Principles of Operations Management: Sustainability and Supply Chain Management

Twelfth Edition, Global Edition

Chapter 4

Forecasting

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Outline

- **Global Company Profile:** *Walt Disney Parks & Resorts*
- What Is Forecasting?
- The Strategic Importance of Forecasting
- Seven Steps in the Forecasting System
- Forecasting Approaches

2

Outline (continued)

- Time-Series Forecasting
- Associative Forecasting Methods: Regression and Correlation Analysis
- Monitoring, Controlling and Adapting Forecasts
- Forecasting in the Service Sector

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How Forecasting Provides a Competitive Advantage for Disney (1 of 4)

- Global portfolio includes parks in Shanghai, Hong Kong, Paris, Tokyo, Orlando, and Anaheim
- Revenues are derived from people - how many visitors and how they spend their money
- Daily management report contains only yesterday's forecast and actual attendance at each park – an error close to zero is expected

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How Forecasting Provides a Competitive Advantage for Disney (2 of 4)

- Disney generates daily, weekly, monthly, annual, and 5-year forecasts
- Forecast used by labor management, maintenance, operations, finance, and park scheduling
- Forecast used to adjust opening times, rides, shows, staffing levels, and guests admitted

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How Forecasting Provides a Competitive Advantage for Disney (3 of 4)

- 20% of customers come from outside the USA
- Economic model includes gross domestic product (GDP), cross-exchange rates, arrivals into the USA
- A staff of 35 analysts and 70 field people survey 1 million park guests, employees, and travel professionals each year

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How Forecasting Provides a Competitive Advantage for Disney
(4 of 4)

- Inputs to the forecasting model include airline specials, Federal Reserve policies, Wall Street trends, vacation/holiday schedules for 3,000 school districts around the world
- Average forecast error for the 5-year forecast is 5%
- Average forecast error for annual forecasts is between 0% and 3%

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Learning Objectives

When you complete this chapter you should be able to:

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

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

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

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Learning Objectives (continued)

When you complete this chapter you should be able to:

4.4 ***Compute*** three measures of forecast accuracy

4.5 ***Develop*** seasonal indices

4.6 ***Conduct*** a regression and correlation analysis

4.7 ***Use*** a tracking signal

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What is Forecasting?

- The art and science of predicting future events
- Underlying basis of all business decisions
  - Production
  - Inventory
  - Personnel
  - Facilities

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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 planning, production planning and budgeting, cash budgeting, and analysis of various operating plans
3. *Long-range forecast*
   - 3+ years
   - New product planning, facility location or expansion, capital expenditures, research and development

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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

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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

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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

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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

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The Realities!

- Most forecasting techniques assume that there is some underlying stability in the system; many firms automate their predictions using computerized forecasting software
- Product family and aggregated forecasts are more accurate than individual product forecasts – helps balance the over- and underpredictions
- Outside factors that we cannot predict or control often impact the forecast: extreme events can wreck havoc in the forecasting systems – e.g. the COVID-19 pandemic

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Forecasting Approaches

Qualitative Methods

- Used when situation is vague and little data exist
  – New products
  – New technology
- Involves intuition, emotions, personal experiences, and value system

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Forecasting Approaches (continued)

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

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Overview of Qualitative Methods

1. **Jury of executive opinion**
   – Pool opinions of high-level experts or managers, sometimes augmented by statistical models
2. **Delphi method**
   – Panel of experts (decision makers, staff personnel and respondents), queried iteratively

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Overview of Qualitative Methods (continued)

3. **Sales force composite**
   – Estimates from individual salespersons are reviewed for reasonableness, then aggregated
4. **Market Survey**
   – Ask the customer about future purchasing plans

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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

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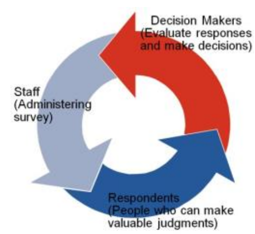
Delphi Method

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



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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

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Market Survey

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

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Overview of Quantitative Approaches

1. Naive approach 2. Moving averages 3. Exponential smoothing 4. Trend projection	Time-series models
5. Linear regression	Associative model

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Time-Series Forecasting

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

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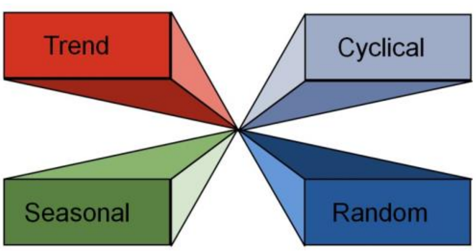
Time-Series Components



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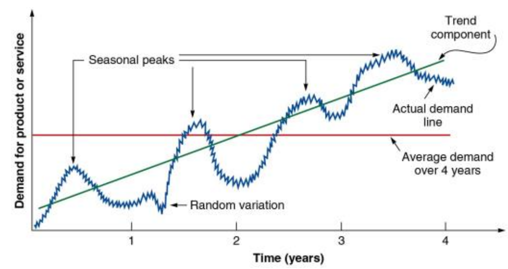
Components of Demand

