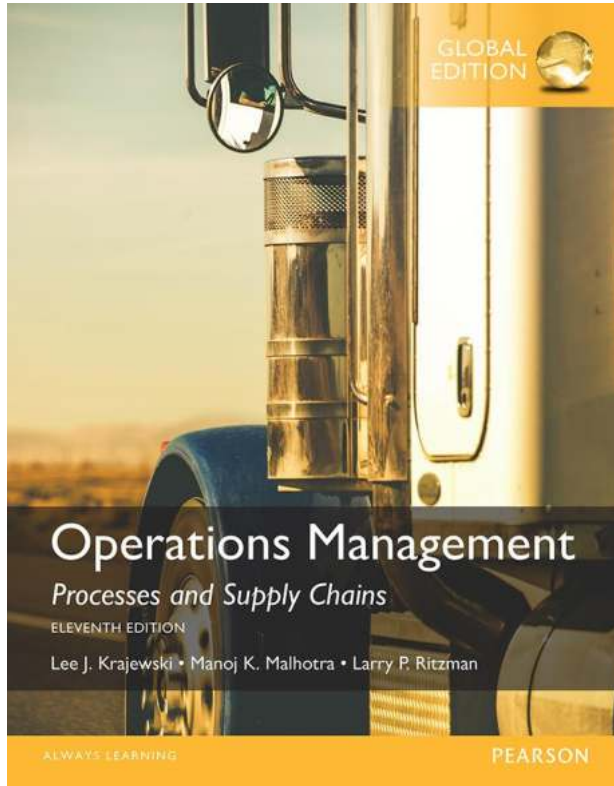


# 8

# MANAGING DEMAND AND FORECASTING



**PowerPoint Slides  
by Julius Bankole**

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# Forecasting

- **Forecast**
  - **A prediction of future events used for planning purposes**
- **Demand forecast**

# *Patterns of Demand*

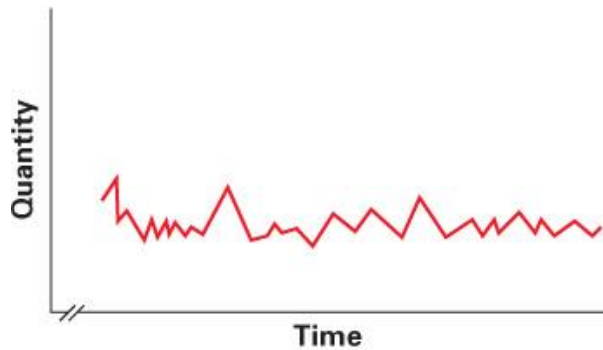
- 1. Horizontal**
- 2. Trend**
- 3. Seasonal**
- 4. Cyclical**
- 5. Random**

# Demand Patterns

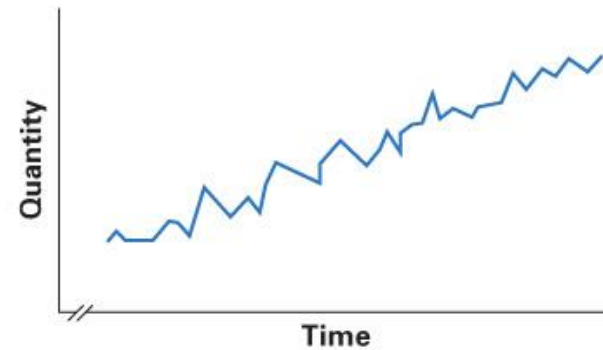
- There are five basic patterns of demand time series.
  1. **Horizontal.** The fluctuation of data around a constant mean
  2. **Trend.** The systematic increase or decrease in the mean of the series over time
  3. **Seasonal.** A repeatable pattern of increases or decreases in demand, depending on the time of day, week, month, or season
  4. **Cyclical.** The less predictable gradual increases or decreases over longer periods of time (years or decades)
  5. **Random.** The unforecastable variation in demand

