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Forecasting

PowerPoint presentation to accompany
Heizer and Render
Operations Management, Eleventh Edition
Principles of Operations Management, Ninth Edition

PowerPoint slides by Jeff Heyl

Forecasting Provides a Competitive Advantage for Disney

- Global portfolio includes parks in 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 the forecast and actual attendance at each park

Forecasting Provides a Competitive Advantage for Disney

- 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
- 20% of customers come from outside the USA
- Economic model includes gross domestic product, 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

Forecasting Provides a Competitive Advantage for Disney

- 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%

What is Forecasting?

- Process of predicting a future event
- Underlying basis of all business decisions
  - Production
  - Inventory
  - Personnel
  - Facilities

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 and production planning, budgeting
3. ***Long-range forecast***
   - 3^+ years
   - New product planning, facility location, research and development

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

Types of Forecasts

1. **Economic forecasts** address the business cycle by predicting inflation rates, money supplies, housing starts, and other planning indicators.
2. **Technological forecasts** are concerned with rates of technological progress, which can result in the birth of exciting new products, requiring new plants and equipment.
3. **Demand forecasts** are projections of demand for a company’s products or services. Forecasts drive decisions, so managers need immediate and accurate information about real demand.

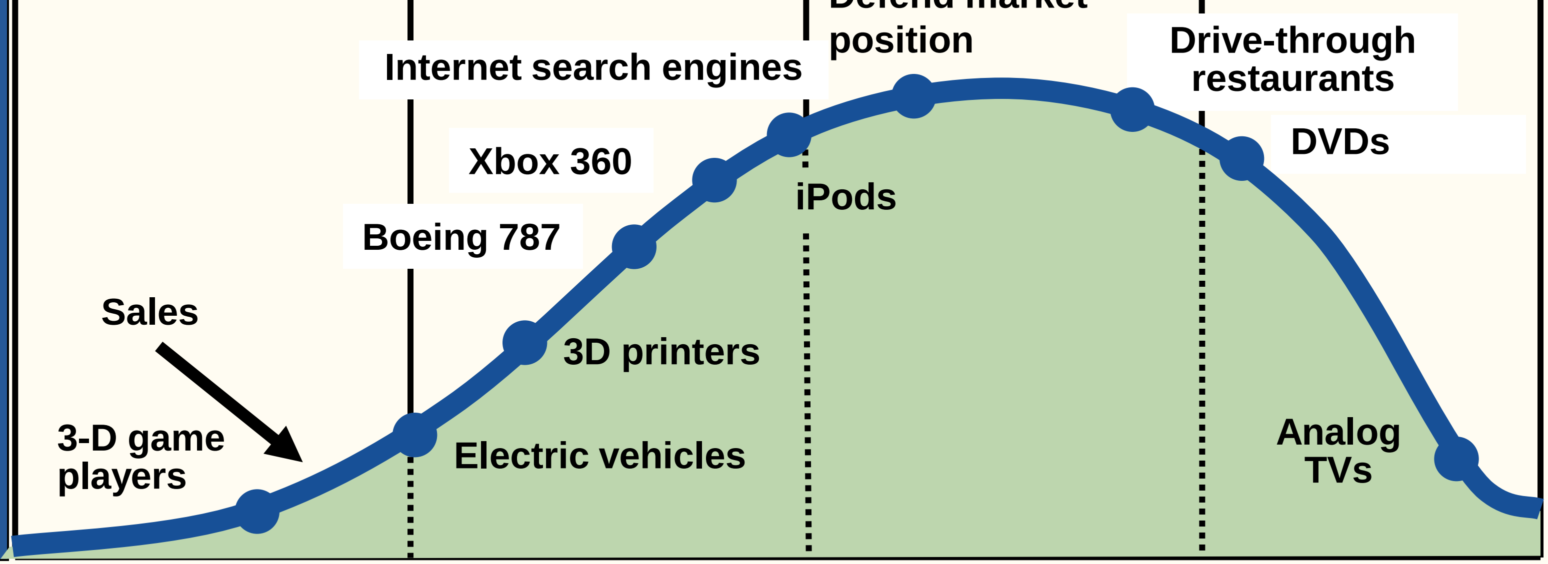
Influence of Product Life Cycle

Introduction – Growth – Maturity – Decline

- Introduction and growth require longer forecasts than maturity and decline
- As product passes through life cycle, forecasts are useful in projecting
  - Staffing levels
  - Inventory levels
  - Factory capacity

Product Life Cycle

Company Strategy/Issues	Introduction	Growth	Maturity	Decline
	Best period to increase market share R&D engineering is critical	Practical to change price or quality image Strengthen niche	Poor time to change image, price, or quality Competitive costs become critical Defend market position	Cost control critical



Product Life Cycle

OM Strategy/Issues	Introduction	Growth	Maturity	Decline
	Product design and development critical Frequent product and process design changes Short production runs High production costs Limited models Attention to quality	Forecasting critical Product and process reliability Competitive product improvements and options Increase capacity Shift toward product focus Enhance distribution	Standardization Fewer product changes, more minor changes Optimum capacity Increasing stability of process Long production runs Product improvement and cost cutting	Little product differentiation Cost minimization Overcapacity in the industry Prune line to eliminate items not returning good margin Reduce capacity

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

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 results

The Realities!

- **Forecasts are seldom perfect,** unpredictable outside factors may impact the forecast
- Most techniques assume an **underlying stability in the system**
- Product family and **aggregated forecasts are more accurate than individual** product forecasts

Forecasting Approaches

Qualitative Methods

- **Used when situation is vague and little data exist**
  - New products
  - New technology
- **Involves intuition, experience**
  - e.g., forecasting sales on Internet

