Chapter 12

Forecasting

Russell and Taylor

Operations and Supply Chain Management,
8th Edition

Lecture Outline

- Strategic Role of Forecasting in Supply Chain Management
- Components of Forecasting Demand
- Time Series Methods
- Forecast Accuracy
- Time Series Forecasting Using Excel
- Regression Methods

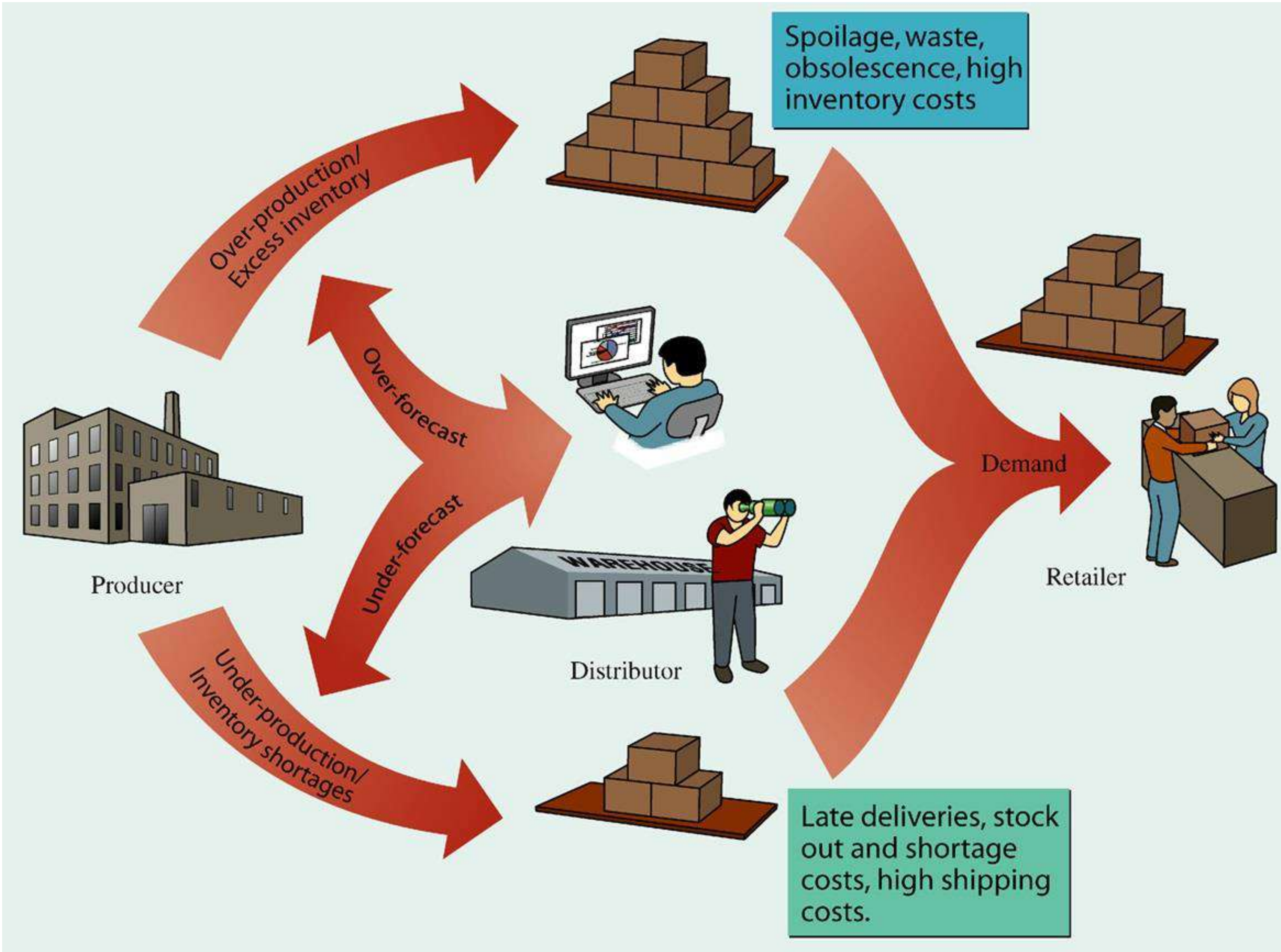
Forecasting

- Predicting the future
- Qualitative forecast methods
  - subjective
- Quantitative forecast methods
  - based on mathematical formulas

Strategic Role of Forecasting in Supply Chain Management

- Accurate forecasting determines inventory levels in the supply chain
- Continuous replenishment
  - supplier & customer share continuously updated data
  - typically managed by the supplier
  - reduces inventory for the company
  - speeds customer delivery
- Variations of continuous replenishment
  - quick response—the way retailers accommodate ‘fads’
  - JIT (just-in-time)
  - VMI (vendor-managed inventory)
  - stockless inventory
    - THESE SYSTEMS RELY HEAVILY ON ACCURATE SHORT-TERM FORECASTS

The Effect of Inaccurate Forecasting



Forecasting

- Quality Management
  - Accurately forecasting customer demand is a key to providing good quality service
- Strategic Planning
  - Successful strategic planning requires accurate forecasts of future products and markets

