Chapter 7

Demand Forecasting in a Supply Chain

Learning Objectives

- Understand the role of forecasting for both an enterprise and a supply chain.
- Identify the components of a demand forecast.
- Forecast demand in a supply chain given historical demand data using time-series methodologies.
- Analyze demand forecasts to estimate forecast error.

Role of Forecasting in a Supply Chain

- The basis for all planning decisions in a supply chain
- Used for both push and pull processes
  - Production scheduling, inventory, aggregate planning
  - Sales force allocation, promotions, new production introduction
  - Plant/equipment investment, budgetary planning
  - Workforce planning, hiring, layoffs
- All of these decisions are interrelated

Characteristics of Forecasts

- Forecasts are always inaccurate and should thus include both the expected value of the forecast and a measure of forecast error
- Long-term forecasts are usually less accurate than short-term forecasts
- Aggregate forecasts are usually more accurate than disaggregate forecasts
- In general, the farther up the supply chain a company is, the greater is the distortion of information it receives

Components and Methods

- Companies must identify the factors that influence future demand and then ascertain the relationship between these factors and future demand
  - Past demand
  - Lead time of product replenishment
  - Planned advertising or marketing efforts
  - Planned price discounts
  - State of the economy
  - Actions that competitors have taken

Components and Methods

- Qualitative
  - Primarily subjective
  - Rely on judgment
- Time series
  - Use historical demand only
  - Best with stable demand
- Causal
  - Relationship between demand and some other factor
- Simulation
  - Imitate consumer choices that give rise to demand

Components of an Observation

Observed demand (*O*) = systematic component (*S*)
+ random component (*R*)

- Systematic component – expected value of demand
  - *Level* (current deseasonalized demand)
  - *Trend* (growth or decline in demand)
  - *Seasonality* (predictable seasonal fluctuation)
- Random component – part of forecast that deviates from systematic component
- Forecast error – difference between forecast and actual demand

Basic Approach

- Understand the objective of forecasting.
- Integrate demand planning and forecasting throughout the supply chain.
- Identify the major factors that influence the demand forecast.
- Forecast at the appropriate level of aggregation.
- Establish performance and error measures for the forecast.

Time-Series Forecasting Methods

- Three ways to calculate the systematic component
  - **Multiplicative**

    S = level x trend x seasonal factor
  - **Additive**

    S = level + trend + seasonal factor
  - **Mixed**

    S = (level + trend) x seasonal factor

Static Methods

$$\text{Systematic component} = (\text{level} + \text{trend}) \times \text{seasonal factor}$$

$$F_{t+l} = [L + (t + l)T]S_{t+l}$$

where

L = Estimate of level at $t = 0$

T = Estimate of trend

S_t = Estimate of seasonal factor for Period t

D_t = Actual demand observed in Period t

F_t = Forecast of demand for Period t

Tahoe Salt

Year	Quarter	Period, t	Demand, D_t
1	2	1	8,000
1	3	2	13,000
1	4	3	23,000
2	1	4	34,000
2	2	5	10,000
2	3	6	18,000
2	4	7	23,000
3	1	8	38,000
3	2	9	12,000
3	3	10	13,000
3	4	11	32,000
4	1	12	41,000