Figure 4.1



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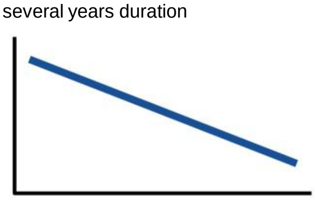
Trend Component

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



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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

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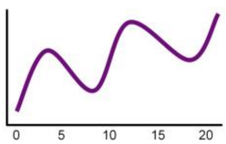
Cyclical Component

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



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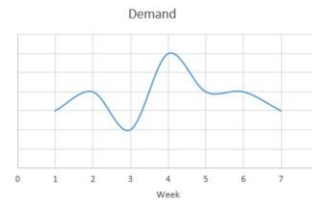
Random Component

- "Blips" in data caused by chance and unusual situations
- Follow no discernible pattern
- Cannot be predicted



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Naive Approach

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

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Moving Averages

- MA is a series of arithmetic means
- Useful is we can assume that market demands will stay fairly steady over time
- Used often for smoothing
  - Provides overall impression of data over time

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

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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 $^2/_3$

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Weighted Moving Average (1 of 3)

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

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

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Weighted Moving Average (2 of 3)

MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	[(3 x 13) + (2 x 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 = (3 x Sales last mo. + 2 x Sales 2 mos. ago + 1 x Sales 3 mos. ago) / Sum of the weights

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Weighted Moving Average (3 of 3)

MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	[(3 x 13) + (2 x 12) + (10)]/6 = 12 1/6
May	19	[(3 x 16) + (2 x 13) + (12)]/6 = 14 1/3
June	23	[(3 x 19) + (2 x 16) + (13)]/6 = 17
July	26	[(3 x 23) + (2 x 19) + (16)]/6 = 20 1/2
August	30	[(3 x 26) + (2 x 23) + (19)]/6 = 23 5/6
September	28	[(3 x 30) + (2 x 26) + (23)]/6 = 27 1/2
October	18	[(3 x 28) + (2 x 30) + (26)]/6 = 28 1/3
November	16	[(3 x 18) + (2 x 28) + (30)]/6 = 23 1/3
December	14	[(3 x 16) + (2 x 18) + (28)]/6 = 18 2/3

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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

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Graph of Moving Averages

Figure 4.2

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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

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Exponential Smoothing (continued)

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

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Exponential Smoothing Example (1 of 3)

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

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Exponential Smoothing Example (2 of 3)

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

New forecast $= 142 + .2(153 - 142)$

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Exponential Smoothing Example (3 of 3)

Predicted demand = 142 Ford Mustangs

Actual demand = 153

Smoothing constant $\alpha = .20$

New forecast $= 142 + .2(153 - 142)$
$= 142 + 2.2$
$= 142.2 \approx 144$ cars

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Effect of Smoothing Constants

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

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

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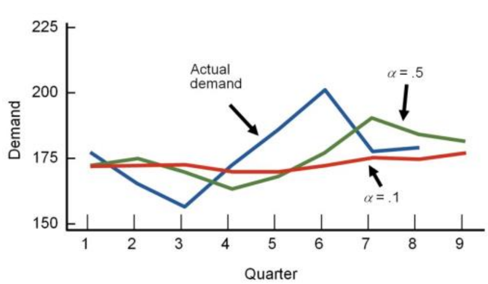
Impact of Different α



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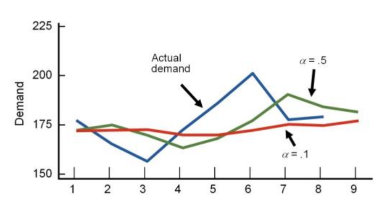
Impact of Different α (continued)



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

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Measuring Forecast Error

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)

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Common Measures of Error (1 of 3)

Mean Absolute Deviation (MAD)

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

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Determining the MAD

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH α = .10	FORECAST WITH α = .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

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Determining the MAD (continued)

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST WITH α = .10	ABSOLUTE DEVIATION FOR α = .10	FORECAST WITH α = .50	ABSOLUTE DEVIATION FOR α = .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
	$\text{MAD} = \frac{\Sigma\lvert\text{Deviations}\rvert}{n}$		10.31		12.33

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Common Measures of Error (2 of 3)

Mean Squared Error (MSE)

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

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Determining the MSE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR α = .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

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

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Common Measures of Error (3 of 3)

Mean Absolute Percent Error (MAPE)

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

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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%

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

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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 $\alpha = .10$ 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 $\alpha = .10$ 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 $\alpha = .10$ 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.