Components of Forecasting Demand

- Time frame
- Demand behavior
- Causes of behavior

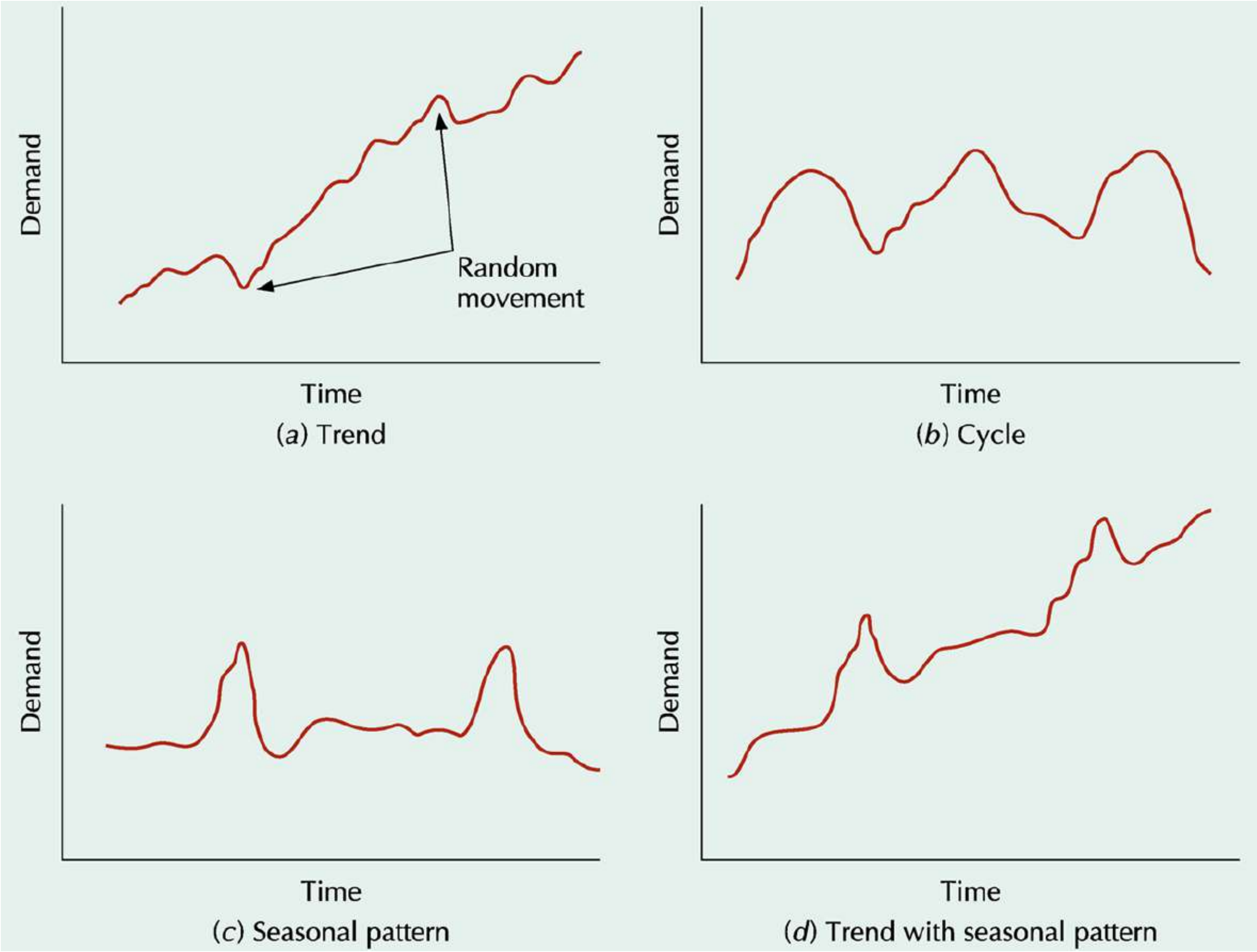
Time Frame

- Indicates how far into the future is forecast
  - Short-range forecast
    - typically encompasses the immediate future up to six months
    - Use for detailed scheduling of goods and services
  - Medium-range forecast
    - Six months to two years
    - 18 months is a typical medium-range forecast
    - Addresses aggregate planning—what HR, what inventory, what technology
  - Long-range forecast
    - usually encompasses a period of time longer than two years out to say 50 years with 5 years being a typical long-range forecast
    - Used to make capital investment decisions—what facilities located where, by when?

Demand Behavior

- Trend
  - a gradual, long-term up or down movement of demand
- Random variations
  - movements in demand that do not follow a pattern
- Cycle
  - an up-and-down repetitive movement in demand
- Seasonal pattern
  - an up-and-down repetitive movement in demand occurring periodically