Forecasting Approaches

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

Overview of Qualitative Methods

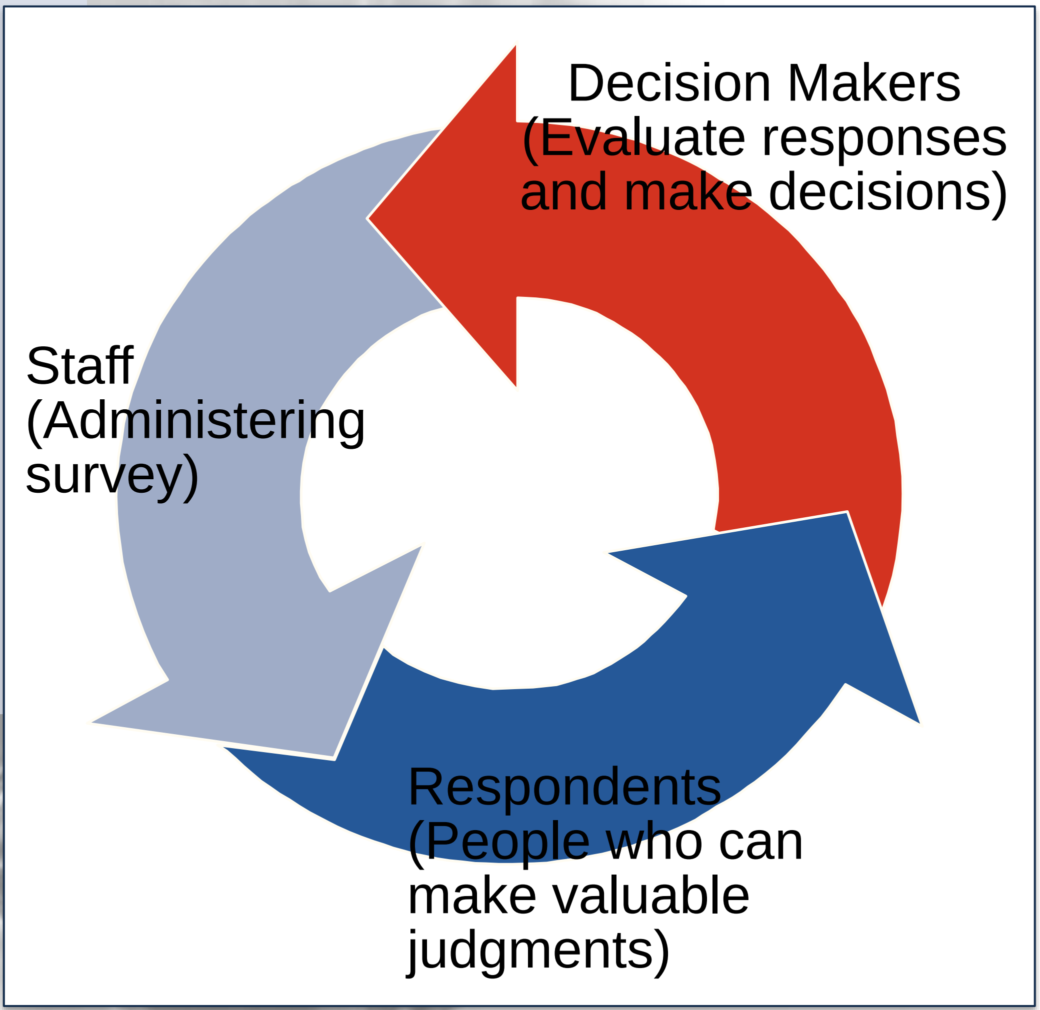
1. Jury of executive opinion
   - Pool opinions of high-level experts, sometimes augment by statistical models
2. Delphi method
   - Panel of experts, queried iteratively
3. Sales force composite
   - Estimates from individual salespersons are reviewed for reasonableness, then aggregated
4. Market Survey
   - Ask the customer