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Comparison of Forecast Error (1 of 5)

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

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Comparison of Forecast Error (2 of 5)

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

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

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Comparison of Forecast Error (3 of 5)

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

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

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Comparison of Forecast Error (4 of 5)

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

For $\alpha = .10$

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

For $\alpha = .50$

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

	...d ...st	Absolute Deviation for $\alpha = .50$
	...0	5.00
	0	9.50
	5	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

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Comparison of Forecast Error (5 of 5)

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%

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Exponential Smoothing with Trend Adjustment (1 of 3)

When a trend is present, exponential smoothing must be modified

MONTH	ACTUAL DEMAND	FORECAST (F_t) FOR MONTHS 1 – 5
1	100	$F_1 = 100$ (given)
2	200	$F_2 = F_1 + \alpha(A_1 - F_1) = 100 + .4(100 - 100) = 100$
3	300	$F_3 = F_2 + \alpha(A_2 - F_2) = 100 + .4(200 - 100) = 140$
4	400	$F_4 = F_3 + \alpha(A_3 - F_3) = 140 + .4(300 - 140) = 204$
5	500	$F_5 = F_4 + \alpha(A_4 - F_4) = 204 + .4(400 - 204) = 282$

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Exponential Smoothing with Trend Adjustment (2 of 3)

Forecast including trend(FIT_t) = Exponentially smoothed forecast average(F_t) + Exponentially smoothed trend(T_t)

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

$$T_t = \beta(F_t - F_{t-1}) + (1-\beta)\,T_{t-1}$$

where

F_t = exponentially smoothed forecast average

T_t = exponentially smoothed trend

A_t = actual demand

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

β = smoothing constant for trend $(0 \le \beta \le 1)$

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Exponential Smoothing with Trend Adjustment (3 of 3)

Step 1: Compute F_t

Step 2: Compute T_t

Step 3: Calculate the forecast $FIT_t = F_t + T_t$

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Exponential Smoothing with Trend Adjustment Example (1 of 6)

MONTH (t)	ACTUAL DEMAND (A_t)	MONTH (t)	ACTUAL DEMAND (A_t)
1	12	6	21
2	17	7	31
3	20	8	28
4	19	9	36
5	24	10	?

$\alpha = .2$ $\beta = .4$

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Exponential Smoothing with Trend Adjustment Example (2 of 6)

Table 4.2 Forecast with $\alpha = .2$ and $\beta = .4$

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80		
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 1: Average for Month 2

$$F_2 = \alpha A_1 + (1 - \alpha)(F_1 + T_1)$$
$$F_2 = (.2)(12) + (1 - .2)(11 + 2)$$
$$= 2.4 + (.8)(13) = 2.4 + 10.4$$
$$= 12.8 \text{ units}$$

Pearson

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Exponential Smoothing with Trend Adjustment Example (3 of 6)

Table 4.2 Forecast with $\alpha = .2$ and $\beta = .4$

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 2: Trend for Month 2

$$T_2 = \beta(F_2 - F_1) + (1 - \beta)T_1$$
$$T_2 = (.4)(12.8 - 11) + (1 - .4)(2)$$
$$= .72 + 1.2 = 1.92 \text{ units}$$

Pearson

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Exponential Smoothing with Trend Adjustment Example (4 of 6)

Table 4.2 Forecast with $\alpha = .2$ and $\beta = .4$

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	14.72
3	20			
4	19			
5	24			
6	21			
7	31			
8	28			
9	36			
10	—			

Step 3: Calculate *FIT* for Month 2

$$FIT_2 = F_2 + T_2$$
$$FIT_2 = 12.8 + 1.92$$
$$= 14.72 \text{ units}$$

Pearson

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Exponential Smoothing with Trend Adjustment Example (5 of 6)

Table 4.2 Forecast with $\alpha = .2$ and $\beta = .4$

MONTH	ACTUAL DEMAND	SMOOTHED FORECAST AVERAGE, F_t	SMOOTHED TREND, T_t	FORECAST INCLUDING TREND, FIT_t
1	12	11	2	13.00
2	17	12.80	1.92	14.72
3	20	15.18	2.10	17.28
4	19	17.82	2.32	20.14
5	24	19.91	2.23	22.14
6	21	22.51	2.38	24.89
7	31	24.11	2.07	26.18
8	28	27.14	2.45	29.59
9	36	29.28	2.32	31.60
10		32.48	2.68	35.16

Pearson

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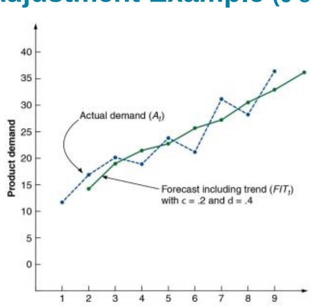
Exponential Smoothing with Trend Adjustment Example (6 of 6)