Table 7-1

Tahoe Salt

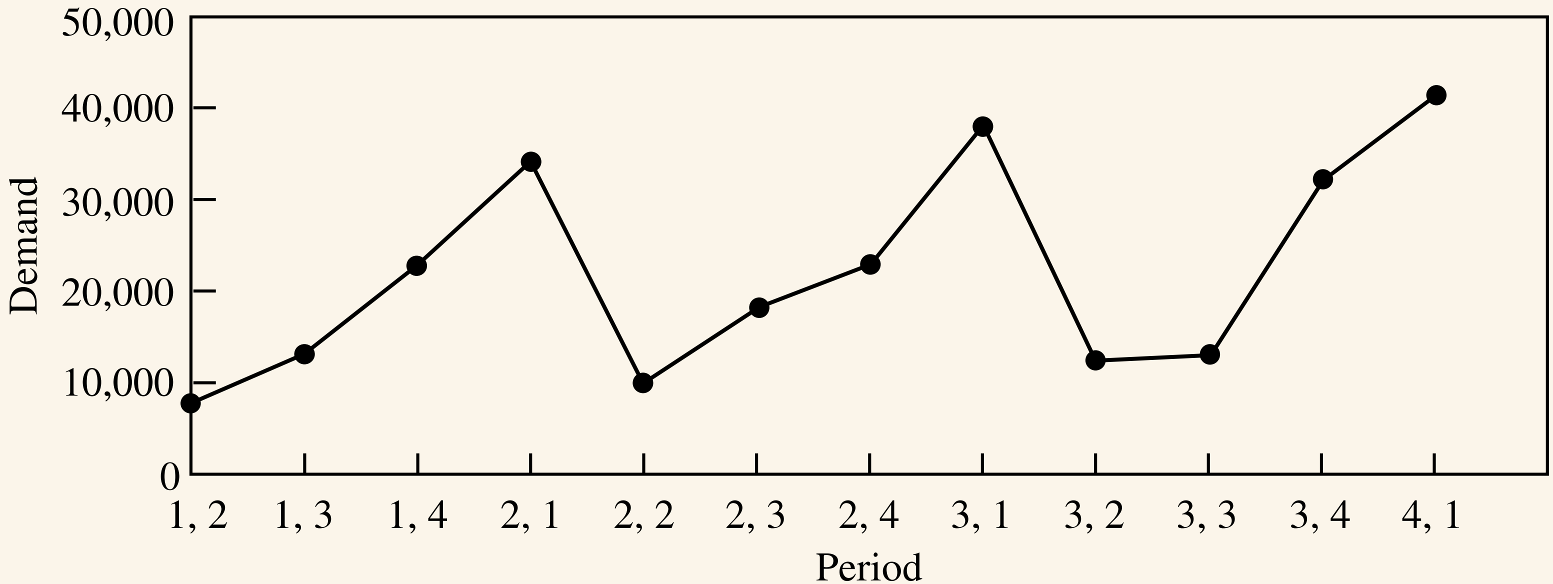

Figure 7-1

Estimate Level and Trend

Periodicity $p = 4$, $t = 3$

$$\bar{D}_t = \begin{cases} \left[D_{t-(p/2)} + D_{t+(p/2)} + \sum_{i=t+1-(p/2)}^{t-1+(p/2)} 2D_i \right] / (2p) & \text{for } p \text{ even} \\ \sum_{i=t-[(p-1)/2]}^{t+[(p-1)/2]} D_i / p & \text{for } p \text{ odd} \end{cases}$$

$$\bar{D}_t = \left[D_{t-(p/2)} + D_{t+(p/2)} + \sum_{i=t+1-(p/2)}^{t-1+(p/2)} 2D_i \right] / (2p)$$

$$= D_1 + D_5 + \sum_{i=2}^{4} 2D_i / 8$$

Tahoe Salt

	A	B	C
1	*Period* *t*	*Demand* D_t	*Deseasonalized Demand*
2	1	8,000	
3	2	13,000	
4	3	23,000	19,750
5	4	34,000	20,625
6	5	10,000	21,250
7	6	18,000	21,750
8	7	23,000	22,500
9	8	38,000	22,125
10	9	12,000	22,625
11	10	13,000	24,125
12	11	32,000	
13	12	41,000	

Cell	Cell Formula	Equation	Copied to
C4	=(B2+B6+2*SUM(B3:B5))/8	7.2	C5:C11

Figure 7-2

Tahoe Salt

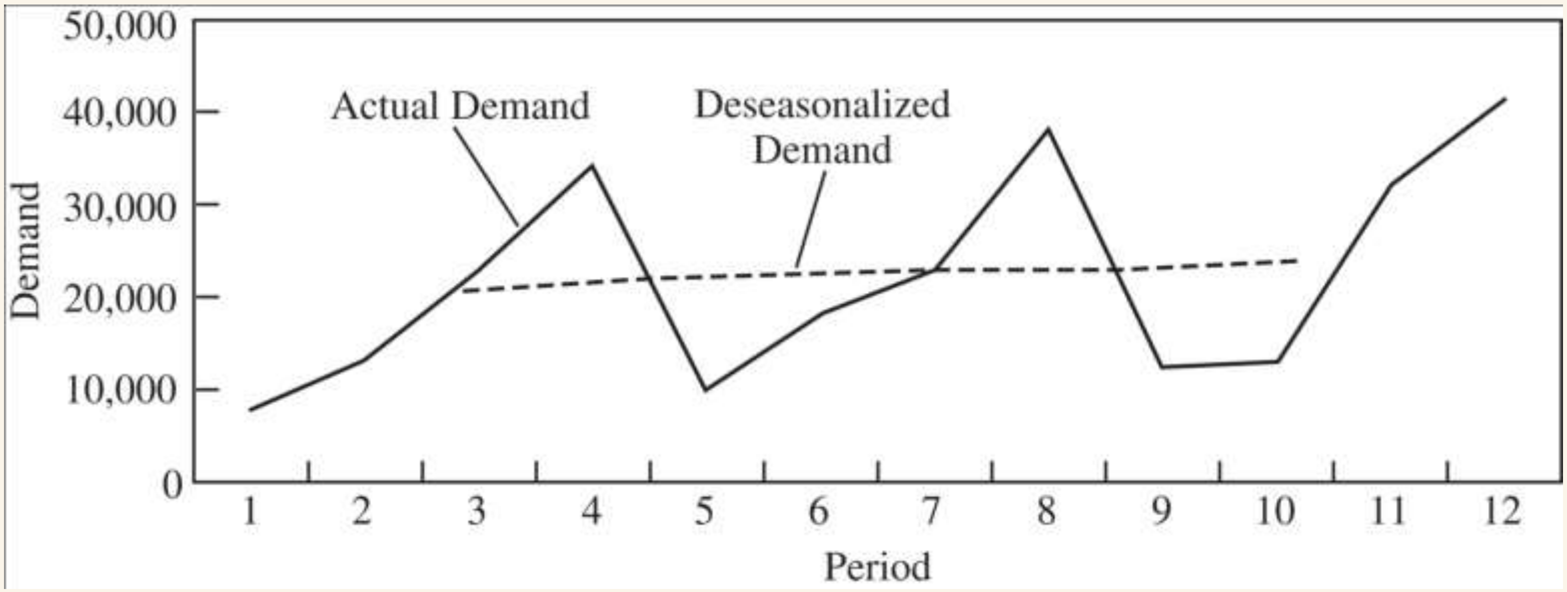

Figure 7-3

A linear relationship exists between the deseasonalized demand and time based on the change in demand over time