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

DELPHI METHOD

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



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

Market Survey

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

Overview of Quantitative Approaches

1. Naive approach
2. Moving averages
3. Exponential smoothing
4. Trend projection
5. Linear regression

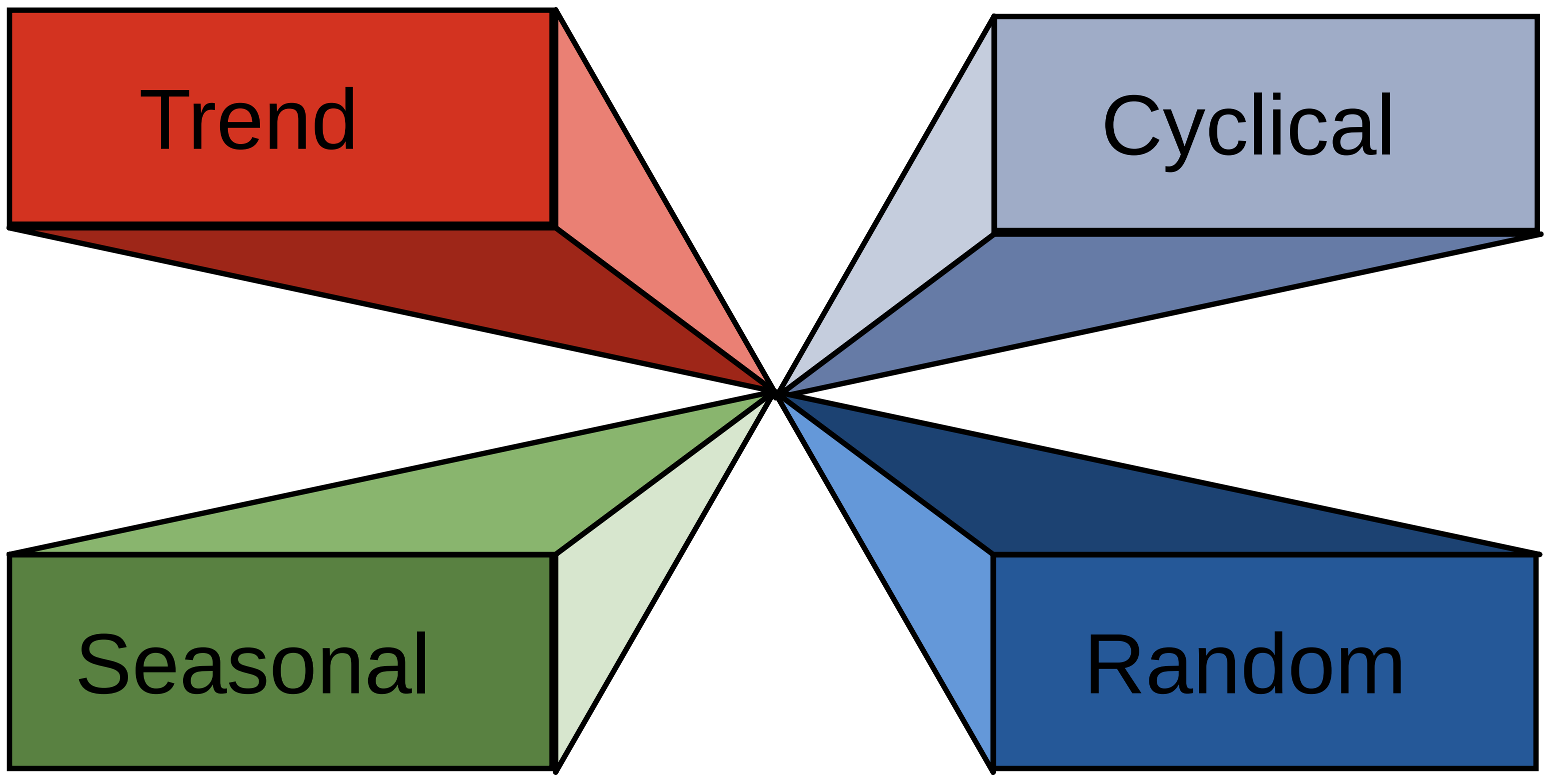
Items 1–4: Time-series models

Item 5: Associative model

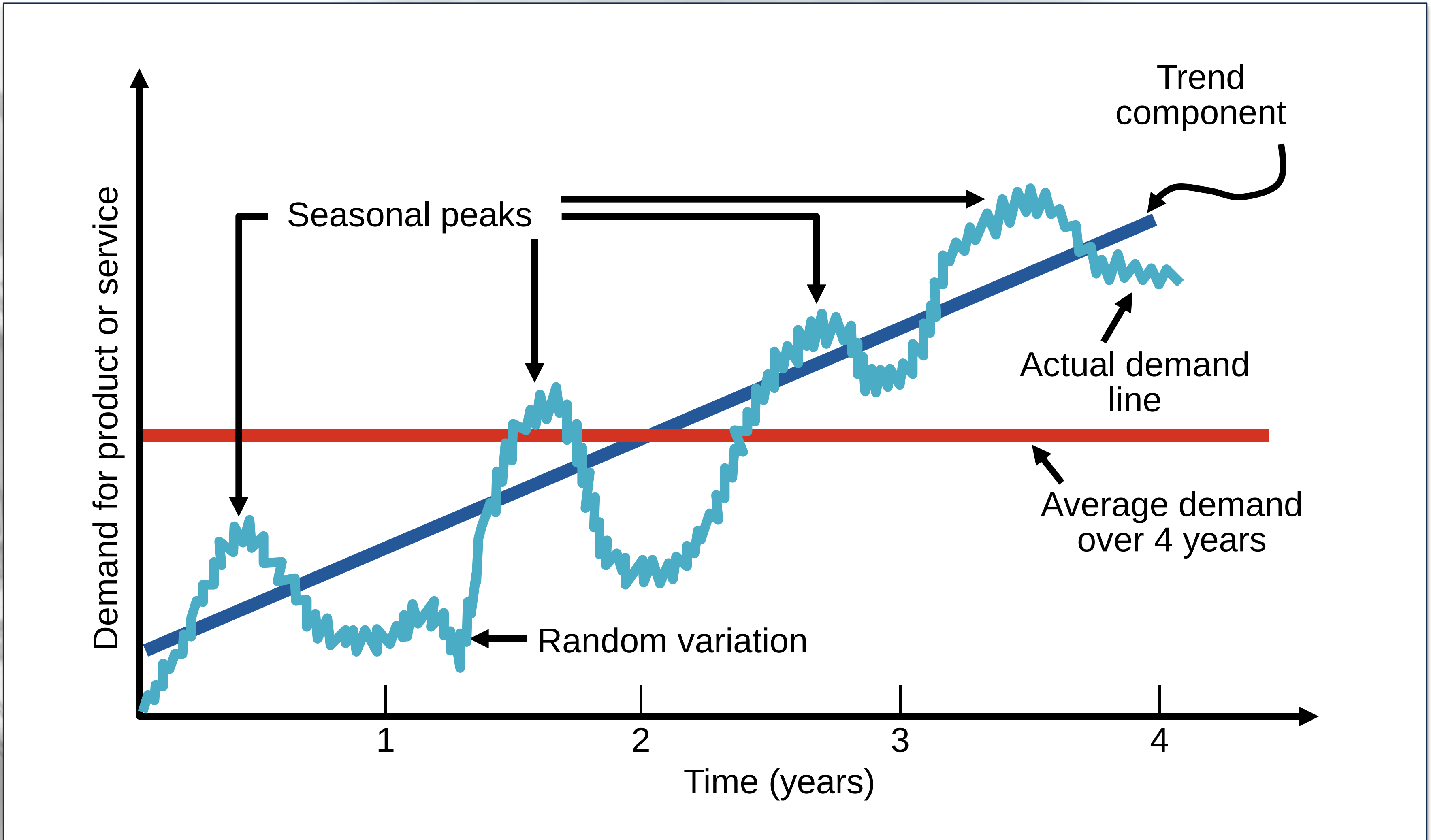
Time-Series Forecasting

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

Time-Series Components

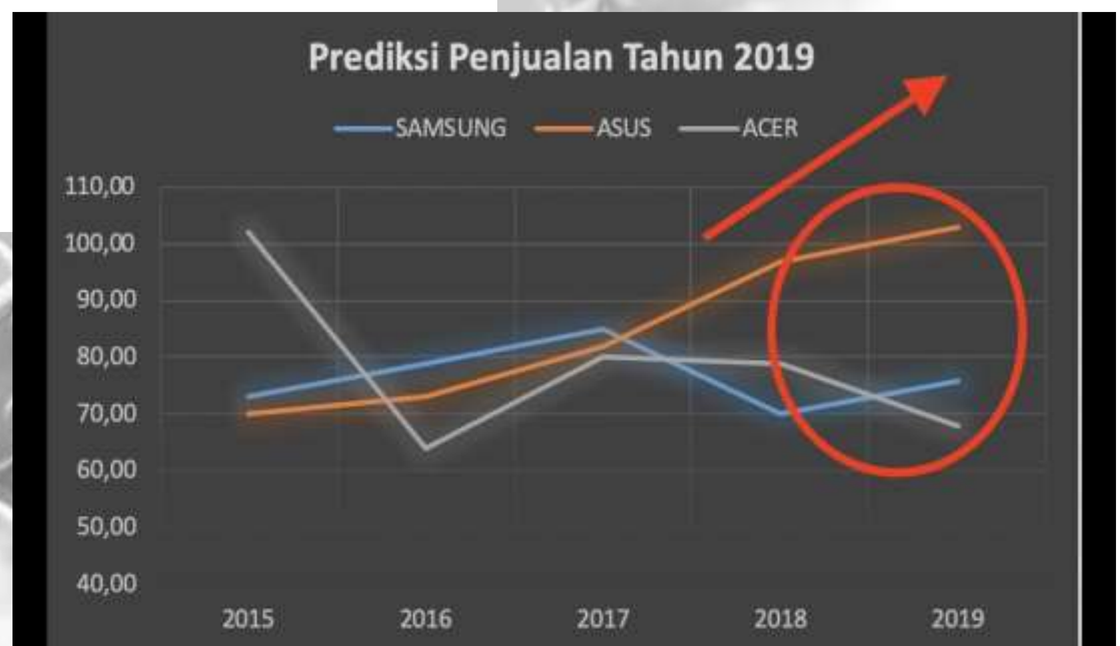


Components of Demand



Trend Component

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



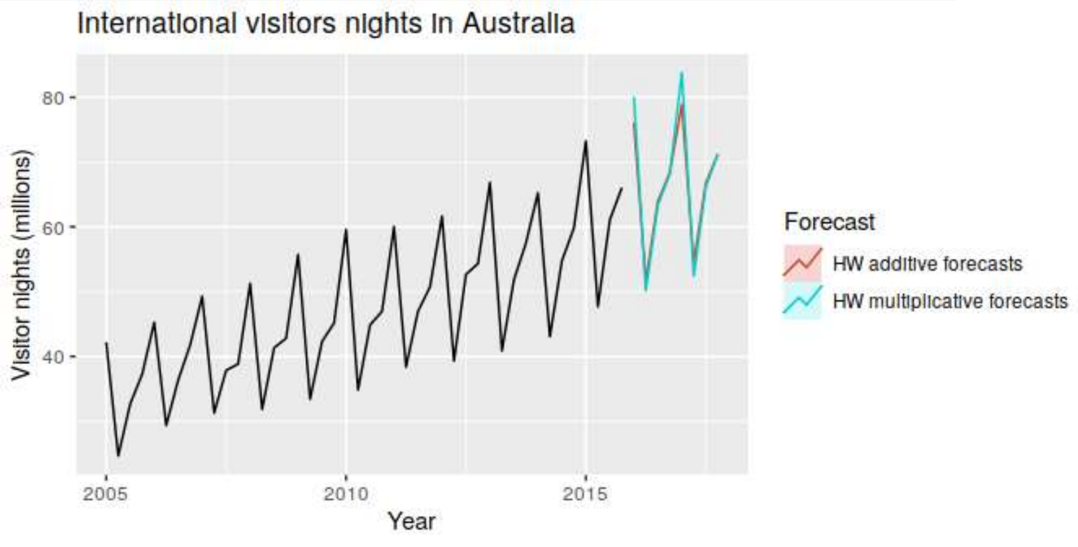
Seasonal Component

- 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

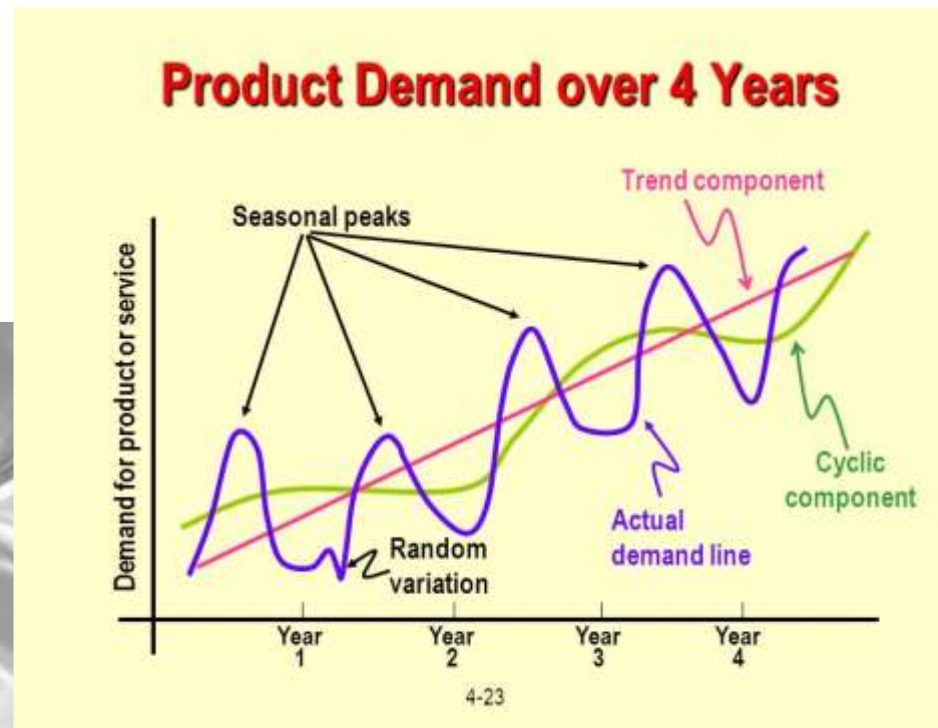
Cyclical Component

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



RANDOM COMPONENT

- Erratic, unsystematic, ‘residual’ fluctuations
- Due to random variation or unforeseen events
- Short duration and nonrepeating



NAIVE APPROACH

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

Moving Average Method

- MA is a series of arithmetic means
- Used if little or no trend
- Used often for smoothing
  - Provides overall impression of data over time

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

Moving Average Method

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	$(29 + 30 + 28)/3 = 28$
November	16	$(30 + 28 + 18)/3 = 25\,^{1}/_{3}$
December	14	$(28 + 18 + 16)/3 = 20\,^{2}/_{3}$

Weighted Moving Average

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

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

Weighted Moving Average

MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (10)]/6 = 12\ ^{1}/_{6}$
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 =

$$\frac{3 \times \text{Sales last mo.} + 2 \times \text{Sales 2 mos. ago} + 1 \times \text{Sales 3 mos. ago}}{\text{Sum of the weights}}$$