# Demand Patterns

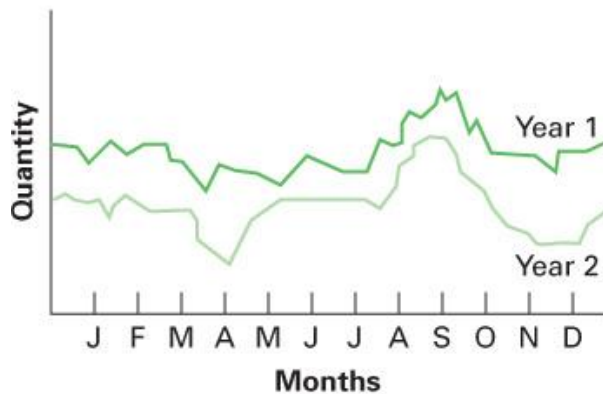
**FIGURE 10.1** *Patterns of Demand*



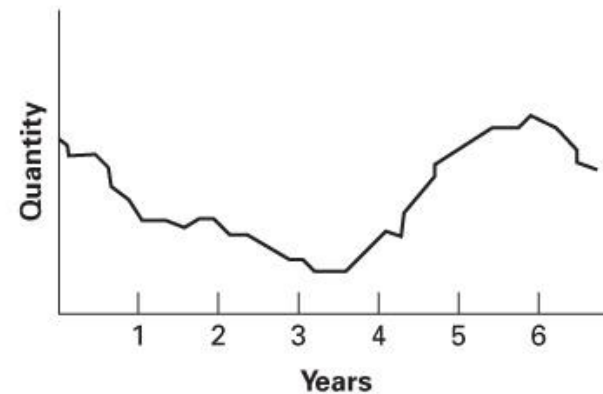
(a) Horizontal: Data cluster about a horizontal line.



(b) Trend: Data consistently increase or decrease.



(c) Seasonal: Data consistently show peaks and valleys.



(d) Cyclical: Data reveal gradual increases and decreases over extended periods of time.

# ***Managing Demand***

- **Matching supply to demand becomes a challenge when forecasts call for high variability in demand patterns**
- **Marketing and Operations managers can jointly influence demand through the following options:**
  - **Complementary Services and Products**
  - **Promotional Pricing**
  - **Prescheduled Appointments and Reservations**
  - **Revenue Management**
  - **Backlogs, Backorders and Stockouts**

# ***Managing Demand ... cont.***

- **Complementary Services and Products**
  - Produce complementary products or services that have similar resource requirements but different demand cycles
- **Promotional Pricing**
  - Promotional campaigns are designed to increase sales with creative pricing
- **Prescheduled Appointments and Reservations**
  - Service providers often can schedule customers for specific times

# ***Managing Demand ... cont.***

- **Revenue Management**

- **A specialized combination of the pricing and reservation options for service providers**

- **Backlogs, Backorders and Stockouts**

- **Backlog**

- **An accumulation of customer orders that a manufacturer has promised for delivery at some future date**

- **Backorder**

- **A customer order that cannot be filled when promised or demanded but is filled later**

- **Stockouts**

- **An order that is lost and causes the customer to go elsewhere**

# ***Designing the Forecasting System***

- **Before using forecasting techniques to predict the demand, a manager must make three decisions:**
  - **Organizational inputs**
  - **Deciding what to forecast**
  - **Choosing the type of forecasting method**

# *Organizational Inputs*

- **There are many inputs to the forecasting process** (history of past demand, sales-force estimates, market research studies, competitor behavior, etc.)
- **Collaborative planning, forecasting, and replenishment (CPFR)**
  - **An approach to forecasting that allows a manufacturer and its customers to work together to make and refine a forecast over the internet**

# ***Deciding What to Forecast***

- **Few companies err by more than 5 percent when forecasting total demand for all their services or products**
- **Errors in forecasts for individual items may be much higher**
- **Level of aggregation**
  - **The act of clustering several similar services or products so that companies can obtain more accurate forecasts**
- **Units of measurement**
  - **Forecasts of sales revenue are not helpful because prices fluctuate**
    - **Forecast the number of units of demand**
    - **If not possible, forecast the standard labor- or machine-hours required of each of the critical resources**

# Choosing the Type of Forecasting Technique

- **Judgment methods**

- A forecasting method that translates the opinions of managers, expert opinions, consumer surveys, and sales force estimates into quantitative estimates

- **Causal methods**

- A forecasting method that uses historical data on related variables, such as promotional campaigns, economic conditions, and competitors' actions, to predict demand

- **Time-series analysis**

- A statistical approach that relies heavily on historical demand data to project the future size of demand and recognizes trends and seasonal patterns

# ***Judgment Methods ... cont.***

- **Sales-force estimates**

- The forecasts that are compiled from estimates of future demands made periodically by members of a company's sales force