$$\bar{D}_t = L + T_t$$

Estimating Seasonal Factors

	A	B	C	D
1	Period t	Demand D_t	Deseasonalized Demand (Eqn 7.4) $\overline{D}_t$	Seasonal Factor (Eqn 7.5) $\overline{S}_t$
2	1	8,000	18,963	0.42
3	2	13,000	19,487	0.67
4	3	23,000	20,011	1.15
5	4	34,000	20,535	1.66
6	5	10,000	21,059	0.47
7	6	18,000	21,583	0.83
8	7	23,000	22,107	1.04
9	8	38,000	22,631	1.68
10	9	12,000	23,155	0.52
11	10	13,000	23,679	0.55
12	11	32,000	24,203	1.32
13	12	41,000	24,727	1.66

Cell	Cell Formula	Equation	Copied to
C2	=18439+A2*524	7.4	C3:C13
D2	=B2/C2	7.5	D3:D13

$$\overline{S}_t = \frac{D_i}{\overline{D}_t}$$

Figure 7-4

Estimating Seasonal Factors

$$S_i = \frac{\sum_{j=0}^{r-1} \bar{S}_{jp+1}}{r}$$

$$S_1 = (\bar{S}_1 + \bar{S}_5 + \bar{S}_9)/3 = (0.42 + 0.47 + 0.52)/3 = 0.47$$

$$S_2 = (\bar{S}_2 + \bar{S}_6 + \bar{S}_{10})/3 = (0.67 + 0.83 + 0.55)/3 = 0.68$$

$$S_3 = (\bar{S}_3 + \bar{S}_7 + \bar{S}_{11})/3 = (1.15 + 1.04 + 1.32)/3 = 1.17$$

$$S_4 = (\bar{S}_4 + \bar{S}_8 + \bar{S}_{12})/3 = (1.66 + 1.68 + 1.66)/3 = 1.67$$

$$F_{13} = (L + 13T)S_{13} = (18{,}439 + 13 \times 524)0.47 = 11{,}868$$

$$F_{14} = (L + 14T)S_{14} = (18{,}439 + 14 \times 524)0.68 = 17{,}527$$

$$F_{15} = (L + 15T)S_{15} = (18{,}439 + 15 \times 524)1.17 = 30{,}770$$

$$F_{16} = (L + 16T)S_{16} = (18{,}439 + 16 \times 524)1.67 = 44{,}794$$

Adaptive Forecasting

- The estimates of level, trend, and seasonality are adjusted after each demand observation
- Estimates incorporate all new data that are observed

Adaptive Forecasting

$$F_{t+1} = (L_t + lT_t)S_{t+1}$$

where

L_t = estimate of level at the end of Period t

T_t = estimate of trend at the end of Period t

S_t = estimate of seasonal factor for Period t

F_t = forecast of demand for Period t (made Period $t - 1$ or earlier)

D_t = actual demand observed in Period t

E_t = $F_t - D_t$ = forecast error in Period t

Steps in Adaptive Forecasting

- Initialize
  - Compute initial estimates of level *(L_0)*, trend *(T_0)*, and seasonal factors *($S_1, \ldots, S_p$)*
- Forecast
  - Forecast demand for period *($t + 1$)*
- Estimate error
  - Compute error $(E_{t+1}) = F_{t+1} - D_{t+1}$
- Modify estimates
  - Modify the estimates of level L_{t+1}, trend T_{t+1}, and seasonal factor S_{t+p+1}, given the error E_{t+1}

Moving Average

- Used when demand has no observable trend or seasonality
  - Systematic component of demand = level
- The level in period t is the average demand over the last N periods

$$L_t = (D_t + D_t\text{-}1 + \ldots + D_{t-N+1}) / N$$

$$F_{t+1} = L_t \text{ and } F_{t+n} = L_t$$

- After observing the demand for period t + 1, revise the estimates
  - $L_{t+1} = (D_{t+1} + D_t + \ldots + D_{t\text{-}N+2}) / N, F_{t+2} = L_{t+1}$

Moving Average Example

- A supermarket has experienced weekly demand of milk of D_1 = 120, D_2 = 127, D_3 = 114, and D_4 = 122 gallons over the past four weeks
  - Forecast demand for Period 5 using a four-period moving average
  - What is the forecast error if demand in Period 5 turns out to be 125 gallons?