Figure 4.3



Pearson

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Trend Projections

- Fitting a trend line to historical data points, to project into the medium to long-range
- Linear trends can be found using the least-squares technique

$$\hat{y} = a + bx$$

where $\hat{y}$ = computed value of the variable to be predicted (dependent variable)

a = y-axis intercept
b = slope of the regression line
x = the independent variable

Pearson

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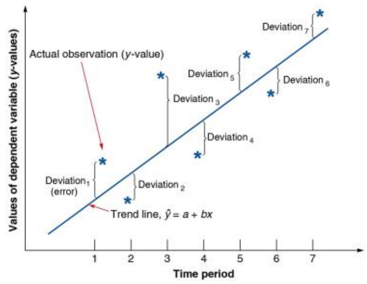
Least Squares Method

Figure 4.4



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Least Squares Method (continued)

Equations to calculate the regression variables

$$\hat{y} = a + bx$$

$$b = \frac{\sum xy - n\overline{x}\overline{y}}{\sum x^2 - n\overline{x}^2}$$

$$a = \overline{y} - b\overline{x}$$

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Least Squares Example (1 of 5)

YEAR	ELECTRICAL POWER DEMAND	YEAR	ELECTRICAL POWER DEMAND
1	74	5	105
2	79	6	142
3	80	7	122
4	90		

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Least Squares Example (2 of 5)

YEAR (x)	ELECTRICAL POWER DEMAND (y)	x^2	xy
1	74	1	74
2	79	4	158
3	80	9	240
4	90	16	360
5	105	25	525
6	142	36	852
7	122	49	854
$\sum x = 28$	$\sum y = 692$	$\sum x^2 = 140$	$\sum xy = 3,063$

$$\overline{x} = \frac{\sum x}{n} = \frac{28}{7} = 4 \qquad \overline{y} = \frac{\sum y}{n} = \frac{692}{7} = 98.86$$

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Least Squares Example (3 of 5)

$$b = \frac{\sum xy - n\overline{x}\overline{y}}{\sum x^2 - n\overline{x}^2} = \frac{3,063 - (7)(4)(98.86)}{140 - (7)(4^2)} = \frac{295}{28} = 10.54$$

$$a = \overline{y} - b\overline{x} = 98.86 - 10.54(4) = 56.70$$

$$\text{Thus,} \quad \hat{y} = 56.70 + 10.54x$$

$\sum x = 28$	$\sum y = 692$	$\sum x^2 = 140$	$\sum xy = 3,063$

$$\overline{x} = \frac{\sum x}{n} = \frac{28}{7} = 4 \qquad \overline{y} = \frac{\sum y}{n} = \frac{692}{7} = 98.86$$

77

Least Squares Example (4 of 5)

$$b = \frac{\sum xy - n\overline{x}\overline{y}}{\sum x^2 - n\overline{x}^2} = \frac{3,063 - (7)(4)(98.86)}{140 - (7)(4^2)} = \frac{295}{28} = 10.54$$

$$a = \overline{y} - b\overline{x} = 98.86 - 10.54(4) = 56.70$$

$$\text{Thus,} \quad \hat{y} = 56.70 + 10.54x$$

Demand in year 8 = 56.70 + 10.54(8)
= 141.02, or 141 megawatts

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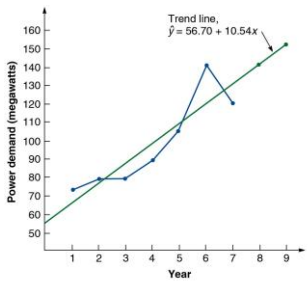
Least Squares Example (5 of 5)

Figure 4.5



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Least Squares Requirements

1. We always plot the data to insure a linear relationship
2. We do not predict time periods far beyond the database
3. Deviations around the least squares line are assumed to be random

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Seasonal Variations In Data

The multiplicative seasonal model can adjust trend data for seasonal variations in demand

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Seasonal Variations In Data (continued)

Steps in the process for monthly seasons:

1. Find average historical demand for each month.
2. Compute the average demand over all months.
3. Compute a seasonal index for each month.
4. Estimate next year's total demand.
5. Divide this estimate of total demand by the number of months, then multiply it by the seasonal index for that month. This provides the seasonal forecast.