Forms of Forecast Movement



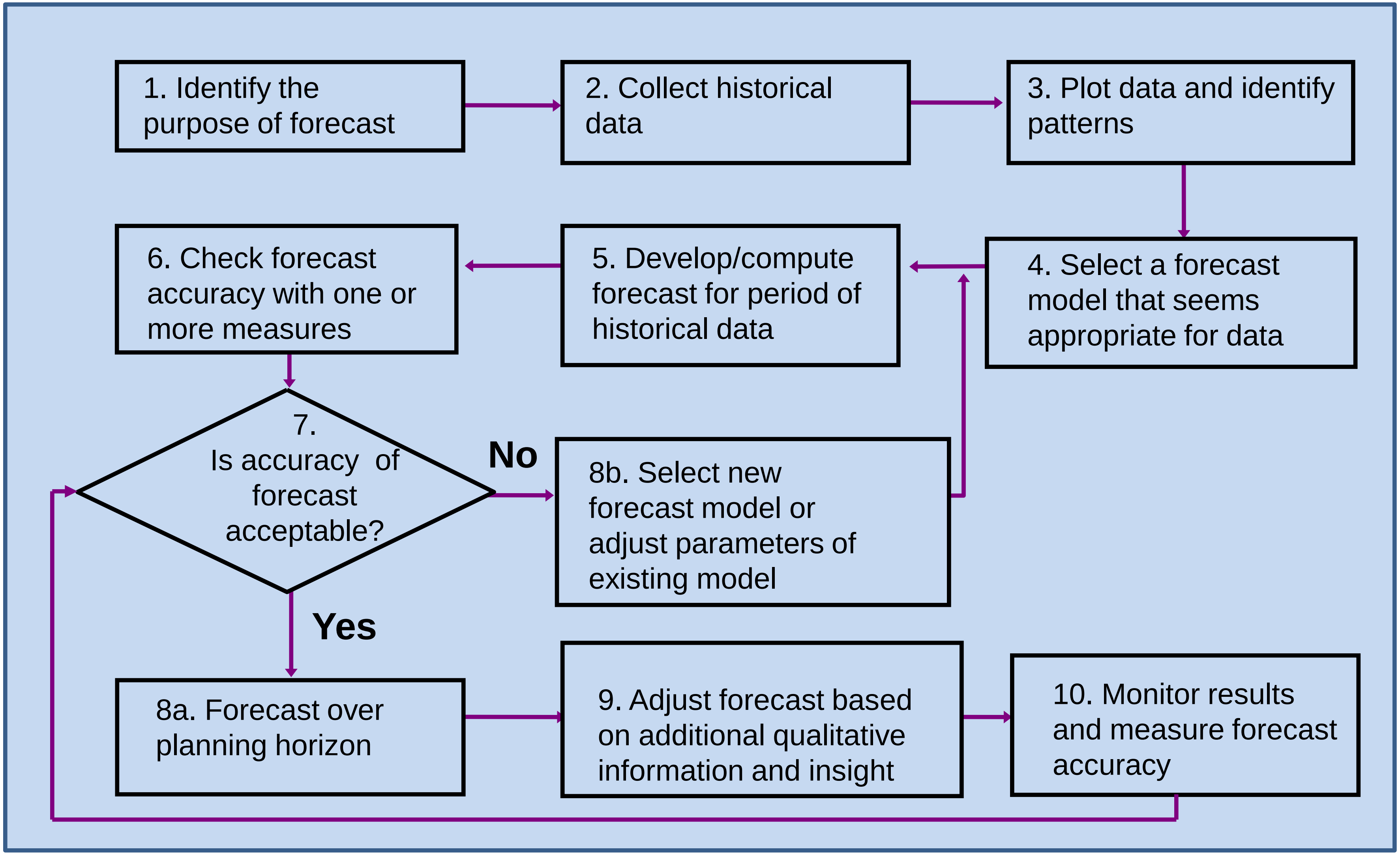
Forecasting Methods

- Time series
  - statistical techniques that use historical demand data to predict future demand
- Regression methods
  - attempt to develop a mathematical relationship between demand and factors that cause its behavior
- Qualitative
  - use management judgment, expertise, and opinion to predict future demand

Qualitative Methods

- Management, marketing, purchasing, and engineering are sources for internal qualitative forecasts
- Delphi method
  - involves soliciting forecasts about technological advances from experts

Forecasting Process



Time Series

- Time is often the independent variable in forecasting
- Assumes that what has occurred in the past will continue to occur in the future
- Relate the forecast to only one factor - time
- Include
  - naïve forecast
  - moving average
  - exponential smoothing
  - linear trend line

Moving Average

- *Naive* forecast
  - demand in current period is used as next period's forecast
- Simple moving average
  - uses average demand for a fixed sequence of periods
  - good for stable demand with no pronounced behavioral patterns
- Weighted moving average
  - weights are assigned to most recent data

Moving Average: Naïve Approach

MONTH	ORDERS PER MONTH	FORECAST
Jan	120	-
Feb	90	120
Mar	100	90
Apr	75	100
May	110	75
June	50	110
July	75	50
Aug	130	75
Sept	110	130
Oct	90	110
Nov	-	90

Simple Moving Average

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

where

n = number of periods in the moving average

D_i = demand in period i

3-month Simple Moving Average

MONTH	ORDERS PER MONTH	MOVING AVERAGE
Jan	120	–
Feb	90	–
Mar	100	–
Apr	75	103.3
May	110	88.3
June	50	95.0
July	75	78.3
Aug	130	78.3
Sept	110	85.0
Oct	90	105.0
Nov	-	110.0

