DEMAND FORECASTING IN A SUPPLY CHAIN

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

1. Forecasts are always inaccurate and should thus include both the expected value of the forecast and a measure of forecast error
2. Long-term forecasts are usually less accurate than short-term forecasts
3. Aggregate forecasts are usually more accurate than disaggregate forecasts
4. 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

1. Qualitative
   - Primarily subjective
   - Rely on judgment
2. Time Series
   - Use historical demand only
   - Best with stable demand
3. Causal
   - Relationship between demand and some other factor
4. 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

1. Understand the objective of forecasting.
2. Integrate demand planning and forecasting throughout the supply chain.
3. Identify the major factors that influence the demand forecast.
4. Forecast at the appropriate level of aggregation.
5. 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

Systematic component = (level + trend) ´ 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

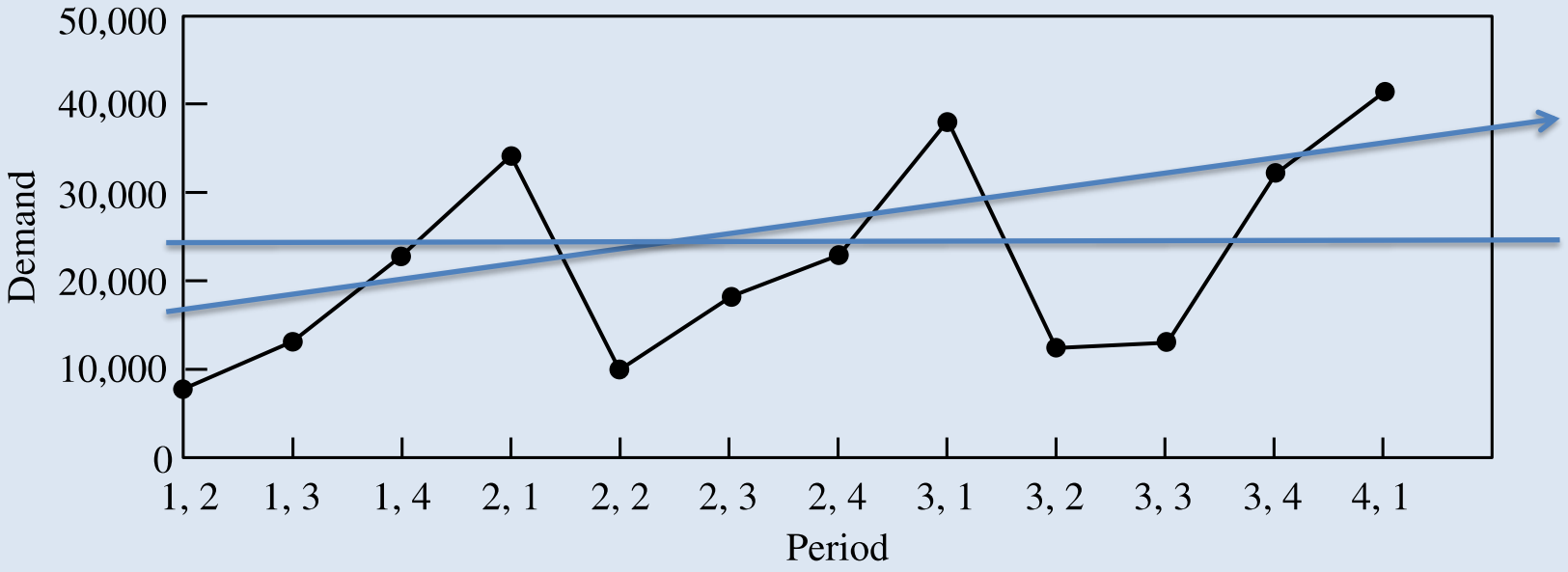

Figure 7-1

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,…,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

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

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

- After observing the demand for period $t + 1$, revise the estimates

  $$L_{t+1} = (D_{t+1} + D_t + \ldots + D_{t-N+2}) / N, \quad F_{t+2} = L_{t+1}$$

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

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

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

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

Measures of Forecast Error

$$E_t = F_t - D_t$$

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

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

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

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

$$s = 1.25MAD$$

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

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

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