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Seasonal Index Example (1 of 6)

	DEMAND					
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90		
Feb	70	85	85	80		
Mar	80	93	82	85		
Apr	90	95	115	100		
May	113	125	131	123		
June	110	115	120	115		
July	100	102	113	105		
Aug	88	102	110	100		
Sept	85	90	95	90		
Oct	77	78	85	80		
Nov	75	82	83	80		
Dec	82	78	80	80		
		Total average annual demand =		1,128		

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Seasonal Index Example (2 of 6)

	DEMAND					
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	
Feb	70	85	85	80	94	
Mar	[illegible]	[illegible]	[illegible]	[illegible]	94	
Apr	[illegible]	[illegible]	[illegible]	[illegible]	94	
May	[illegible]	[illegible]	[illegible]	[illegible]	94	
June	[illegible]	[illegible]	[illegible]	[illegible]	94	
July	100	102	113	105	94	
Aug	88	102	110	100	94	
Sept	85	90	95	90	94	
Oct	77	78	85	80	94	
Nov	75	82	83	80	94	
Dec	82	78	80	80	94	
		Total average annual demand =		1,128		

$$\text{Average monthly demand} = \frac{1,128}{12 \text{ months}} = 94$$

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Seasonal Index Example (3 of 6)

DEMAND						
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	.957 (= 90/94)
Feb	70	85	85	80	94	
Mar	80	93	82	85	94	
Apr	90	95	115	100	94	
Sept	85	90	95	90	94	
Oct	77	78	85	80	94	
Nov	75	82	83	80	94	
Dec	82	78	80	80	94	
			Total average annual demand =	1,128		

$$\text{Seasonal index} = \frac{\text{Average monthly demand for past 3 years}}{\text{Average monthly demand}}$$

Seasonal Index Example (4 of 6)

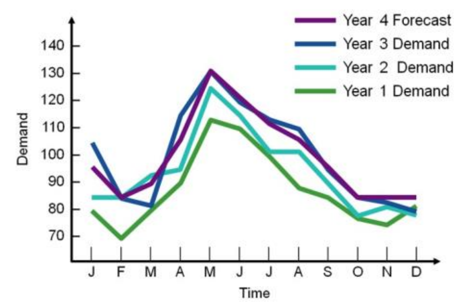
DEMAND						
MONTH	YEAR 1	YEAR 2	YEAR 3	AVERAGE PERIOD DEMAND	AVERAGE MONTHLY DEMAND	SEASONAL INDEX
Jan	80	85	105	90	94	.957 (= 90/94)
Feb	70	85	85	80	94	.851 (= 80/94)
Mar	80	93	82	85	94	.904 (= 85/94)
Apr	90	95	115	100	94	1.064 (= 100/94)
May	113	125	131	123	94	1.309 (= 123/94)
June	110	115	120	115	94	1.223 (= 115/94)
July	100	102	113	105	94	1.117 (= 105/94)
Aug	88	102	110	100	94	1.064 (= 100/94)
Sept	85	90	95	90	94	.957 (= 90/94)
Oct	77	78	85	80	94	.851 (= 80/94)
Nov	75	82	83	80	94	.851 (= 80/94)
Dec	82	78	80	80	94	.851 (= 80/94)
			Total average annual demand =	1,128		

Seasonal Index Example (5 of 6)

Seasonal forecast for Year 4

MONTH	DEMAND	MONTH	DEMAND
Jan.	$\frac{1,200}{12} \times .957 = 96$	July	$\frac{1,200}{12} \times 1.117 = 112$
Feb.	$\frac{1,200}{12} \times .851 = 85$	Aug.	$\frac{1,200}{12} \times 1.064 = 106$
Mar.	$\frac{1,200}{12} \times .904 = 90$	Sept.	$\frac{1,200}{12} \times .957 = 96$
Apr.	$\frac{1,200}{12} \times 1.064 = 106$	Oct.	$\frac{1,200}{12} \times .851 = 85$
May	$\frac{1,200}{12} \times 1.309 = 131$	Nov.	$\frac{1,200}{12} \times .851 = 85$
June	$\frac{1,200}{12} \times 1.223 = 122$	Dec.	$\frac{1,200}{12} \times .851 = 85$

Seasonal Index Example (6 of 6)



Applying both Trend and Seasonal Indices – Example 10: San Diego Hospital

Figure 4.6

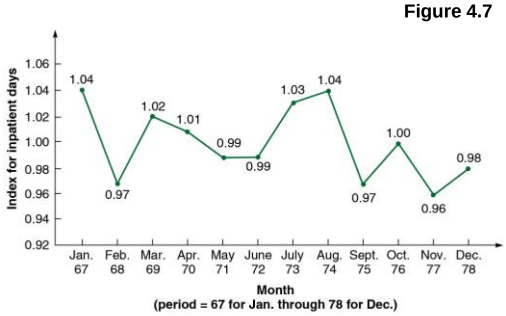
San Diego Hospital (1 of 4)

Seasonality Indices for Adult Inpatient Days at San Diego Hospital

MONTH	SEASONALITY INDEX	MONTH	SEASONALITY INDEX
January	1.04	July	1.03
February	0.97	August	1.04
March	1.02	September	0.97
April	1.01	October	1.00
May	0.99	November	0.96
June	0.99	December	0.98

San Diego Hospital (2 of 4)

Figure 4.7



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San Diego Hospital (3 of 4)