Moving Average Example

$L_4 = (D_4 + D_3 + D_2 + D_1)/4$
$= (122 + 114 + 127 + 120)/4 = 120.75$

- Forecast demand for Period 5

  $F_5 = L_4 = 120.75$ gallons

- Error if demand in Period 5 = 125 gallons

  $E_5 = F_5 – D_5 = 125 – 120.75 = 4.25$

- Revised demand

  $L_5 = (D_5 + D_4 + D_3 + D_2)/4$
  $= (125 + 122 + 114 + 127)/4 = 122$

Simple Exponential Smoothing

- Used when demand has no observable trend or seasonality
  - Systematic component of demand = level

- Initial estimate of level, L_0, assumed to be the average of all historical data

Simple Exponential Smoothing

Given data for Periods 1 to n

$$L_0 = \frac{1}{n}\sum_{i=1}^{n} D_i$$

Current forecast

$$F_{t+1} = L_t \quad \text{and} \quad F_{t+n} = L_t$$

Revised forecast using smoothing constant 0 < α < 1

$$L_{t+1} = \alpha D_{t+1} + (1-\alpha)L_t$$

Thus

$$L_{t+1} = \sum_{n=0}^{t-1} \alpha(1-\alpha)^n D_{t+1-n} + (1-\alpha)^t D_1$$

Simple Exponential Smoothing

- **Supermarket data**

$$L_0 = \sum_{i=1}^{4} D_i / 4 = 120.75$$

$$F_1 = L_0 = 120.75$$

$$E_1 = F_1 - D_1 = 120.75 - 120 = 0.75$$

$$L_1 = \alpha D_1 + (1 - \alpha) L_0$$

$$= 0.1 \times 120 + 0.9 \times 120.75 = 120.68$$

Trend-Corrected Exponential Smoothing (Holt's Model)

- Appropriate when the demand is assumed to have a level and trend in the systematic component of demand but no seasonality
  - Systematic component of demand = level + trend

Trend-Corrected Exponential Smoothing (Holt's Model)

- Obtain initial estimate of level and trend by running a linear regression

$$D_t = a_t + b$$
$$T_0 = a, L_0 = b$$

- In Period t, the forecast for future periods is

$$F_{t+1} = L_t + T_t \text{ and } F_{t+n} = L_t + nT_t$$

- Revised estimates for Period t

$$L_{t+1} = \alpha D_{t+1} + (1 - \alpha)(L_t + T_t)$$
$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$

Trend-Corrected Exponential Smoothing (Holt's Model)

- MP3 player demand

$$D_1 = 8{,}415,\ D_2 = 8{,}732,\ D_3 = 9{,}014,$$
$$D_4 = 9{,}808,\ D_5 = 10{,}413,\ D_6 = 11{,}961$$
$$\alpha = 0.1,\ \beta = 0.2$$

- Using regression analysis

$$L_0 = 7{,}367 \text{ and } T_0 = 673$$

- Forecast for Period 1

$$F_1 = L_0 + T_0 = 7{,}367 + 673 = 8{,}040$$

Trend-Corrected Exponential Smoothing (Holt's Model)

- Revised estimate

  $L_1 = \alpha D_1 + (1 - \alpha)(L_0 + T_0)$

  $= 0.1 \times 8{,}415 + 0.9 \times 8{,}040 = 8{,}078$

  $T_1 = \beta(L_1 - L_0) + (1 - \beta)T_0$

  $= 0.2 \times (8{,}078 - 7{,}367) + 0.8 \times 673 = 681$

- With new L_1

  $F_2 = L_1 + T_1 = 8{,}078 + 681 = 8{,}759$

- Continuing

  $F_7 = L_6 + T_6 = 11{,}399 + 673 = 12{,}072$

Trend- and Seasonality-Corrected Exponential Smoothing

- Appropriate when the systematic component of demand is assumed to have a level, trend, and seasonal factor

Systematic component = (Level + Trend) x Seasonal factor

$$F_{t+1} = (L_t + T_t)S_{t+1} \text{ and } F_{t+l} = (L_t + lT_t)S_{t+l}$$

Trend- and Seasonality-Corrected Exponential Smoothing

- After observing demand for period (t + 1), revise estimates for level, trend, and seasonal factors

$$L_{t+1} = \alpha(D_{t+1}/S_{t+1}) + (1 - \alpha)(L_t + T_t)$$
$$T_{t+1} = \beta(L_{t+1} - L_t) + (1 - \beta)T_t$$
$$S_{t+p+1} = \gamma(D_{t+1}/L_{t+1}) + (1 - \gamma)S_{t+1}$$

Where,

- α = smoothing constant for level
- β = smoothing constant for trend
- γ = smoothing constant for seasonal factor

Winter's Model

$L_0 = 18{,}439, \;\; T_0 = 524$

$S_1 = 0.47,\ S_2 = 0.68,\ S_3 = 1.17,\ S_4 = 1.67$

$F_1 = (L_0 + T_0)S_1 = (18{,}439 + 524)(0.47) = 8{,}913$

The observed demand for Period 1, $D_1 = 8{,}000$

Forecast error for Period 1

$= E_1 = F_1 - D_1$

$= 8{,}913 - 8{,}000 = 913$

Winter's Model

- Assume $\alpha = 0.1$, $\beta = 0.2$, $\gamma = 0.1$; revise estimates for level and trend for period 1 and for seasonal factor for Period 5