$$MA_3 = \frac{\sum_{i=1}^{3} D_i}{3}$$

$$= \frac{90 + 110 + 130}{3}$$

= 110 orders for Nov

5-month Simple Moving Average

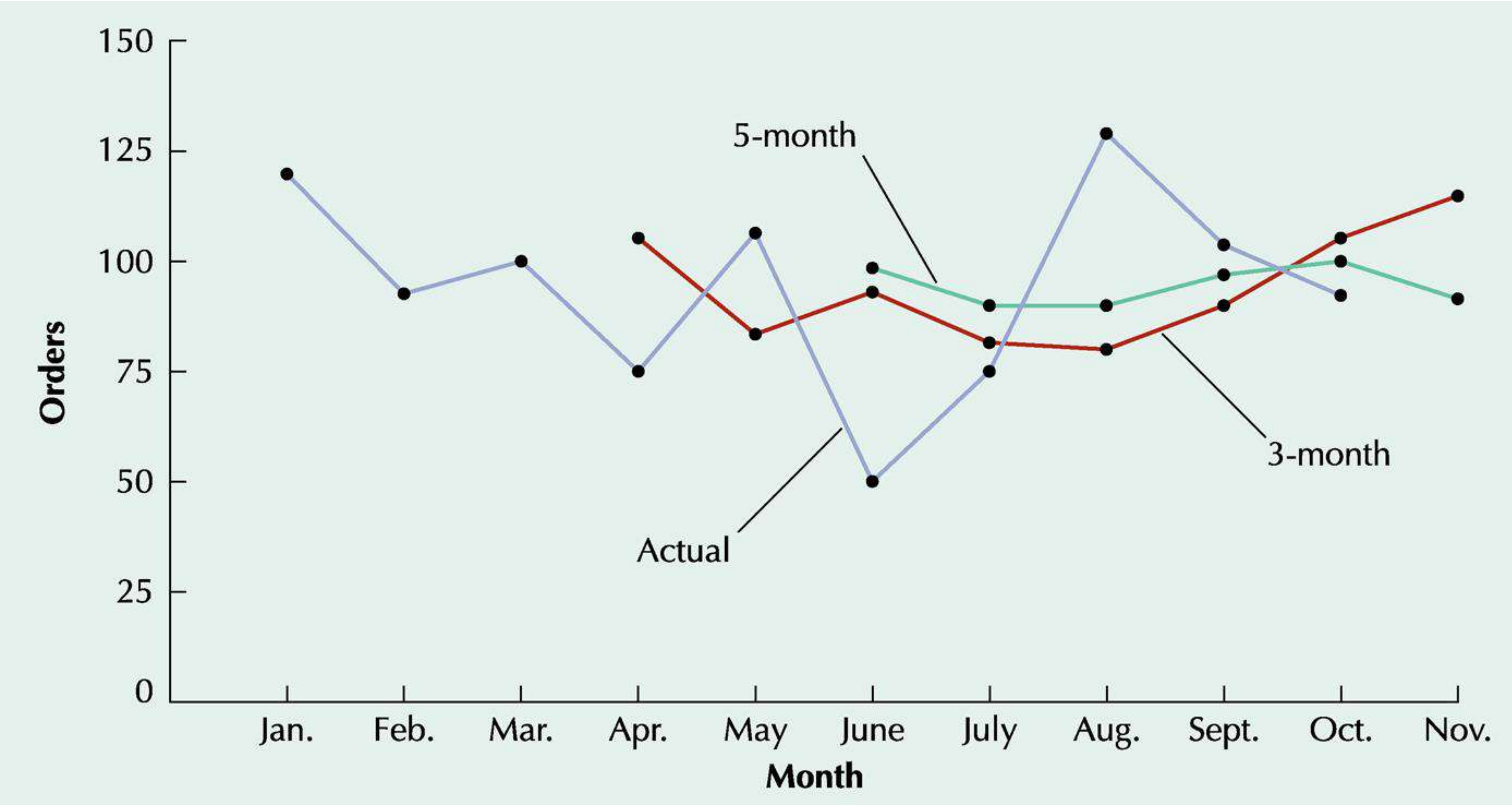
MONTH	ORDERS PER MONTH	MOVING AVERAGE
Jan	120	–
Feb	90	–
Mar	100	–
Apr	75	–
May	110	–
June	50	99.0
July	75	85.0
Aug	130	82.0
Sept	110	88.0
Oct	90	95.0
Nov	-	91.0

$$MA_5 = \frac{\sum_{i=1}^{5} D_i}{5}$$

$$= \frac{90 + 110 + 130+75+50}{5}$$

= 91 orders for Nov

Smoothing Effects



Weighted Moving Average

- Adjusts moving average method to more closely reflect data fluctuations

$$WMA_n = \sum_{i=1}^{n} W_i D_i$$

where

W_i = the weight for period i, between 0 and 100 percent

$$\sum W_i = 1.00$$

Weighted Moving Average Example

MONTH	*WEIGHT*	*DATA*
August	17%	130
September	33%	110
October	50%	90

November Forecast $$WMA_3 = \sum_{i=1}^{3} W_i D_i$$

$$= (0.50)(90) + (0.33)(110) + (0.17)(130)$$

$$= 103.4 \text{ orders}$$

Exponential Smoothing

- Averaging method
- Weights most recent data more strongly
- Reacts more to recent changes
- Widely used, accurate method
- Smoothing constant, α
    - applied to most recent data

Exponential Smoothing

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

where:

F_{t+1} = forecast for next period

D_t = actual demand for present period

F_t = previously determined forecast for present period

α = weighting factor, smoothing constant

Effect of Smoothing Constant

$$0.0 \le \alpha \le 1.0$$

If $\alpha = 0.20$, then $F_{t+1} = 0.20\, D_t + 0.80\, F_t$

If $\alpha = 0$, then $F_{t+1} = 0\, D_t + 1\, F_t = F_t$

Forecast does not reflect recent data

If $\alpha = 1$, then $F_{t+1} = 1\, D_t + 0\, F_t = D_t$

Forecast based only on most recent data

Exponential Smoothing (α=0.30)

PERIOD	MONTH	DEMAND
1	Jan	37
2	Feb	40
3	Mar	41
4	Apr	37
5	May	45
6	Jun	50
7	Jul	43
8	Aug	47
9	Sep	56
10	Oct	52
11	Nov	55
12	Dec	54