- **Executive opinion**

- A forecasting method in which the opinions, experience, and technical knowledge of one or more managers are summarized to arrive at a single forecast

- **Market research**

- A systematic approach to gathering market information to determine customer interest in a service or product, including surveys of potential customers

- **Delphi method**

- A process of gaining consensus from a group of experts while maintaining their anonymity

# *Commonly used Forecasting Methods*

- **Causal methods**

- **Used when historical data are available and the relationship between the factor to be forecasted and other external or internal factors can be identified**

# ***Causal Methods: Linear Regression***

- **Linear regression**

- A causal method in which one variable (the dependent variable) is related to one or more independent variables by a linear equation

- **Dependent variable**

- The variable that one wants to forecast

- **Independent variables**

- Variables that are assumed to affect the dependent variable and thereby “cause” the results observed in the past

# Linear Regression

- **Simplest linear regression model**
  - **Dependent variable function of only one independent variable**
  - **Theoretical relationship a straight line**

$$Y = a + bX$$

Y = Dependent variable

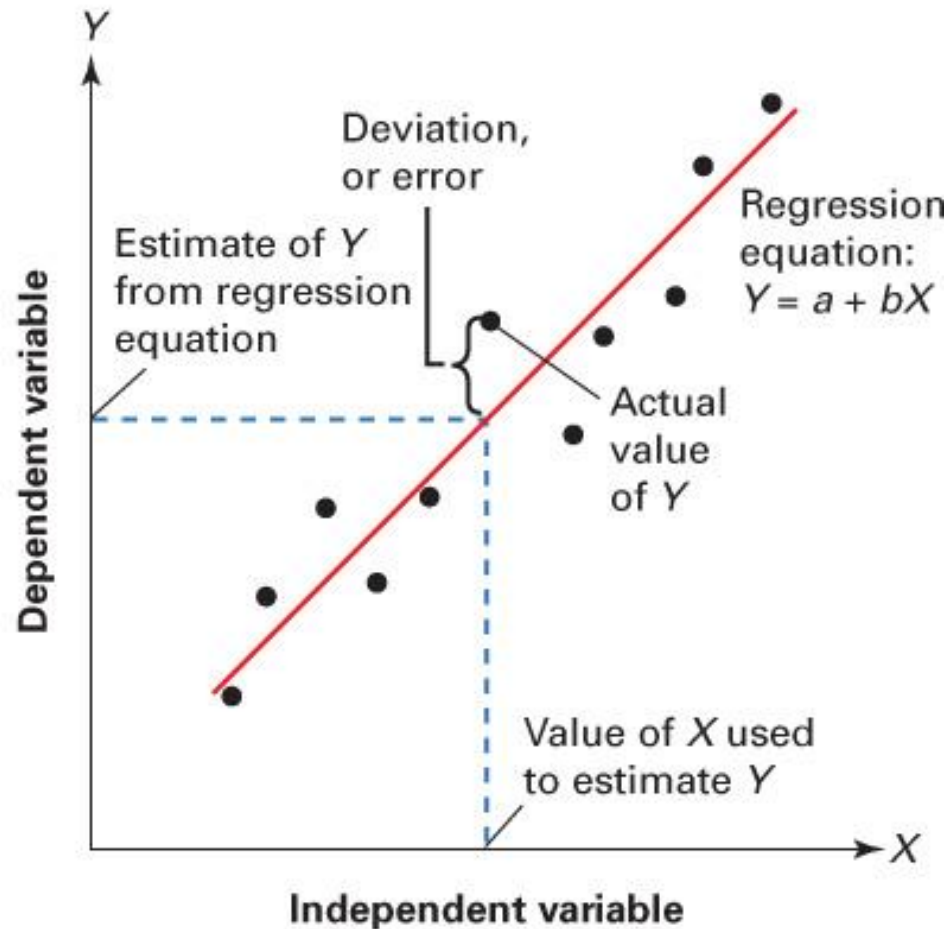
X = Independent variable

a = Y intercept of the line

b = slope of the line

# Linear Regression

**FIGURE 10.2** *Linear Regression Line Relative to Actual Data*



# *Linear Regression*

- **Sample correlation coefficient,  $r$** 
  - **Measures the direction and strength of the relationship between the independent and dependent variables**
  - **Value of  $r$  ranges from -1 to +1**
  - **Correlation of +1 indicates a strong relationship of the movements of the independent and dependent variables in the same direction**
  - **Correlation of -1 indicates that the two variables move in different directions**
  - **A zero  $r$  value indicates no relationship**
  - **Look for  $r$  value close to  $\pm 1$**