Period	67	68	69	70	71	72
Month	Jan	Feb	Mar	Apr	May	June
Forecast with Trend & Seasonality	9,911	9,265	9,764	9,691	9,520	9,542
Period	73	74	75	76	77	78
Month	July	Aug	Sept	Oct	Nov	Dec
Forecast with Trend & Seasonality	9,949	10,068	9,411	9,724	9,355	9,572

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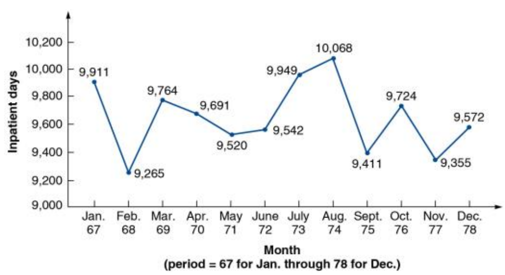
San Diego Hospital (4 of 4)

Figure 4.8



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Adjusting Trend Data with Seasonal Indices (Example 11)

Management at Jagoda Wholesalers, in Calgary, Canada, has used time-series regression based on point-of-sale data to forecast sales for the next 4 quarters. Sales estimates are \$100,000, \$120,000, \$140,000, and \$160,000 for the respective quarters. Seasonal indices for the 4 quarters have been found to be 1.30, .90, .70, and 1.10, respectively.

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Adjusting Trend Data with Seasonal Indices (Example 11) (continued)

$$\hat{y}_{\text{seasonal}} = \text{Index} \times \hat{y}_{\text{trend forecast}}$$

$$\text{Quarter I}: \hat{y}_{I} = (1.30)(\$100{,}000) = \$130{,}000$$

$$\text{Quarter II}: \hat{y}_{II} = (.90)(\$120{,}000) = \$108{,}000$$

$$\text{Quarter III}: \hat{y}_{III} = (.70)(\$140{,}000) = \$98{,}000$$

$$\text{Quarter IV}: \hat{y}_{IV} = (1.10)(\$160{,}000) = \$176{,}000$$

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Cyclical Variations

- Cycles – patterns in the data that occur every several years
  - Forecasting is difficult
  - Wide variety of factors

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Associative Forecasting

Used when changes in one or more independent variables can be used to predict the changes in the dependent variable

Most common technique is **linear-regression analysis**

We apply this technique just as we did in the time-series example

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Using Regression Analysis for Forecasting

Forecasting an outcome based on predictor variables using the least squares technique

$$\hat{y} = a + bx$$

where $\hat{y}$ = value of dependent variable

a = y-axis intercept
b = slope of the regression line
x = the independent variable

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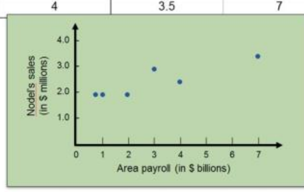
Associative Forecasting Example
(1 of 6)

NODEL'S SALES (IN $ MILLIONS), y	AREA PAYROLL (IN $ BILLIONS), x	NODEL'S SALES (IN $ MILLIONS), y	AREA PAYROLL (IN $ BILLIONS), x
2.0	1	2.0	2
3.0	3	2.0	1
2.5	4	3.5	7



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Associative Forecasting Example
(2 of 6)

SALES, y	PAYROLL, x	x^2	xy
2.0	1	1	2.0
3.0	3	9	9.0
2.5	4	16	10.0
2.0	2	4	4.0
2.0	1	1	2.0
3.5	7	49	24.5
$\sum y = 15.0$	$\sum x = 18$	$\sum x^2 = 80$	$\sum xy = 51.5$

$$\bar{x} = \frac{\sum x}{6} = \frac{18}{6} = 3 \qquad \bar{y} = \frac{\sum y}{6} = \frac{15}{6} = 2.5$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

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Associative Forecasting Example
(3 of 6)

SALES, y	PAYROLL, x	x^2	xy
2.0			
3.0			
2.5			
2.0			
2.0			
3.5	7	49	24.5
$\Sigma y =$ 15.0	$\Sigma x =$ 18	$\Sigma x^2 =$ 80	$\Sigma xy =$ 51.5

$$\hat{y} = 1.75 + .25x$$

$$\text{Sales} = 1.75 + .25(\text{payroll})$$

$$\bar{x} = \frac{\sum x}{6} = \frac{18}{6} = 3 \qquad \bar{y} = \frac{\sum y}{6} = \frac{15}{6} = 2.5$$

$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

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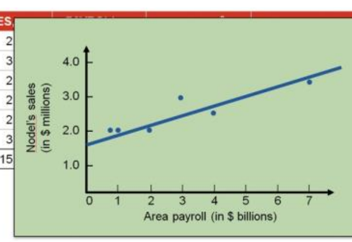
Associative Forecasting Example
(4 of 6)

SALES
2
3
2
2
2
3
$\Sigma y =$ 15



$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

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Associative Forecasting Example (5 of 6)