$$F_2 = \alpha D_1 + (1 - \alpha)F_1$$
$$= (0.30)(37) + (0.70)(37)$$
$$= 37$$

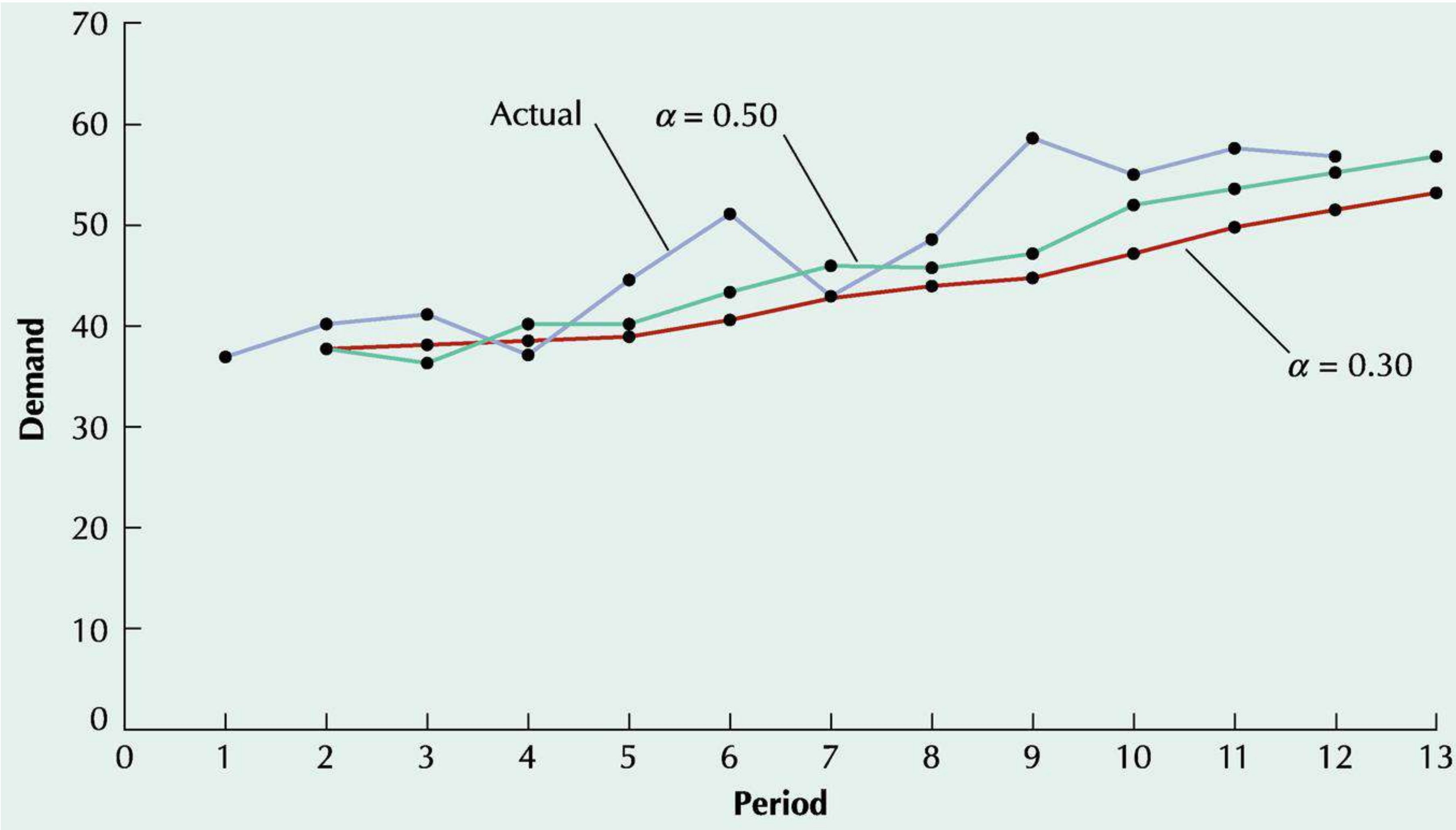
$$F_3 = \alpha D_2 + (1 - \alpha)F_2$$
$$= (0.30)(40) + (0.70)(37)$$
$$= 37.9$$

$$F_{13} = \alpha D_{12} + (1 - \alpha)F_{12}$$
$$= (0.30)(54) + (0.70)(50.84)$$
$$= 51.79$$

Exponential Smoothing

PERIOD	MONTH	DEMAND	FORECAST, F_{t+1} ($\alpha = 0.3$)	($\alpha = 0.5$)
1	Jan	37	–	–
2	Feb	40	37.00	37.00
3	Mar	41	37.90	38.50
4	Apr	37	38.83	39.75
5	May	45	38.28	38.37
6	Jun	50	40.29	41.68
7	Jul	43	43.20	45.84
8	Aug	47	43.14	44.42
9	Sep	56	44.30	45.71
10	Oct	52	47.81	50.85
11	Nov	55	49.06	51.42
12	Dec	54	50.84	53.21
13	Jan	–	51.79	53.61

Exponential Smoothing



Adjusted Exponential Smoothing

$$AF_{t+1} = F_{t+1} + T_{t+1}$$

where

T = an exponentially smoothed trend factor

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

where

T_t = the last period trend factor

β = a smoothing constant for trend

$0 \le \beta \le 1$

Adjusted Exponential Smoothing (β=0.30)

PERIOD	MONTH	DEMAND
1	Jan	37
2	Feb	40
3	Mar	41
4	Apr	37
5	May	45
6	Jun	50
7	Jul	43
8	Aug	47
9	Sep	56
10	Oct	52
11	Nov	55
12	Dec	54

$$T_3 = \beta(F_3 - F_2) + (1 - \beta)\, T_2$$
$$= (0.30)(38.5 - 37.0) + (0.70)(0)$$
$$= 0.45$$