# *Linear Regression*

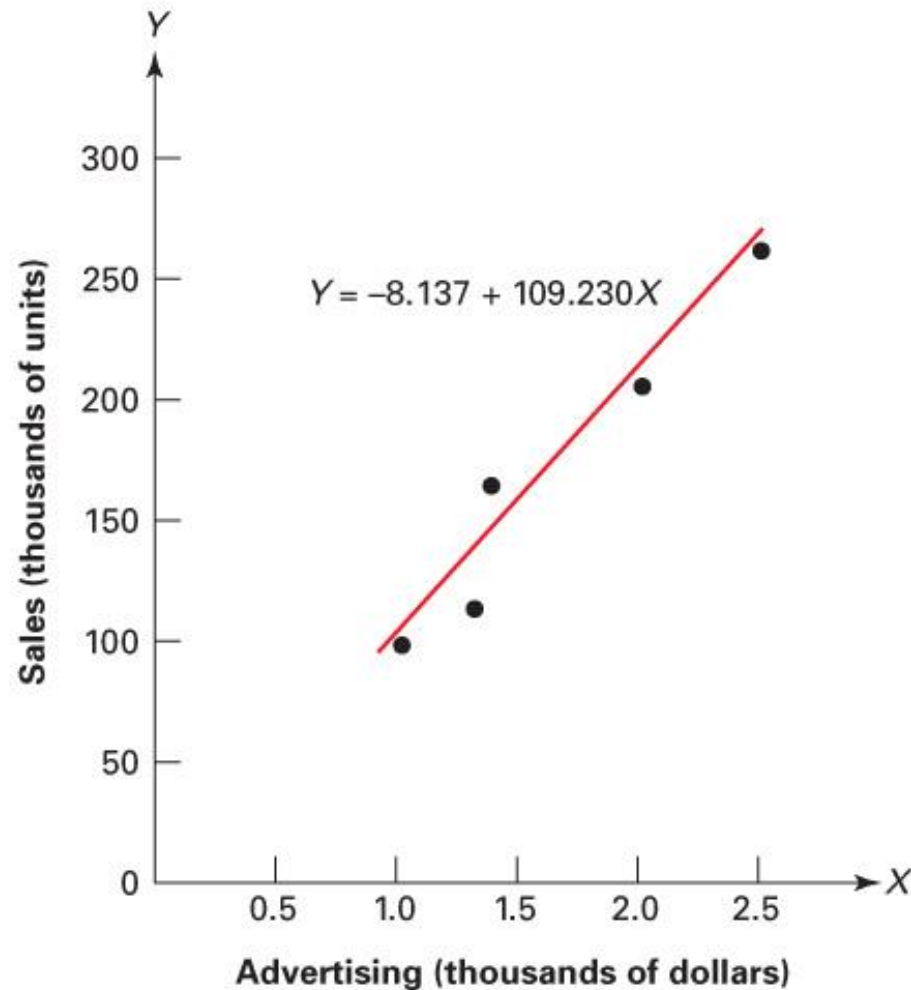
- **Sample coefficient of determination  $r^2$** 
  - **Measures the amount of variation in the dependent variable about its mean that is explained by the regression line**
  - **$r^2$  = square of correlation coefficient**
  - **Range 0 to 1**
  - **Higher values of  $r^2$  indicate more variance is explained and that the forecasts generated by the regression equation are closely related to the dependent variable**

# Linear Regression

- **Standard error of the estimate,  $s_{yx}$** 
  - **Measures how closely the data on the dependent variable cluster around the regression line**
  - **Measures the error from the dependent variable Y to the regression line rather than the mean**
  - **It is the standard deviation of the difference between the actual demand and the estimate provided by the regression equation**

# Linear Regression – Example 10.1

**FIGURE 10.3** *Linear Regression Line for Sales Data*



# *Time-Series Methods*

- Uses historical information regarding the **dependent** variable
- Identify underlying patterns of demand
- Key Assumption
  - Past patterns will continue in the future
- Develop a model to replicate it

# Time Series Methods

- **Naive forecast**

- A time-series method whereby the forecast for the next period equals the demand for the current period, or *Forecast* =  $D_t$