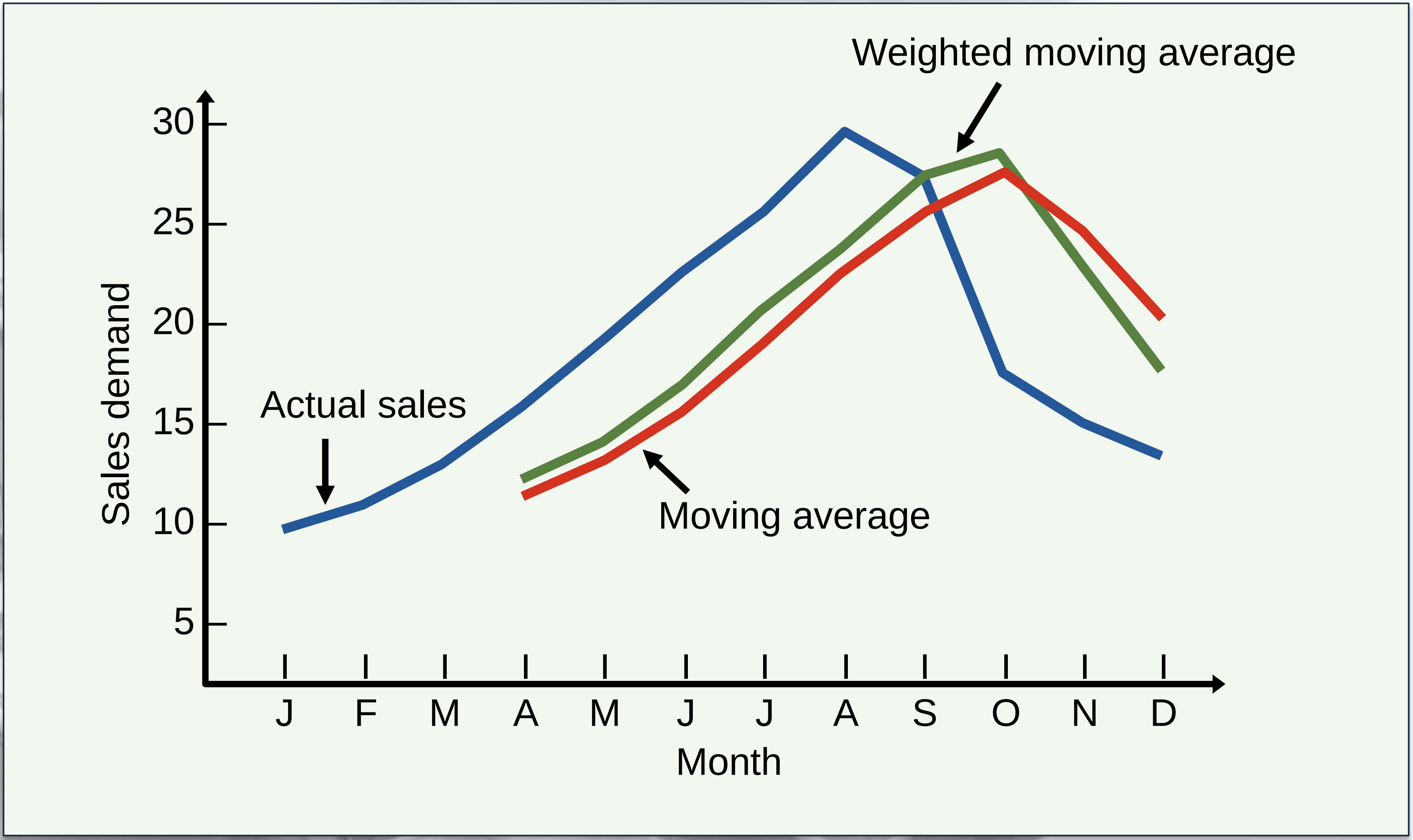
Weighted Moving Average

MONTH	ACTUAL SHED SALES	3-MONTH WEIGHTED MOVING AVERAGE
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (10)]/6 = 12\ ^1/_6$
May	19	$[(3 \times 16) + (2 \times 13) + (12)]/6 = 14\ ^1/_3$
June	23	$[(3 \times 19) + (2 \times 16) + (13)]/6 = 17$
July	26	$[(3 \times 23) + (2 \times 19) + (16)]/6 = 20\ ^1/_2$
August	30	$[(3 \times 26) + (2 \times 23) + (19)]/6 = 23\ ^5/_6$
September	28	$[(3 \times 30) + (2 \times 26) + (23)]/6 = 27\ ^1/_2$
October	18	$[(3 \times 28) + (2 \times 30) + (26)]/6 = 28\ ^1/_3$
November	16	$[(3 \times 18) + (2 \times 28) + (30)]/6 = 23\ ^1/_3$
December	14	$[(3 \times 16) + (2 \times 18) + (28)]/6 = 18\ ^2/_3$

Potential Problems With Moving Average

- Increasing *n* smooths the forecast but makes it **less sensitive to changes**
- Does not **forecast trends well**
- Requires **extensive historical data**

Graph of Moving Averages



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

Exponential Smoothing

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

Exponential Smoothing
Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

Exponential Smoothing Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

New forecast = 142 + .2(153 – 142)

Exponential Smoothing
Example

Predicted demand = 142 Ford Mustangs
Actual demand = 153
Smoothing constant α = .20

