22	100(3.78/182) = 2.08%
			Sum of % errors = 44.75%

$$\text{MAPE} = \frac{\text{å absolute percent error}}{n} = \frac{44.75\%}{8} = 5.59\%$$

Comparison of Measures

TABLE 4.1	Comparison of Measures of Forecast Error	
MEASURE	**MEANING**	**APPLICATION TO CHAPTER EXAMPLE**
Mean absolute deviation (MAD)	How much the forecast missed the target	For α = .10 in Example 4, the forecast for grain unloaded was off by an average of 10.31 tons.
Mean squared error (MSE)	The square of how much the forecast missed the target	For α = .10 in Example 5, the square of the forecast error was 190.8. This number does not have a physical meaning, but is useful when compared to the MSE of another forecast.
Mean absolute percent error (MAPE)	The average percent error	For α = .10 in Example 6, the forecast is off by 5.59% on average. As in Examples 4 and 5, some forecasts were too high, and some were low.

Comparison of Forecast Error

Quarter	Actual Tonnage Unloaded	Rounded Forecast with $\alpha = .10$	Absolute Deviation for $\alpha = .10$	Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.5	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
			82.45		98.62

Comparison of Forecast Error

$$MAD = \frac{\sum |\text{deviations}|}{n}$$

For $\alpha = .10$

$= 82.45/8 = 10.31$

For $\alpha = .50$

$= 98.62/8 = 12.33$

Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
175	5.00
177.50	9.50
172.75	13.75
165.88	9.12
170.44	19.56
180.22	24.78
192.61	12.61
186.30	4.30
	98.62

82.45

Comparison of Forecast Error

$$\text{MSE} = \frac{\sum (\text{forecast errors})^2}{n}$$

For $\alpha = .10$

$= 1{,}526.52/8 = 190.8$

For $\alpha = .50$

$= 1{,}561.91/8 = 195.24$

Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
175	5.00
177.50	9.50
172.75	13.75
165.88	9.12
170.44	19.56
180.22	24.78
192.61	12.61
186.30	4.30

	82.45		98.62
MAD	10.31		12.33

Comparison of Forecast Error

$$\text{MAPE} = \frac{\sum_{i=1}^{n} 100|\text{deviation}_i|/\text{actual}_i}{n}$$

For $\alpha = .10$

$= 44.75\%/8 = 5.59\%$

For $\alpha = .50$

$= 54.00\%/8 = 6.75\%$

			...ed ...st ...0	Absolute Deviation for $\alpha = .50$
				5.00
			...0	9.50
			...75	13.75
			...8	9.12
			...4	19.56
			...2	24.78
			...1	12.61
			...0	4.30
		82.45		98.62
	MAD	10.31		12.33
	MSE	190.82		195.24

Comparison of Forecast Error

Quarter	Actual Tonnage Unloaded	Rounded Forecast with $\alpha = .10$	Absolute Deviation for $\alpha = .10$	Rounded Forecast with $\alpha = .50$	Absolute Deviation for $\alpha = .50$
1	180	175	5.00	175	5.00
2	168	175.5	7.50	177.50	9.50
3	159	174.75	15.75	172.75	13.75
4	175	173.18	1.82	165.88	9.12
5	190	173.36	16.64	170.44	19.56
6	205	175.02	29.98	180.22	24.78
7	180	178.02	1.98	192.61	12.61
8	182	178.22	3.78	186.30	4.30
			82.45		98.62
		MAD	10.31		12.33
		MSE	190.82		195.24
		MAPE	5.59%		6.75%