If payroll next year is estimated to be $6 billion, then:

$$\text{Sales (in \$ millions)} = 1.75 + .25(6)$$
$$= 1.75 + 1.5 = 3.25$$
$$\text{Sales} = \$3{,}250{,}000$$

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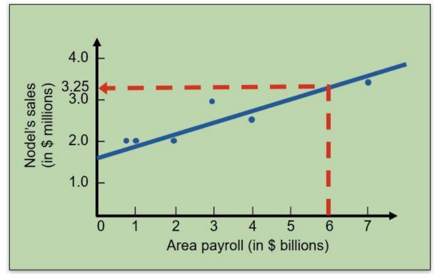
Associative Forecasting Example (6 of 6)



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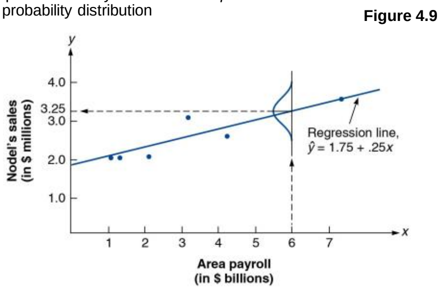
Standard Error of the Estimate (1 of 4)

- A forecast is just a *point estimate* of a future value
- This point is actually the *mean* or *expected value* of a probability distribution

Figure 4.9



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Standard Error of the Estimate (2 of 4)

$$S_{y,x} = \sqrt{\frac{\sum (y - y_c)^2}{n - 2}}$$

Where y = y-value of each data point

y_c = computed value of the dependent variable, from the regression equation

n = number of data points

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Standard Error of the Estimate (3 of 4)

Computationally, this equation is considerably easier to use

$$S_{y,x} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n - 2}}$$

We use the standard error to set up prediction intervals around the point estimate

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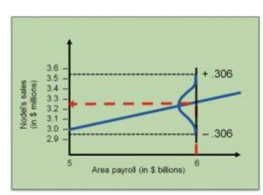
Standard Error of the Estimate (4 of 4)

$$S_{y,x} = \sqrt{\frac{\sum y^2 - a\sum y - b\sum xy}{n - 2}} = \sqrt{\frac{39.5 - 1.75(15.0) - .25(51.5)}{6 - 2}}$$
$$= \sqrt{.09375}$$
$$= .306 (\textit{in \$ millions})$$

The standard error of the estimate is $306,000 in sales



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Correlation

- How strong is the linear relationship between the variables?
- Correlation does not necessarily imply causality!
- **Coefficient of correlation**, *r*, measures degree of association
  - Values range from −1 to +1

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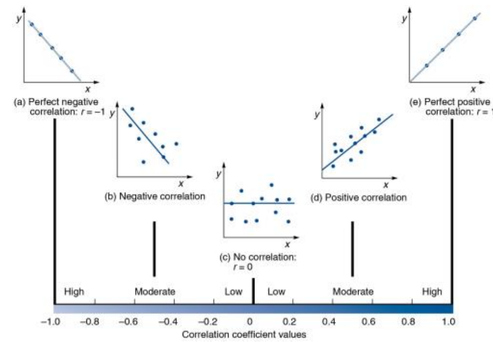
Correlation Coefficient (1 of 4) **Figure 4.10**



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Correlation Coefficient (2 of 4)

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

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Correlation Coefficient (3 of 4)

y	x	x^2	xy	y^2
2.0	1	1	2.0	4.0
3.0	3	9	9.0	9.0
2.5	4	16	10.0	6.25
2.0	2	4	4.0	4.0
2.0	1	1	2.0	4.0
3.5	7	49	24.5	12.25
$\sum y = \overline{15.0}$	$\sum x = \overline{18}$	$\sum x^2 = \overline{80}$	$\sum xy = \overline{51.5}$	$\sum y^2 = \overline{39.5}$

$$r = \frac{(6)(51.5) - (18)(15.0)}{\sqrt{\left[(6)(80) - (18)^2\right]\left[(6)(39.5) - (15.0)^2\right]}}$$

$$= \frac{309 - 270}{\sqrt{(156)(12)}} = \frac{39}{\sqrt{1{,}872}} = \frac{39}{43.3} = .901$$

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Correlation (continued)

- **Coefficient of Determination**, r^2, measures the percent of change in *y* predicted by the change in *x*
  - Values range from 0 to 1
  - Easy to interpret – percent of variation in the dependent variable (*y*) that is explained by the regression equation

For the Nodel Construction example:

$$r = .901$$
$$r^2 = .81$$

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Multiple-Regression Analysis

If more than one independent variable is to be used in the model, linear regression can be extended to multiple regression to accommodate several independent variables

$$\hat{y} = a + b_1x_1 + b_2x_2$$

Computationally, this is quite complex and generally done on the computer

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Multiple-Regression Analysis (continued)