  $L_1 = \alpha(D_1/S_1) + (1 - \alpha)(L_0 + T_0)$

  $= 0.1 \times (8{,}000/0.47) + 0.9 \times (18{,}439 + 524) = 18{,}769$

  $T_1 = \beta(L_1 - L_0) + (1 - \beta)T_0$

  $= 0.2 \times (18{,}769 - 18{,}439) + 0.8 \times 524 = 485$

  $S_5 = \gamma(D_1/L_1) + (1 - \gamma)S_1$

  $= 0.1 \times (8{,}000/18{,}769) + 0.9 \times 0.47 = 0.47$

  $F_2 = (L_1 + T_1)S_2 = (18{,}769 + 485)0.68 = 13{,}093$

Time Series Models

Forecasting Method	Applicability
Moving average	No trend or seasonality
Simple exponential smoothing	No trend or seasonality
Holt's model	Trend but no seasonality
Winter's model	Trend and seasonality

Measures of Forecast Error

$$E_t = F_t - D_t$$

$$MSE_n = \frac{1}{n}\sum_{t=1}^{n} E_t^2$$

$$MAPE_n = \frac{\sum_{t=1}^{n} \left|\frac{E_t}{D_t}\right| 100}{n}$$

$$A_t = \left|E_t\right| \qquad MAD_n = \frac{1}{n}\sum_{t=1}^{n} A_t$$

$$bias_n = \sum_{t=1}^{n} E_t$$

$$\sigma = 1.25 MAD$$

$$TS_t \frac{bias_t}{MAD_t}$$

Declining alpha $\qquad \alpha_t = \frac{\alpha_{t-1}}{\rho + \alpha_{t-1}} = \frac{1-\rho}{1-\rho^t}$

Selecting the Best Smoothing Constant

	A	B	C	D	E	F	G	H
1	Period t	Demand D_t	Level L_t	Forecast F_t	Error E_t	Squared Error	Absolute Errror A_t	% Error
2	0		2017.9					
3	1	2024	2021.2	2017.9	-6.1	37	6.1	0.3%
4	2	2076	2050.8	2021.2	-54.8	3003	54.8	2.6%
5	3	1992	2019.0	2050.8	58.8	3463	58.8	3.0%
6	4	2075	2049.3	2019.0	-56.0	3135	56.0	2.7%
7	5	2070	2060.5	2049.3	-20.7	429	20.7	1.0%
8	6	2046	2052.7	2060.5	14.5	210	14.5	0.7%
9	7	2027	2038.8	2052.7	25.7	658	25.7	1.3%
10	8	1972	2002.7	2038.8	66.8	4459	66.8	3.4%
11	9	1912	1953.6	2002.7	90.7	8218	90.7	4.7%
12	10	1985	1970.6	1953.6	-31.4	985	31.4	1.6%
13		2017.9			87	2,460	42.5	2.1%
14	α =	0.54						

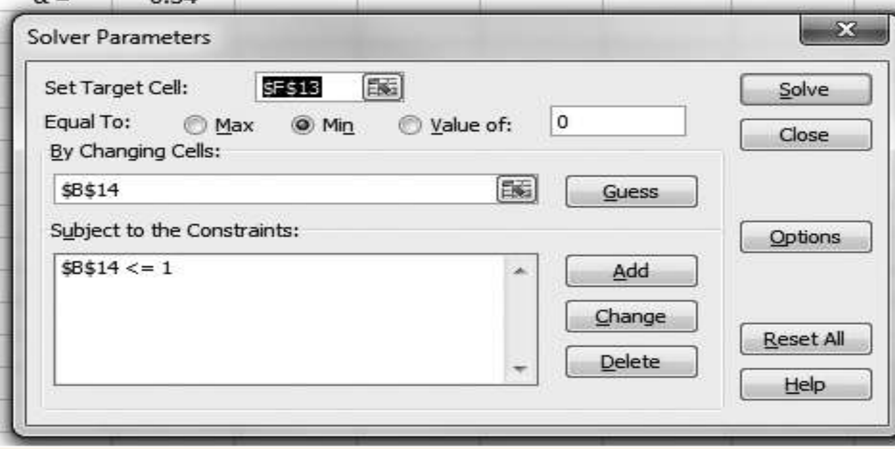

Figure 7-5

Selecting the Best Smoothing Constant

Period t	Demand D_t	Level L_t	Forecast F_t	Error E_t	Squared Error	Absolute Errror A_t	% Error
0		2017.9					
1	2024	2019.8	2017.9	-6.1	37	6.1	0.3%
2	2076	2037.8	2019.8	-56.2	3153	56.2	2.7%
3	1992	2023.2	2037.8	45.8	2097	45.8	2.3%
4	2075	2039.7	2023.2	-51.8	2687	51.8	2.5%
5	2070	2049.4	2039.7	-30.3	916	30.3	1.5%
6	2046	2048.3	2049.4	3.4	12	3.4	0.2%
7	2027	2041.5	2048.3	21.3	454	21.3	1.1%
8	1972	2019.3	2041.5	69.5	4831	69.5	3.5%
9	1912	1985.0	2019.3	107.3	11511	107.3	5.6%
10	1985	1985.0	1985.0	0.0	0	0.0	0.0%
	2017.9			103	2,570	39.2	2.0%
α =	0.32						