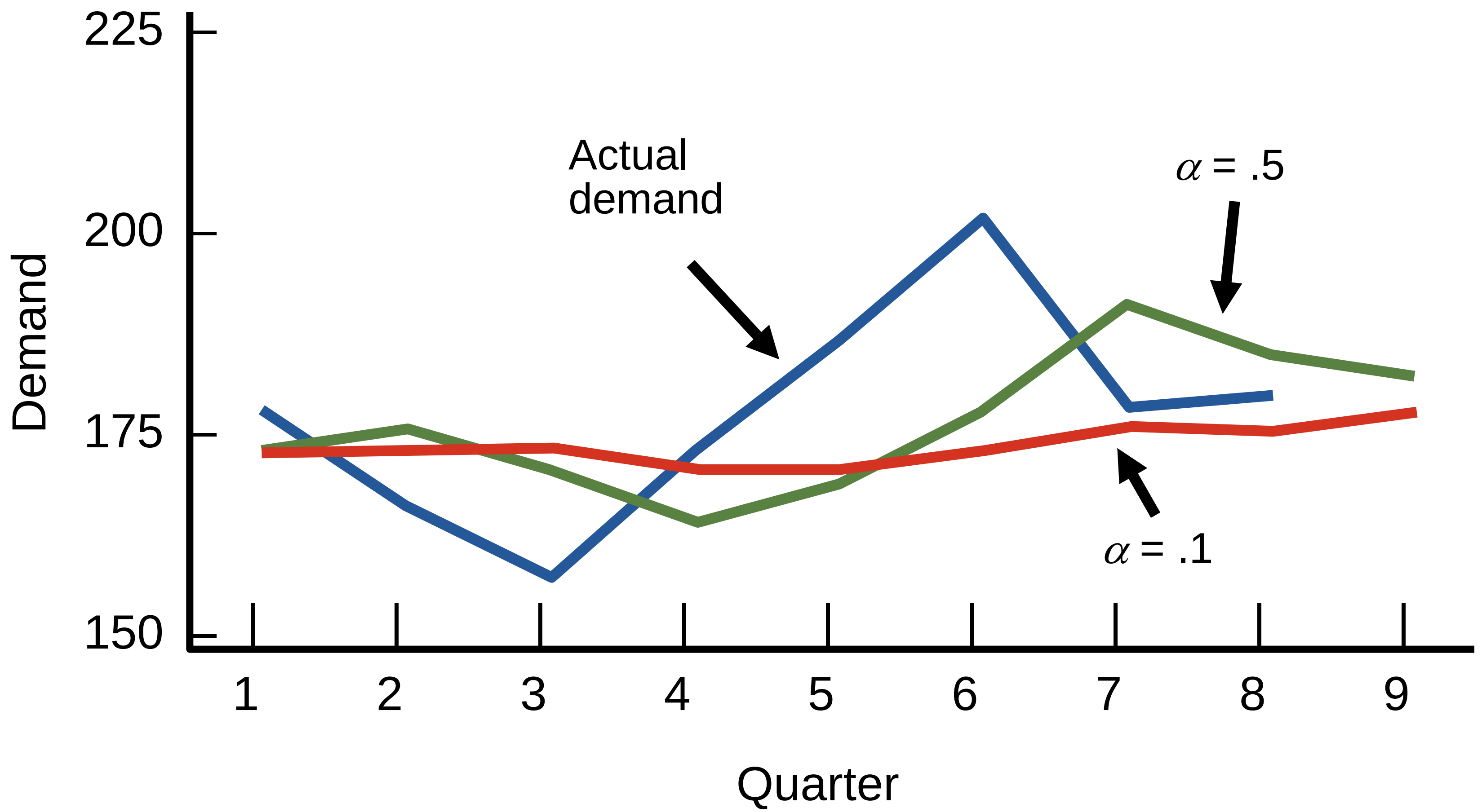
New forecast = 142 + .2(153 – 142)
= 142 + 2.2
= 144.2 ≈ 144 cars

Effect of Smoothing Constants

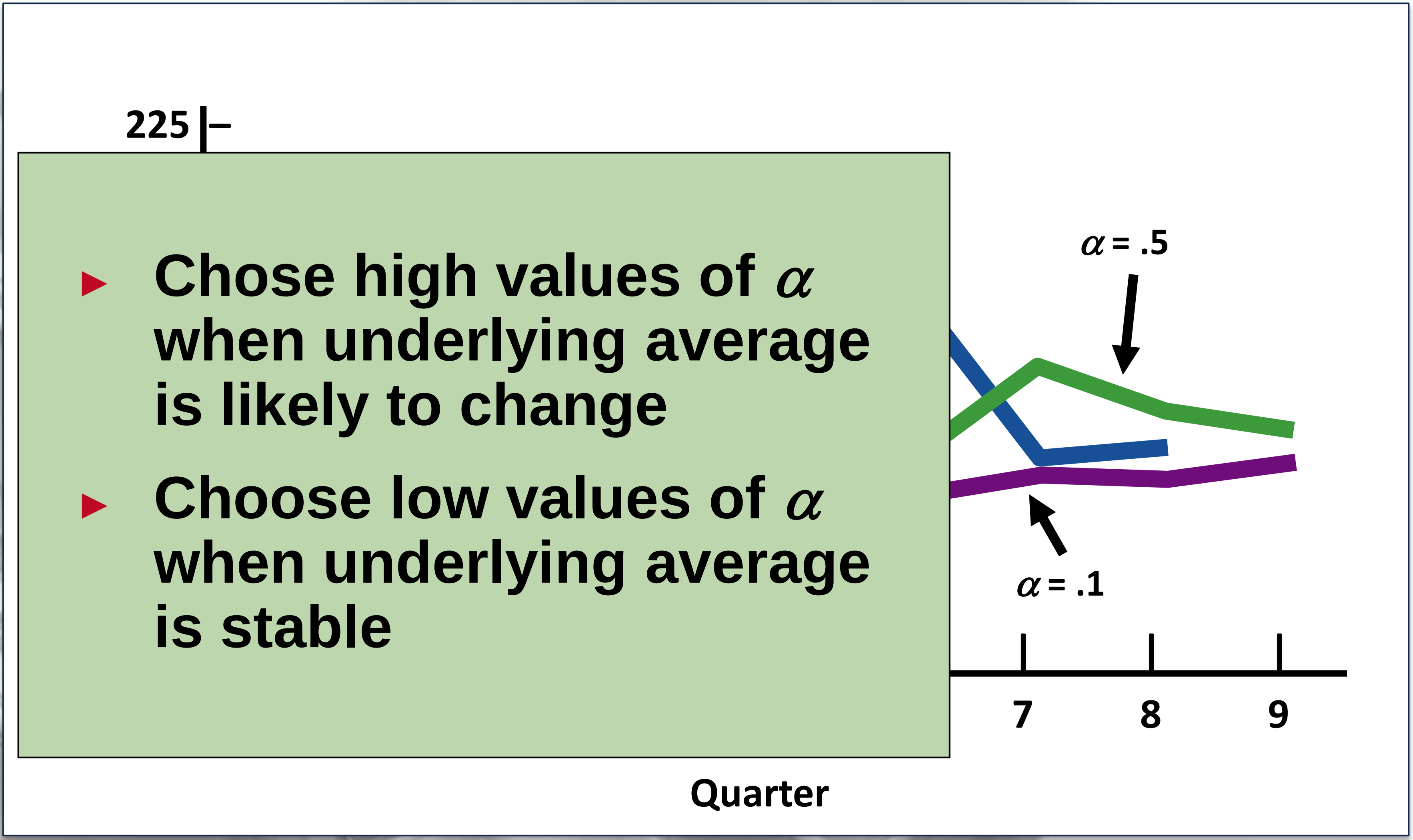
- Smoothing constant generally $.05 \leq \alpha \leq .50$
- As α increases, older values become less significant