- **Simple moving average method**

- A time-series method used to estimate the average of a demand time series by averaging the demand for the  $n$  most recent time periods
  - It removes the effects of random fluctuation and is most useful when demand has no pronounced trend or seasonal influences

$$F_{t+1} = \frac{\text{Sum of last } n \text{ demands}}{n} = \frac{D_t + D_{t-1} + D_{t-2} + \dots + D_{t-n+1}}{n}$$

# ***Moving Average Method – Example 10.2***

**a.** Compute a three-week moving average forecast for the arrival of medical clinic patients in week 4.

The numbers of arrivals for the past 3 weeks were:

<b>Week</b>	<b>Patient Arrivals</b>
<b>1</b>	<b>400</b>
<b>2</b>	<b>380</b>
<b>3</b>	<b>411</b>

**b.** If the actual number of patient arrivals in week 4 is 415, what is the forecast error for week 4?

**c.** What is the forecast for week 5?

# Time Series Methods – Simple Moving Averages

<u>Week</u>	<u>Patient Arrivals</u>
1	400
2	380
3	411

$$F_4 = 397.0 = \frac{400 + 380 + 411}{3}$$

# Time Series Methods – Simple Moving Averages

<u>Week</u>	<u>Patient Arrivals</u>
2	380
3	411
4	415

$$F_5 = \frac{380 + 411 + 415}{3}$$

$$F_5 = 402.0$$

# ***Weighted Moving Average Method***

- **A time-series method in which each historical demand in the average can have its own weight; the sum of the weights equals 1.0**

# Exponential Smoothing Method

- A sophisticated weighted moving average method that calculates the average of a time series by giving recent demands more weight than earlier demands

$$\begin{aligned} F_{t+1} &= \alpha(\text{Demand this period}) + (1 - \alpha)(\text{Forecast calculated last period}) \\ &= \alpha D_t + (1 - \alpha)F_t \end{aligned}$$

or an equivalent equation:  $F_{t+1} = F_t + \alpha (D_t - F_t)$

where alpha ( $\alpha$ ) is a smoothing parameter with a value between 0 and 1.0

Exponential smoothing is the most frequently used formal forecasting method because of its simplicity and the small amount of data needed to support it

# Exponential Smoothing – Example 10.3

Reconsider the medical clinic patient arrival data.

It is now the end of week 3.

- a. Using  $\alpha = 0.10$ , calculate the exponential smoothing forecast for week 4

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

$$F_4 = 0.10(411) + 0.90(390) = 392.1$$

- b. What is the forecast error for week 4 demand turned out to be 415?

$$E_4 = 415 - 392 = 23$$

- c. What is the forecast for week 5?

$$F_5 = 0.10(415) + 0.90(392.1) = 394.4$$

Week	Arrivals
1	400
2	380
3	411
4	415
5	?

Start with average of first two weeks =  $(490+380)/2 = 390$

# ***Trend Adjusted Exponential Smoothing***

- A **trend** in a time series is a systematic increase or decrease in the average of the series over time
  - Where a significant trend is present, exponential smoothing approaches must be modified; otherwise, the forecasts tend to be below or above the actual demand
- **Trend-adjusted exponential smoothing method**
  - The method for incorporating a trend in an exponentially smoothed forecast
    - With this approach, the estimates for both the average and the trend are smoothed, requiring two smoothing constants
    - For each period, we calculate the average and the trend

# Trend Adjusted Exponential Smoothing Formula

$$F_{t+1} = A_t + T_t$$

where  $A_t = \alpha D_t + (1 - \alpha)(A_{t-1} + T_{t-1})$

$$T_t = \beta (A_t - A_{t-1}) + (1 - \beta)T_{t-1}$$

$A_t$  = exponentially smoothed average of the *series* in period  $t$

$T_t$  = exponentially smoothed average of the *trend* in period  $t$

$\alpha$  = smoothing parameter for the average, between 0 to 1

$\beta$  = smoothing parameter for the trend, between 0 and 1

$D_t$  = demand for period  $t$

$F_{t+1}$  = forecast for period  $t + 1$

# Seasonal Patterns

- Seasonal patterns are regularly repeated upward or downward movements in demand measured in periods of less than one year
- An easy way to account for seasonal effects is to use one of the techniques already described but to limit the data in the time series to those time periods in the same season
- If the weighted moving average method is used, high weights are placed on prior periods belonging to the same season
  - **Multiplicative seasonal method** is a method whereby seasonal factors are multiplied by an estimate of average demand to arrive at a seasonal forecast
  - **Additive seasonal method** is a method whereby seasonal forecasts are generated by adding a constant to the estimate of the average demand per season