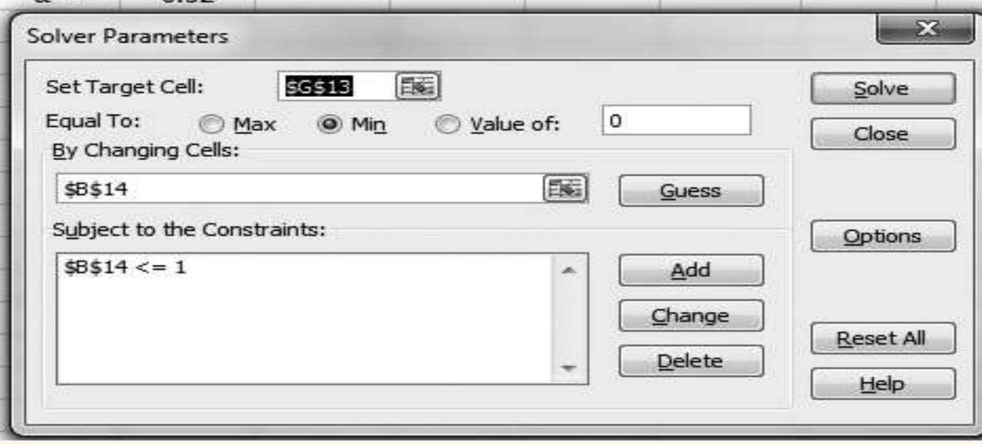

Figure 7-6

Forecasting Demand at Tahoe Salt

- Moving average
- Simple exponential smoothing
- Trend-corrected exponential smoothing
- Trend- and seasonality-corrected exponential smoothing

Forecasting Demand at Tahoe Salt

	A	B	C	D	E	F	G	H	I	J	K
1	Period t	Demand D_t	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Squared Error MSE_t	MAD_t	% Error	$MAPE_t$	TS_t
2	1	8,000									
3	2	13,000									
4	3	23,000									
5	4	34,000	19,500								
6	5	10,000	20,000	19,500	9,500	9,500	90,250,000	9,500	95	95	1.00
7	6	18,000	21,250	20,000	2,000	2,000	47,125,000	5,750	11	53	2.00
8	7	23,000	21,250	21,250	-1,750	1,750	32,437,500	4,417	8	38	2.21
9	8	38,000	22,250	21,250	-16,750	16,750	94,468,750	7,500	44	39	-0.93
10	9	12,000	22,750	22,250	10,250	10,250	96,587,500	8,050	85	49	0.40
11	10	13,000	21,500	22,750	9,750	9,750	96,333,333	8,333	75	53	1.56
12	11	32,000	23,750	21,500	-10,500	10,500	98,321,429	8,643	33	50	0.29
13	12	41,000	24,500	23,750	-17,250	17,250	123,226,563	9,719	42	49	-1.52

Cell	Cell Formula	Equation	Copied to
C5	=Average(B2:B5)	7.9	C6:C13
D6	=C5	7.10	D7:D13
E6	=D6-B6	7.8	E7:E13
F6	=Abs(E6)		F7:F13
G6	=Sumsq($E$6:E6)/(A6-4)	7.21	G7:G13
H6	=Sum($F$6:F6)/(A6-4)	7.22	H7:H13
I6	=100*(F6/B6)		I7:I13
J6	=Average($I$6:I6)	7.24	J7:J13
K6	=Sum($E$6:E6)/ H6	7.26	K7:K13

Figure 7-7

Forecasting Demand at Tahoe Salt

Moving average

$$L_{12} = 24{,}500$$

$$F_{13} = F_{14} = F_{15} = F_{16} = L_{12} = 24{,}500$$

$$\sigma = 1.25 \text{ x } 9{,}719 = 12{,}148$$

Forecasting Demand at Tahoe Salt

	A	B	C	D	E	F	G	H	I	J	K
1	Period t	Demand D_t	Level L_t	Forecast F_t	Error E_t	Absolute Error A_t	Mean Squared Error MSE_t	MAD_t	% Error	$MAPE_t$	TS_t
2	0		22,083								
3	1	8,000	20,675	22,083	14,083	14,083	198,340,278	14,083	176	176	1
4	2	13,000	19,908	20,675	7,675	7,675	128,622,951	10,879	59	118	2
5	3	23,000	20,217	19,908	-3,093	3,093	88,936,486	8,284	13	83	2
6	4	34,000	21,595	20,217	-13,783	13,783	114,196,860	9,659	41	72	0.51
7	5	10,000	20,436	21,595	11,595	11,595	118,246,641	10,046	116	81	1.64
8	6	18,000	20,192	20,436	2,436	2,436	99,527,532	8,777	14	70	2.15
9	7	23,000	20,473	20,192	-2,808	2,808	86,435,714	7,925	12	62	2.03
10	8	38,000	22,226	20,473	-17,527	17,527	114,031,550	9,125	46	60	-0.16
11	9	12,000	21,203	22,226	10,226	10,226	112,979,315	9,247	85	62	0.95
12	10	13,000	20,383	21,203	8,203	8,203	108,410,265	9,143	63	63	1.86
13	11	32,000	21,544	20,383	-11,617	11,617	110,824,074	9,368	36	60	0.58
14	12	41,000	23,490	21,544	-19,456	19,456	133,132,065	10,208	47	59	-1.38