$$AF_3 = F_3 + T_3 = 38.5 + 0.45$$
$$= 38.95$$

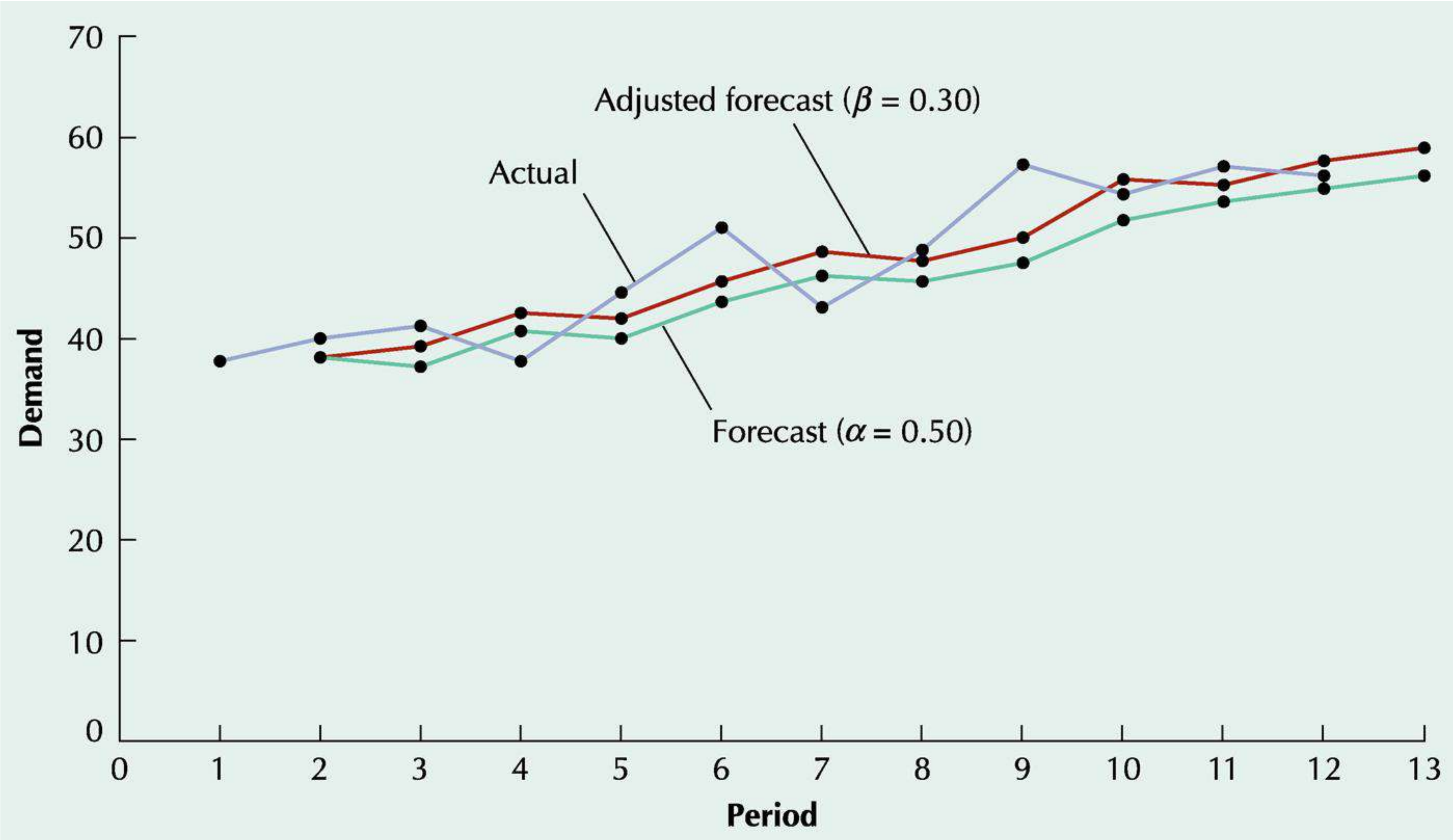
$$T_{13} = \beta(F_{13} - F_{12}) + (1 - \beta)\, T_{12}$$
$$= (0.30)(53.61 - 53.21) + (0.70)(1.77)$$
$$= 1.36$$

$$AF_{13} = F_{13} + T_{13} = 53.61 + 1.36 = 54.97$$

Adjusted Exponential Smoothing

PERIOD	MONTH	DEMAND	FORECAST F_{t+1}	TREND T_{t+1}	ADJUSTED FORECAST AF_{t+1}
1	Jan	37	37.00	–	–
2	Feb	40	37.00	0.00	37.00
3	Mar	41	38.50	0.45	38.95
4	Apr	37	39.75	0.69	40.44
5	May	45	38.37	0.07	38.44
6	Jun	50	38.37	0.07	38.44
7	Jul	43	45.84	1.97	47.82
8	Aug	47	44.42	0.95	45.37
9	Sep	56	45.71	1.05	46.76
10	Oct	52	50.85	2.28	58.13
11	Nov	55	51.42	1.76	53.19
12	Dec	54	53.21	1.77	54.98
13	Jan	–	53.61	1.36	54.96

Adjusted Exponential Smoothing Forecasts



Linear Trend Line

$$y = a + bx$$

where

a = intercept

b = slope of the line

x = time period

y = forecast for demand for period x

$$b = \frac{\Sigma\, xy - n\bar{x}\bar{y}}{\Sigma\, x^2 - n\bar{x}^2}$$

$$a = \bar{y} - b\,\bar{x}$$

where

n = number of periods

$\bar{x} = \dfrac{\Sigma\, x}{n}$ = mean of the x values

$\bar{y} = \dfrac{\Sigma\, y}{n}$ = mean of the y values

Least Squares Example

x(PERIOD)	y(DEMAND)	xy	x^2
1	37	37	1
2	40	80	4
3	41	123	9
4	37	148	16
5	45	225	25
6	50	300	36
7	43	301	49
8	47	376	64
9	56	504	81
10	52	520	100
11	55	605	121
12	54	648	144
78	557	3867	650