# Multiplicative Seasonal Method

- **Step 1:** For each year, calculate the average demand for each season by dividing annual demand by the number of seasons per year
- **Step 2:** For each year, divide the actual demand for each season by the average demand per season, resulting in a **seasonal index** for each season of the year, indicating the level of demand relative to the average demand
- **Step 3:** Calculate the average seasonal index for each season using the results from Step 2. Add the seasonal indices for each season and divide by the number of years of data
- **Step 4:** Calculate each season's forecast for next year

# ***Multiplicative Seasonal Method***

- **The Northville Post Office experiences a seasonal pattern of daily mail volume every week. The following data for two representative weeks are expressed in thousands of pieces of mail.**
  - a) Calculate a seasonal factor for each day of the week.**
  - b) If the postmaster estimates that there will be 230,000 pieces of mail to sort next week, forecast the volume for each day of the week.**

# ***Multiplicative Seasonal Method***

<b>DAY</b>	<b>WEEK 1</b>	<b>WEEK 2</b>
Sunday	5	8
Monday	20	15
Tuesday	30	32
Wednesday	35	30
Thursday	49	45
Friday	70	70
Saturday	15	10
Total	224	210

# Forecast Error

- **Forecasts almost always contains errors**
  - **Eliminating all forecasting errors is impossible**
- **Bias errors**
  - **Consistent mistakes too low or too high**
  - **Often result of neglecting or not accurately estimating patterns of demand such as trends, seasonal, or cyclical patterns**
- **Random errors**
  - **Unpredictable factors cause forecast to deviate from the actual demand**

# Measures of Forecast Error

- **Cumulative sum of forecast errors (CFE):** measurement of the total forecast error that assesses the bias in a forecast  $CFE = \sum E_t$
- **Mean squared error (MSE)** A measurement of the dispersion of forecast errors  $MSE = \frac{\sum E_t^2}{n}$
- **Mean absolute deviation (MAD)** A measurement of the dispersion of forecast errors  $MAD = \frac{\sum |E_t|}{n}$
- **Standard deviation ( $\sigma$ )** A measurement of the dispersion of forecast errors  $\sigma = \sqrt{\frac{\sum (E_t - \bar{E})^2}{n - 1}}$

# Measures of Forecast Error

- **Mean absolute percent error (MAPE)** A measurement that relates the forecast error to the level of demand expressed as a percentage

$$\text{MAPE} = \frac{\sum[|E_t| / D_t](100)}{n}$$

- **Forecast error**

The difference found by subtracting the forecast from actual demand for a given period

$$E_t = D_t - F_t$$

# Calculating Forecast Error Measures

## – Example 10.4

Example 8.4

Month, $t$	Demand, $D_t$	Forecast, $F_t$	Error, $E_t$	Error Squared, $E_t^2$	Absolute Error, $ E_t $	Absolute Percent Error, $( E_t /D_t)(100)$
1	200	225	-25	625	25	12.5%
2	240	220	20	400	20	8.3
3	300	285	15	225	15	5.0
4	270	290	-20	400	20	7.4
5	230	250	-20	400	20	8.7
6	260	240	20	400	20	7.7
7	210	250	-40	1600	40	19.0
8	275	240	35	1225	35	12.7
<b>Total</b>			<b>-15</b>	<b>5275</b>	<b>195</b>	<b>81.3%</b>

# Calculating Forecast Error Measures – Example 10.4

## Measures of Error

$$\text{CFE} = -15$$

$$\bar{E} = \frac{-15}{8} = -1.875$$

$$\text{MSE} = \frac{5275}{8} = 659.4$$

$$\sigma = 27.4$$

$$\text{MAD} = \frac{195}{8} = 24.4$$

$$\text{MAPE} = \frac{81.3\%}{8} = 10.2\%$$

Error, $E_t$	Error Squared, $E_t^2$	Absolute Error, $ E_t $	Absolute Percent Error, $( E_t /D_t)(100)$
-25	625	25	12.5%
20	400	20	8.3
15	225	15	5.0
-20	400	20	7.4
-20	400	20	8.7
20	400	20	7.7
-40	1600	40	19.0
35	1225	35	12.7
-15	5275	195	81.3%