Cell	Cell Formula	Equation	Copied to
C3	=0.1*B3+(1-0.1)*C2	7.13	C4:C14
D3	=C2	7.12	D4:D14
E3	=D3-B3	7.8	E4:E14
F3	=Abs(E3)		F4:F14
G3	=Sumsq($E$3:E3)/A3	7.21	G4:G14
H3	=Sum($G$3:G3)/A3	7.22	H4:H14
I3	=100*(F3/B3)		I4:I14
J3	=Average($I$3:I3)	7.24	J4:J14
K3	=Sum($F$3:F3)/H3	7.26	K4:K14

Figure 7-8

Forecasting Demand at Tahoe Salt

Single exponential smoothing

$$L_0 = 22{,}083$$

$$L_{12} = 23{,}490$$

$$F_{13} = F_{14} = F_{15} = F_{16} = L_{12} = 23{,}490$$

$$\sigma = 1.25 \times 10{,}208 = 12{,}761$$

Forecasting Demand at Tahoe Salt

	A	B	C	D	E	F	G	H	I	J	K	L
1	Period t	Demand D_t	Level L_t	Trend T_t	Forecast F_t	Error E_t	Absolute Error A_t	Mean Squared Error MSE_t	MAD_t	% Error	$MAPE_t$	TS_t
2	0		**12,015**	**1,549**								
3	1	8,000	13,008	1,438	13,564	5,564	5,564	30,958,096	5,564	70	70	1
4	2	13,000	14,301	1,409	14,445	1,445	1,445	16,523,523	3,505	11	40	2
5	3	23,000	16,439	1,555	15,710	-7,290	7,290	28,732,318	4,767	32	37	0
6	4	34,000	19,594	1,875	17,993	-16,007	16,007	85,603,146	7,577	47	39.86	-2.15
7	5	10,000	20,322	1,645	21,469	11,469	11,469	94,788,701	8,355	115	54.83	-0.58
8	6	18,000	21,570	1,566	21,967	3,967	3,967	81,613,705	7,624	22	49.36	-0.11
9	7	23,000	23,123	1,563	23,137	137	137	69,957,267	6,554	1	42.39	-0.11
10	8	38,000	26,018	1,830	24,686	-13,314	13,314	83,369,836	7,399	35	41.48	-1.90
11	9	12,000	26,262	1,513	27,847	15,847	15,847	102,010,079	8,338	132	51.54	0.22
12	10	13,000	26,298	1,217	27,775	14,775	14,775	113,639,348	8,981	114	57.75	1.85
13	11	32,000	27,963	1,307	27,515	-4,485	4,485	105,137,395	8,573	14	53.78	1.41
14	12	41,000	30,443	1,541	29,270	-11,730	11,730	107,841,864	8,836	29	51.68	0.04

Cell	Cell Formula	Equation	Copied to
C3	=0.1*B3+(1-0.1)*(C2+D2)	7.15	C4:C14
D3	=0.2(C3-C2)+(1-0.2)D2	7.16	D4:D14
E3	=C2+D2	7.14	E4:E14
F3	=E3-B3	7.8	F4:F14
G3	=Abs(F3)		G4:G14
H3	=Sumsq($F$3:F3)/A3	7.21	H4:H14
I3	=Sum($G$3:G3)/A3	7.22	I4:I14
J3	=100*(G3/B3)		J4:J14
K3	=Average($J$3:J3)	7.24	K4:K14
L3	=Sum($F$3:F3)/I3	7.26	L4:L14