	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

Impact of Different α



Impact of Different α



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

Choosing α

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

Forecast error = Actual demand – Forecast value

$= A_t - F_t$

Common Measures of Error

Mean Absolute Deviation (MAD)

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

DETERMINING THE MAD

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

DETERMINING THE MAD

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

Common Measures of Error

Mean Squared Error (MSE)

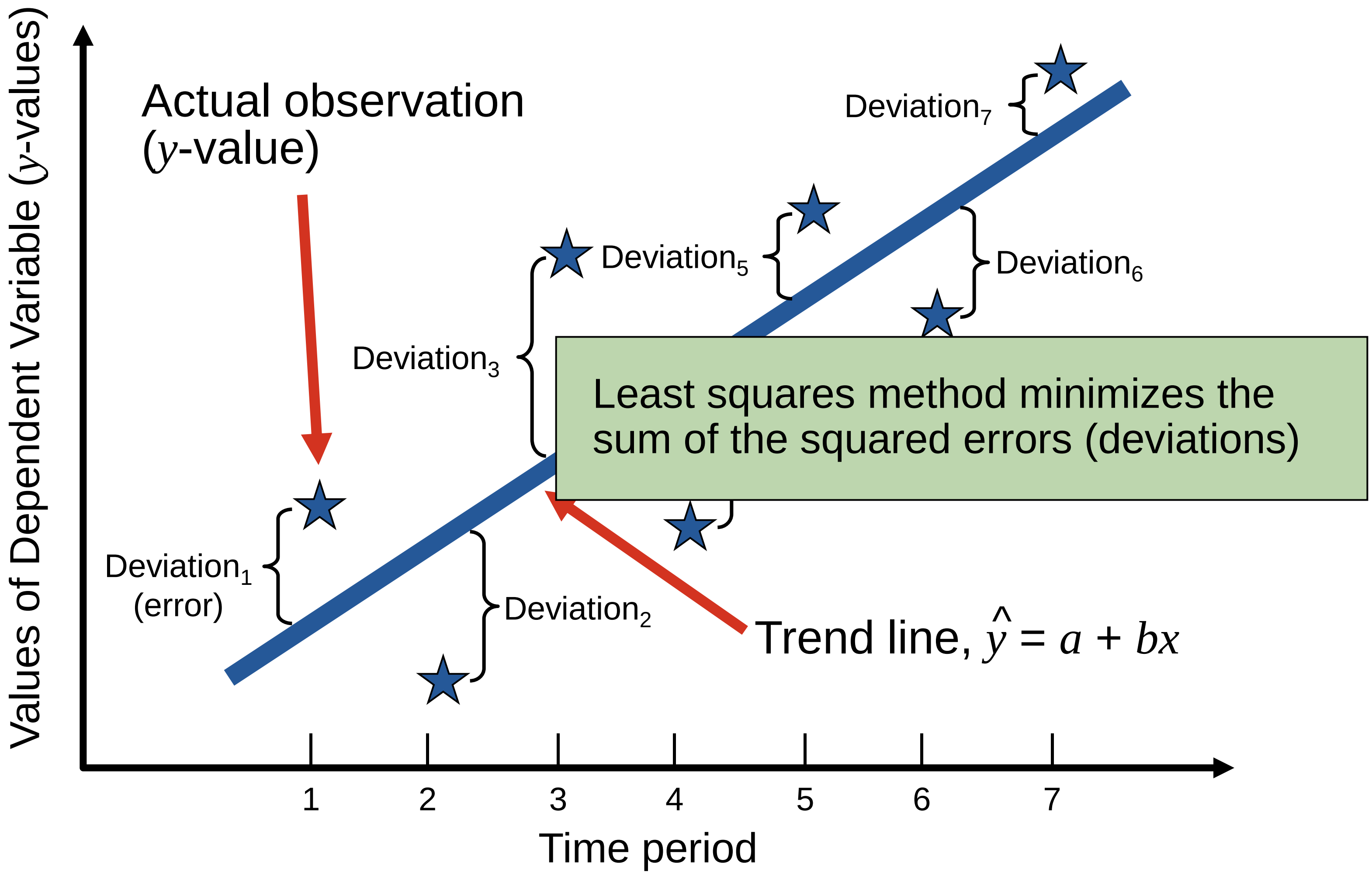
$$\text{MSE} = \frac{\sum \left(\text{Forecast errors}\right)^2}{n}$$

Determining the MSE

QUARTER	ACTUAL TONNAGE UNLOADED	FORECAST FOR a = .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

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

Least Squares Method



Least Squares Method

Equations to calculate the regression variables

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

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

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

Least Squares Method
Example

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

Least Squares Method
Example

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
$\Sigma x = 28$	$\Sigma y = 692$	$\Sigma x^2 = 140$	$\Sigma xy = 3{,}063$