Least Squares Example

$$\bar{x} = \frac{78}{12} = 6.5$$

$$\bar{y} = \frac{557}{12} = 46.42$$

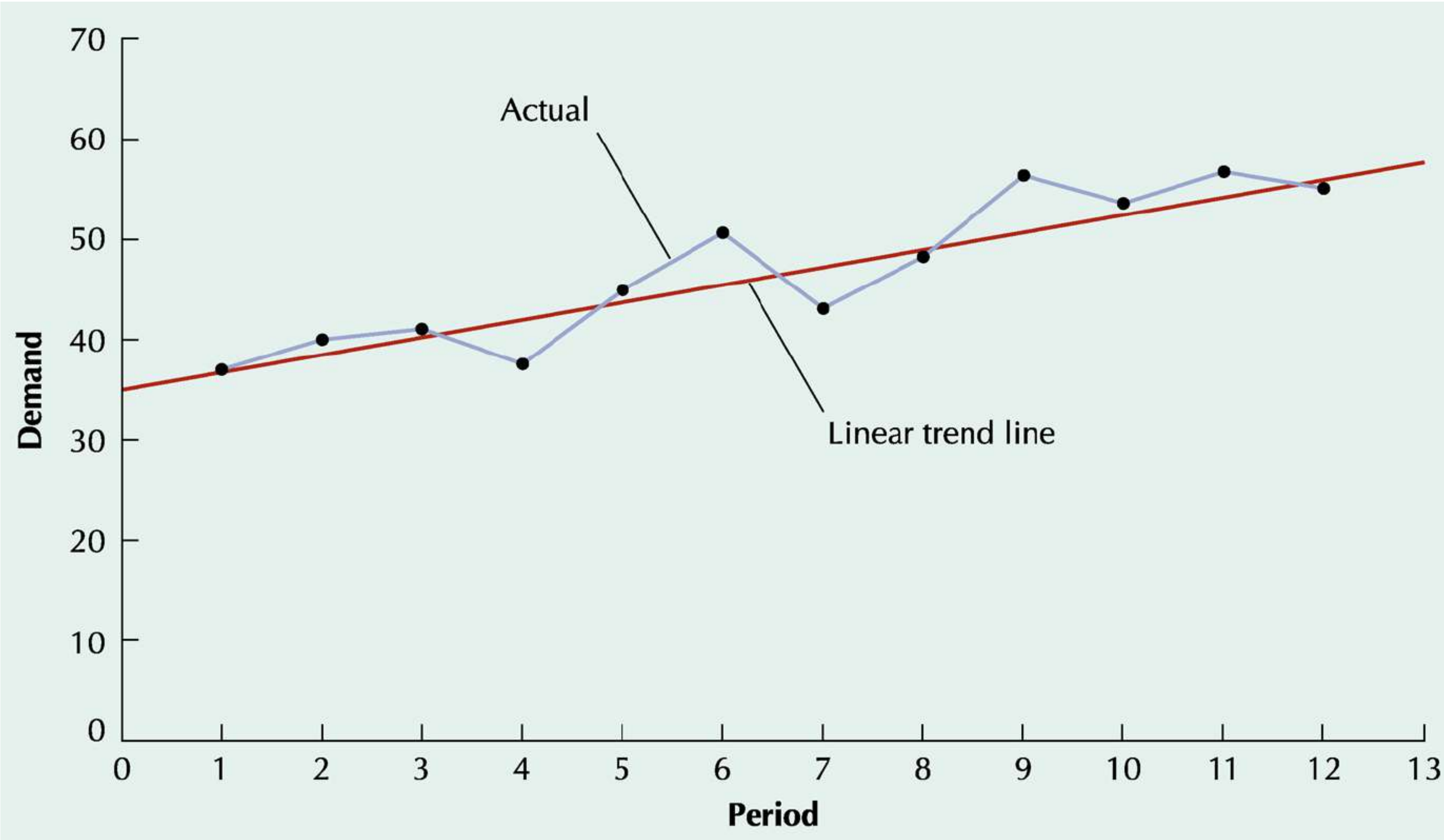
$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{3867 - (12)(6.5)(46.42)}{650 - 12(6.5)^2} = 1.72$$

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

$$= 46.42 - (1.72)(6.5) = 35.2$$

Linear trend line $y = 35.2 + 1.72x$

Forecast for period 13 $y = 35.2 + 1.72(13) = 57.56$ units



Seasonal Adjustments

- Repetitive increase/ decrease in demand
- Use seasonal factor to adjust forecast

$$\text{Seasonal factor} = S_i = \frac{D_i}{\sum D}$$

Seasonal Adjustment

	DEMAND (1000'S PER QUARTER)				
YEAR	*1*	*2*	*3*	*4*	*Total*
2002	12.6	8.6	6.3	17.5	45.0
2003	14.1	10.3	7.5	18.2	50.1
2004	15.3	10.6	8.1	19.6	53.6
Total	42.0	29.5	21.9	55.3	148.7

$$S_1 = \frac{D_1}{\sum D} = \frac{42.0}{148.7} = 0.28 \qquad S_3 = \frac{D_3}{\sum D} = \frac{21.9}{148.7} = 0.15$$

$$S_2 = \frac{D_2}{\sum D} = \frac{29.5}{148.7} = 0.20 \qquad S_4 = \frac{D_4}{\sum D} = \frac{55.3}{148.7} = 0.37$$

Seasonal Adjustment

For 2005

$$y = 40.97 + 4.30x = 40.97 + 4.30(4) = 58.17$$

$$SF_1 = (S_1)\,(F_5) = (0.28)(58.17) = 16.28$$
$$SF_2 = (S_2)\,(F_5) = (0.20)(58.17) = 11.63$$
$$SF_3 = (S_3)\,(F_5) = (0.15)(58.17) = 8.73$$
$$SF_4 = (S_4)\,(F_5) = (0.37)(58.17) = 21.53$$

Forecast Accuracy

- Forecast error
  - difference between forecast and actual demand
- MAD
  - mean absolute deviation
- MAPD
  - mean absolute percent deviation
- Cumulative error
- Average error or bias

Mean Absolute Deviation (MAD)

$$\text{MAD} = \frac{\Sigma| D_t - F_t |}{n}$$

where

t = period number
D_t = demand in period t
F_t = forecast for period t
n = total number of periods
$| \ |$ = absolute value

MAD Example

PERIOD	DEMAND, D_t	F_t (α =0.3)	(D_t - F_t)	|D_t - F_t|
1	37	37.00	–	–
2	40	37.00	3.00	3.00
3	41	37.90	3.10	3.10
4	37	38.83	-1.83	1.83
5	45	38.28	6.72	6.72
6	50	40.29	9.69	9.69
7	43	43.20	-0.20	0.20
8	47	43.14	3.86	3.86
9	56	44.30	11.70	11.70
10	52	47.81	4.19	4.19
11	55	49.06	5.94	5.94
12	54	50.84	3.15	3.15
	557		49.31	53.39

MAD Calculation

$$\text{MAD} = \frac{\Sigma| D_t - F_t |}{n}$$

$$= \frac{53.39}{11}$$

$$= 4.85$$

Other Accuracy Measures

Mean absolute percent deviation (MAPD)

$$MAPD = \frac{\sum |D_t - F_t|}{\sum D_t}$$

Cumulative error

$$E = \sum e_t$$

Average error

$$(E) = \frac{\sum e_t}{n}$$

Comparison of Forecasts

FORECAST	MAD	MAPD	E	($\bar{E}$)
Exponential smoothing (α = 0.30)	4.85	9.6%	49.31	4.48
Exponential smoothing (α = 0.50)	4.04	8.5%	33.21	3.02
Adjusted exponential smoothing (α = 0.50, β = 0.30)	3.81	7.5%	21.14	1.92
Linear trend line	2.29	4.9%	–	–