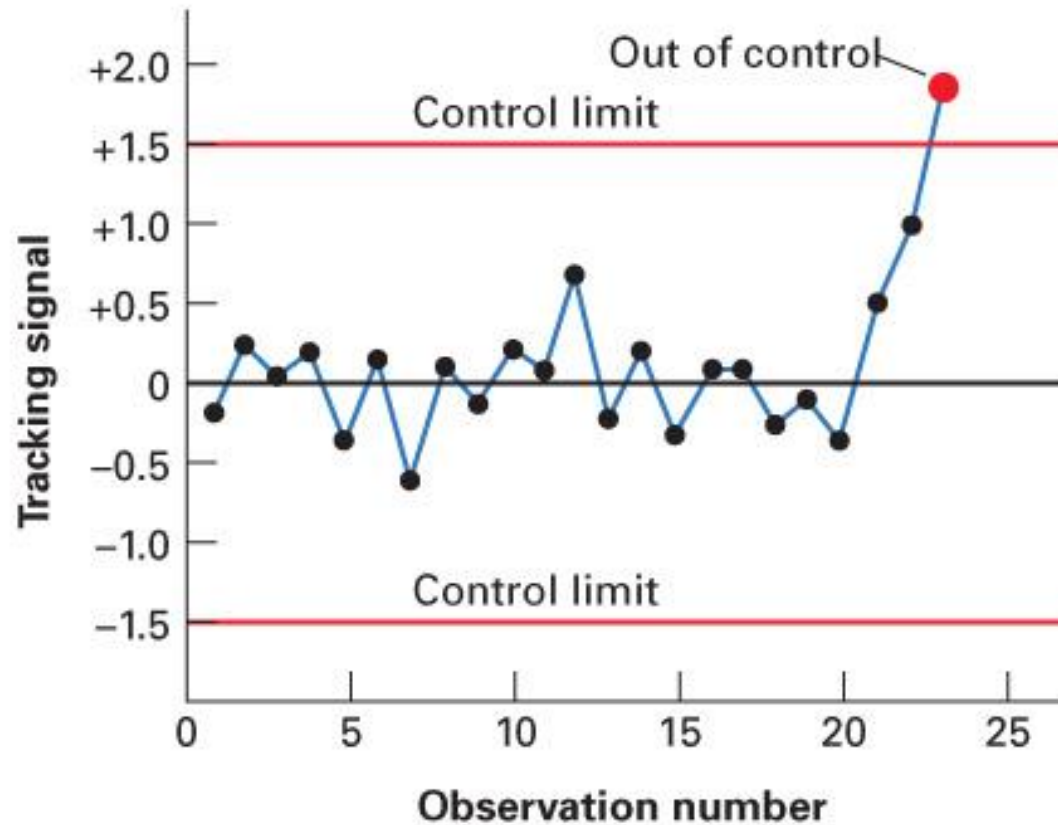
# Choosing a Method – Tracking Signals

- **Tracking signal:**
  - A measure that indicates whether a method of forecasting is accurately predicting actual changes in demand

$$\text{Tracking signal} = \frac{\text{CFE}}{\text{MAD}}$$

# Choosing a Method – Tracking Signals

FIGURE 10.5 *Tracking Signal*



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# Criteria for Selecting Time-Series Methods

- Forecast error measures provide important information for choosing the best forecasting method for a product or service
- They also guide managers in selecting the best values for the parameters needed for the method:
  - $n$  for the moving average method, the **weights** for the weighted moving average method, and  $\alpha$  for exponential smoothing
- The criteria to use in making forecast method and parameter choices include
  1. minimizing bias
  2. minimizing MAPE, MAD, or MSE
  3. meeting managerial expectations of changes in the components of demand
  4. minimizing the forecast error last period

# *Using Multiple Techniques*

- **Research during the last two decades suggests that combining forecasts from multiple sources often produces more accurate forecasts**
- **Combination forecasts**
  - **Forecasts that are produced by averaging independent forecasts based on different methods or different data or both**
- **Focus forecasting**
  - **A method of forecasting that selects the best forecast from a group of forecasts generated by individual techniques**
  - **The forecasts are compared to actual demand, and the method that produces the forecast with the least error is used to make the forecast for the next period. The method used for each item may change from period to period**