In the Nodel example, including interest rates in the model gives the new equation:

$$\hat{y} = 1.80 + .30x_1 - 5.0x_2$$

An improved correlation coefficient of r = .96 suggests this model does a better job of predicting the change in construction sales

$$\text{Sales} = 1.80 + .30(6) - 5.0(.12) = 3.00$$

Sales = $3,000,000

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Monitoring, Controlling, and Adapting Forecasts

Tracking Signal

- Measures how well the forecast is predicting actual values
- Ratio of cumulative forecast errors to mean absolute deviation (MAD)
  - Good tracking signal has low values
  - If forecasts are continually high or low, the forecast has a bias error

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Monitoring, Controlling, and Adapting Forecasts (continued)

$$\text{Tracking signal} = \frac{\text{Cumulative error}}{\text{MAD}}$$

$$= \frac{\sum(\text{Actual demand in period i} - \text{Forecast demad in period i})}{\frac{\sum|\text{Actual} - \text{Forecast}|}{n}}$$

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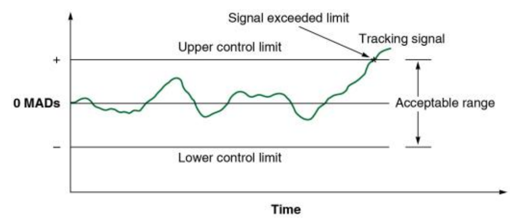
A Plot of Tracking Signals

Figure 4.11



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Tracking Signal Example

QTR	ACTUAL DEMAND	FORECAST DEMAND	ERROR	CUM ERROR	ABSOLUTE FORECAST ERROR	CUM ABS FORECAST ERROR	MAD	TRACKING SIGNAL (CUM ERROR/MAD)
1	90	100	–10	–10	10	10	10.0	–10/10 = –1
2	95	100	–5	–15	5	15	7.5	–15/7.5 = –2
3	115	100	+15	0	15	30	10.0	0/10 = 0
4	100	110	–10	–10	10	40	10.0	10/10 = –1
5	125	110	+15	+5	15	55	11.0	+5/11 = +0.5
6	140	110	+30	+35	30	85	14.2	+35/14.2 = +2.5

$$\text{At the end of quarter 6, MAD} = \frac{\sum|\text{Forecast errors}|}{n} = \frac{85}{6} = 14.2$$

$$\text{Tracking signal} = \frac{\text{Cumulative error}}{\text{MAD}} = \frac{35}{14.2} = 2.5\,\text{MADs}$$

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Adaptive Smoothing

- It's possible to use the computer to continually monitor forecast error and adjust the values of the α and β coefficients used in exponential smoothing to continually minimize forecast error
- This technique is called **adaptive smoothing**

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Focus Forecasting

- Developed at American Hardware Supply, based on two principles:
  1. Sophisticated forecasting models are not always better than simple ones
  2. There is no single technique that should be used for all products or services
- Uses historical data to test multiple forecasting models for individual items
- Forecasting model with the lowest error used to forecast the next demand

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Forecasting Under a Pandemic or Major Disruption

- Examples:
  2020 COVID-19 pandemic
  2008 financial crisis
- Traditional techniques based on historical data may be of little use
- Use of stagger charts (Intel and Motorola)

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Stagger Chart (1 of 3)

- Emphasize current data, some of which may be intuitive or subjective, to provide a reoccurring fresh look at forecasts by using "rolling forecasts"
- Charts compare forecasts against a standard, such as a budget plan, average sales for the period in recent years, or booked sales

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Stagger Chart (2 of 3)

Evaluation questions:

- "In what ways are the assumptions of the forecast made in recent months different from those used when the annual budget plan was prepared?"
- What do we know now that we did not know then?"
- "Is a competitor no longer in business?"
- "Have we had a significant change in demand due to the economy, interest rates, weather, and so on?"

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Stagger Chart (3 of 3)

- Expose crucial insight necessary for adaptation during a disruptive period
- Provide a rapid and economical after-the-fact opportunity for evaluation, learning, and improvement of the forecasting process

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Forecasting in the Service Sector

- Presents unusual challenges
  - Special need for short-term records
  - Needs differ greatly as function of industry and product
  - Holidays and other calendar events
  - Unusual events

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Fast Food Restaurant Forecast

Figure 4.12a

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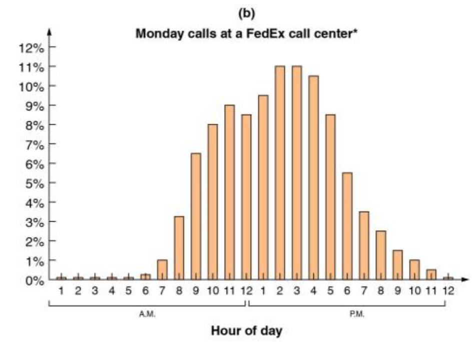
FedEx Call Center Forecast

Figure 4.12b



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