Figure 7-9

Forecasting Demand at Tahoe Salt

Trend-Corrected Exponential Smoothing

$$L_0 = 12{,}015 \text{ and } T_0 = 1{,}549$$

$$L_{12} = 30{,}443 \text{ and } T_{12} = 1{,}541$$

$$F_{13} = L_{12} + T_{12} = 30{,}443 + 1{,}541 = 31{,}984$$

$$F_{14} = L_{12} + 2T_{12} = 30{,}443 + 2 \times 1{,}541 = 33{,}525$$

$$F_{15} = L_{12} + 3T_{12} = 30{,}443 + 3 \times 1{,}541 = 35{,}066$$

$$F_{16} = L_{12} + 4T_{12} = 30{,}443 + 4 \times 1{,}541 = 36{,}607$$

$$\sigma = 1.25 \times 8{,}836 = 11{,}045$$

Forecasting Demand at Tahoe Salt

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	*Period t*	Demand D_t	Level L_t	Trend T_t	Seasonal Factor S_t	Forecast F_t	Error E_t	Absolute Error A_t	Mean Squared Error MSE_t	MAD_t	% Error	$MAPE_t$	TS_t
2			**18,439**	**524**									
3	1	8,000	18,866	514	**0.47**	8,913	913	913	832,857	913	11	11.41	1.00
4	2	13,000	19,367	513	**0.68**	13,179	179	179	432,367	546	1	6.39	2.00
5	3	23,000	19,869	512	**1.17**	23,260	260	260	310,720	450	1	4.64	3.00
6	4	34,000	20,380	512	**1.67**	34,036	36	36	233,364	347	0	3.50	4.00
7	5	10,000	20,921	515	0.47	9,723	-277	277	202,036	333	3	3.36	3.34
8	6	18,000	21,689	540	0.68	14,558	-3,442	3,442	2,143,255	851	19	5.98	-2.74
9	7	23,000	22,102	527	1.17	25,981	2,981	2,981	3,106,508	1,155	13	6.98	0.56
10	8	38,000	22,636	528	1.67	37,787	-213	213	2,723,856	1,037	1	6.18	0.42
11	9	12,000	23,291	541	0.47	10,810	-1,190	1,190	2,578,653	1,054	10	6.59	-0.72
12	10	13,000	23,577	515	0.69	16,544	3,544	3,544	3,576,894	1,303	27	8.66	2.14
13	11	32,000	24,271	533	1.16	27,849	-4,151	4,151	4,818,258	1,562	13	9.05	-0.87
14	12	41,000	24,791	532	1.67	41,442	442	442	4,432,987	1,469	1	8.39	-0.63
15	13				0.47	11,940							
16	14				0.68	17,579							
17	15				1.17	30,930							
18	16				1.67	44,928							

Cell	Cell Formula	Equation	Copied to
C3	=0.05*(B3/E3)+(1-0.05)*(C2+D2)	7.18	C4:C14
D3	=0.1*(C3-C2)+(1-0.1)*D2	7.19	D4:D14
E7	=0.1*(B3/C3)+(1-0.1)*E3	7.20	E8:E18
F3	=(C2+D2)*E3	7.17	F4:F18
G3	=F3-B3	7.8	G4:G14
H3	=Abs(G3)		H4:H14
I3	=Sumsq($G$3:G3)/A3	7.21	I4:I14
J3	=Sum($H$3:H3)/A3	7.22	J4:J14
K3	=100*(H3/B3)		K4:K14
L3	=Average($K$3:K3)	7.24	L4:L14
M3	=Sum($G$3:G3)/J3	7.26	M4:M14

Figure 7-10

Forecasting Demand at Tahoe Salt

Trend- and Seasonality-Corrected

$$L_0 = 18{,}439 \quad T_0 = 524$$

$$S_1 = 0.47 \quad S_2 = 0.68 \quad S_3 = 1.17 \quad S_4 = 1.67$$

$$L_{12} = 24{,}791 \quad T_{12} = 532$$

$$F_{13} = (L_{12} + T_{12})S_{13} = (24{,}791 + 532)0.47 = 11{,}940$$

$$F_{14} = (L_{12} + 2T_{12})S_{13} = (24{,}791 + 2 \text{ x } 532)0.68 = 17{,}579$$

$$F_{15} = (L_{12} + 3T_{12})S_{13} = (24{,}791 + 3 \text{ x } 532)1.17 = 30{,}930$$

$$F_{16} = (L_{12} + 4T_{12})S_{13} = (24{,}791 + 4 \text{ x } 532)1.67 = 44{,}928$$

$$\sigma = 1.25 \text{ x } 1{,}469 = 1{,}836$$

Forecasting Demand at Tahoe Salt

Forecasting Method	MAD	MAPE (%)	TS Range
Four-period moving average	9,719	49	–1.52 to 2.21
Simple exponential smoothing	10,208	59	–1.38 to 2.15
Holt’s model	8,836	52	–2.15 to 2.00
Winter’s model	1,469	8	–2.74 to 4.00

Table 7-2

The Role of IT in Forecasting

- Forecasting module is core supply chain software
- Can be used to best determine forecasting methods for the firm and by product categories and markets
- Real time updates help firms respond quickly to changes in marketplace
- Facilitate demand planning

Risk Management

- Errors in forecasting can cause significant misallocation of resources in inventory, facilities, transportation, sourcing, pricing, and information management

- Common factors are long lead times, seasonality, short product life cycles, few customers and lumpy demand, and when orders placed by intermediaries in a supply chain

- Mitigation strategies – increasing the responsiveness of the supply chain and utilizing opportunities for pooling of demand

Forecasting in Practice

- Collaborate in building forecasts
- Share only the data that truly provide value
- Be sure to distinguish between demand and sales

Summary of Learning Objectives

- Understand the role of forecasting for both an enterprise and a supply chain
- Identify the components of a demand forecast
- Forecast demand in a supply chain given historical demand data using time-series methodologies
- Analyze demand forecasts to estimate forecast error