Forecast Control

- Tracking signal
  - monitors the forecast to see if it is biased high or low

- 1 MAD ≈ 0.8 б
- Control limits of 2 to 5 MADs are used most frequently

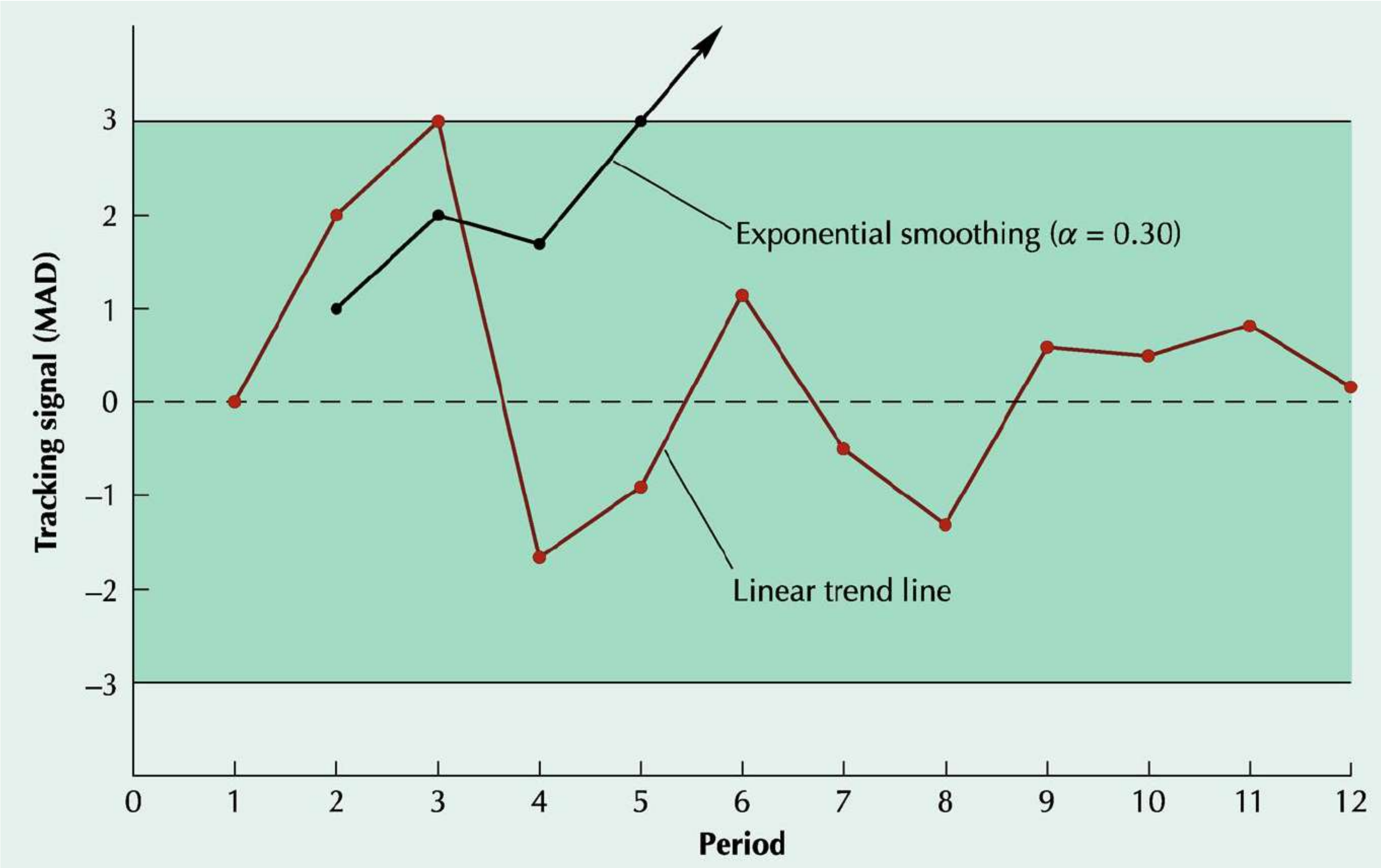
$$\text{Tracking signal} = \frac{\sum(D_t - F_t)}{\text{MAD}} = \frac{E}{\text{MAD}}$$

Tracking Signal Values

PERIOD	DEMAND D_t	FORECAST, F_t	ERROR $D_t - F_t$	$\sum E = \sum(D_t - F_t)$	MAD	**TRACKING SIGNAL**
1	37	37.00	–	–	–	**–**
2	40	37.00	3.00	3.00	3.00	**1.00**
3	41	37.90	3.10	6.10	3.05	**2.00**
4	37	38.83	-1.83	4.27	2.64	**1.62**
5	45	38.28	6.72	10.99	3.66	**3.00**
6	50	40.29	9.69	20.68	4.87	**4.25**
7	43	43.20	-0.20	20.48	4.09	**5.01**
8	47	43.14	3.86	24.34	4.06	**6.00**
9	56	44.30	11.70	36.04	5.01	**7.19**
10	52	47.81	4.19	40.23	4.92	**8.18**
11	55	49.06	5.94	46.17	5.02	**9.20**
12	54	50.84	3.15	49.32	4.85	**10.17**

$$TS_3 = \frac{6.10}{3.05} = 2.00$$

Tracking Signal Plot



Statistical Control Charts

- Using σ we can calculate statistical control limits for the forecast error
- Control limits are typically set at $\pm\ 3\sigma$

$$\sigma = \sqrt{\frac{\sum(D_t - F_t)^2}{n - 1}}$$

- Mean squared error (MSE)
  - Average of squared forecast errors

Statistical Control Charts