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

Least Squares Method
Example

7	122	49	854
Σx = 28	Σy = 692	Σx² = 140	Σxy = 3,063

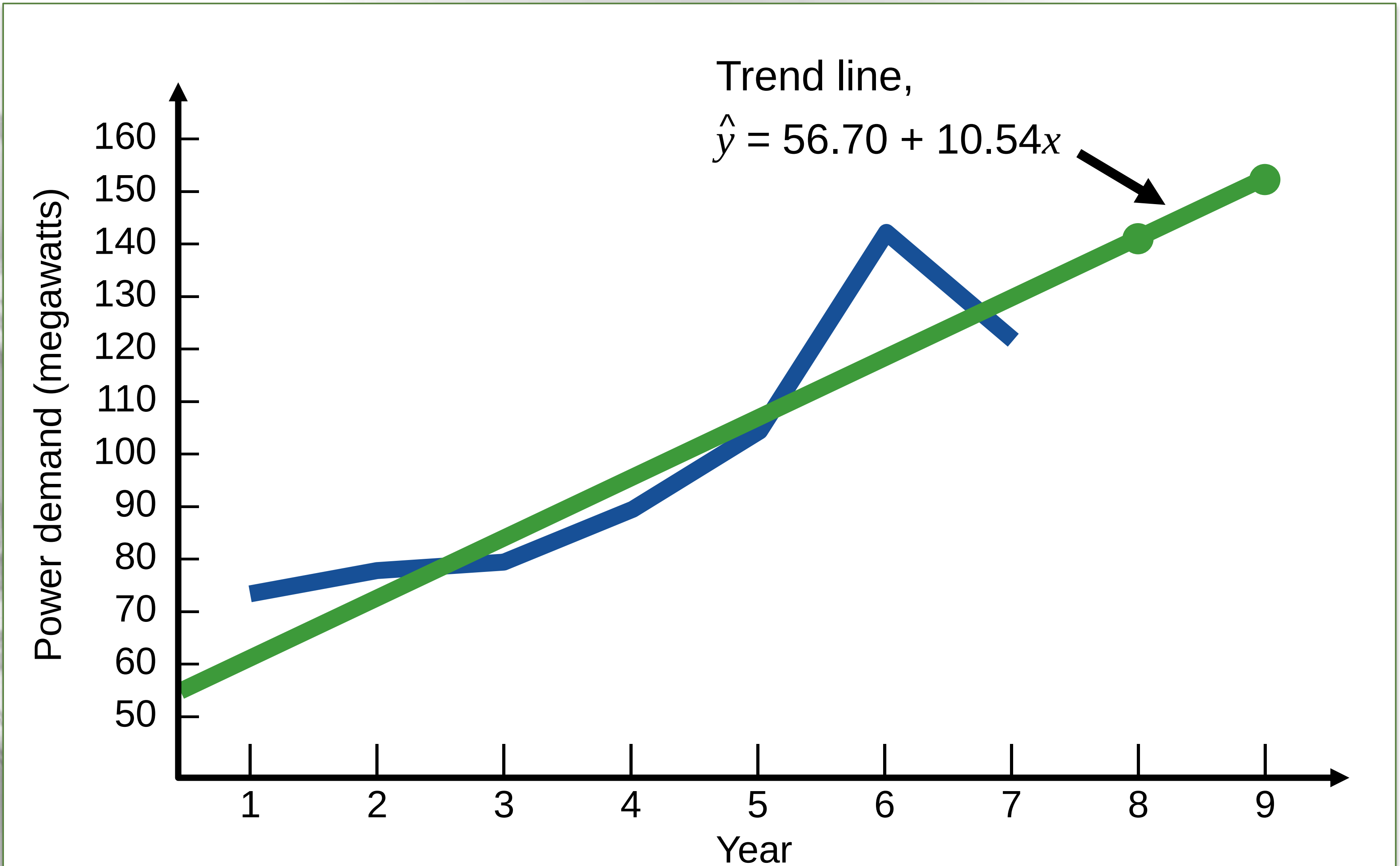
$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{3,063 - (7)(4)(98.86)}{140 - (7)(4^2)} = \frac{295}{28} = 10.54$$

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

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

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

Least Squares Method
Example



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

Associative Forecasting

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

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

where $\hat{y}$ = value of the dependent variable (in our example, sales)

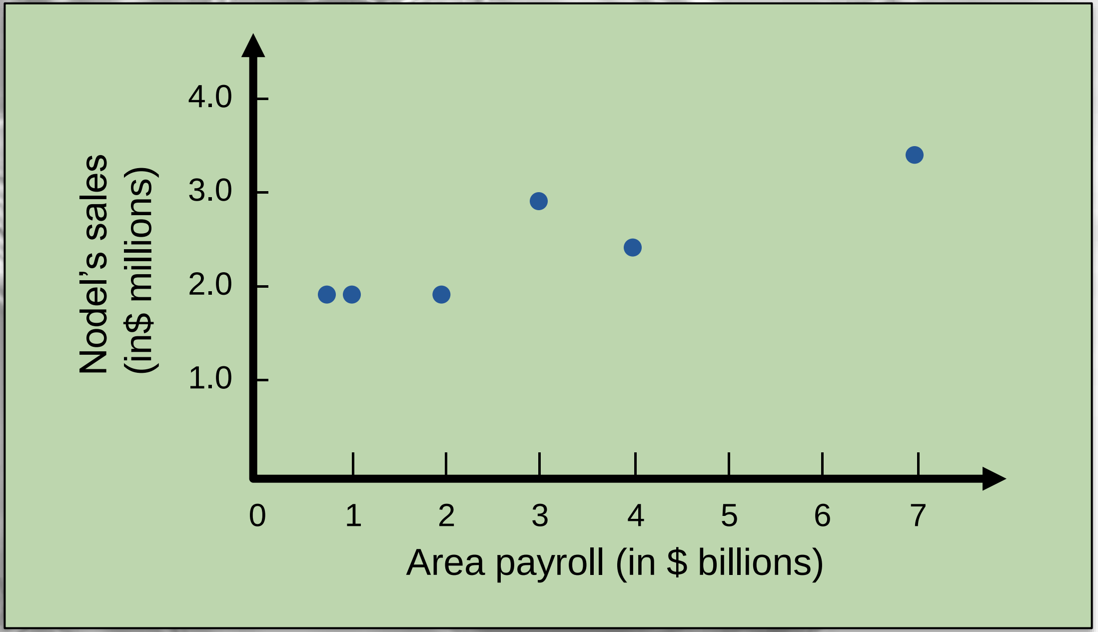
a = y-axis intercept

b = slope of the regression line

x = the independent variable

Associative Forecasting Example

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



Associative Forecasting Example

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
$\Sigma y =$	15.0	$\Sigma x =$	18	$\Sigma x^2 =$	80	$\Sigma xy =$ 51.5

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

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

Associative Forecasting Example

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

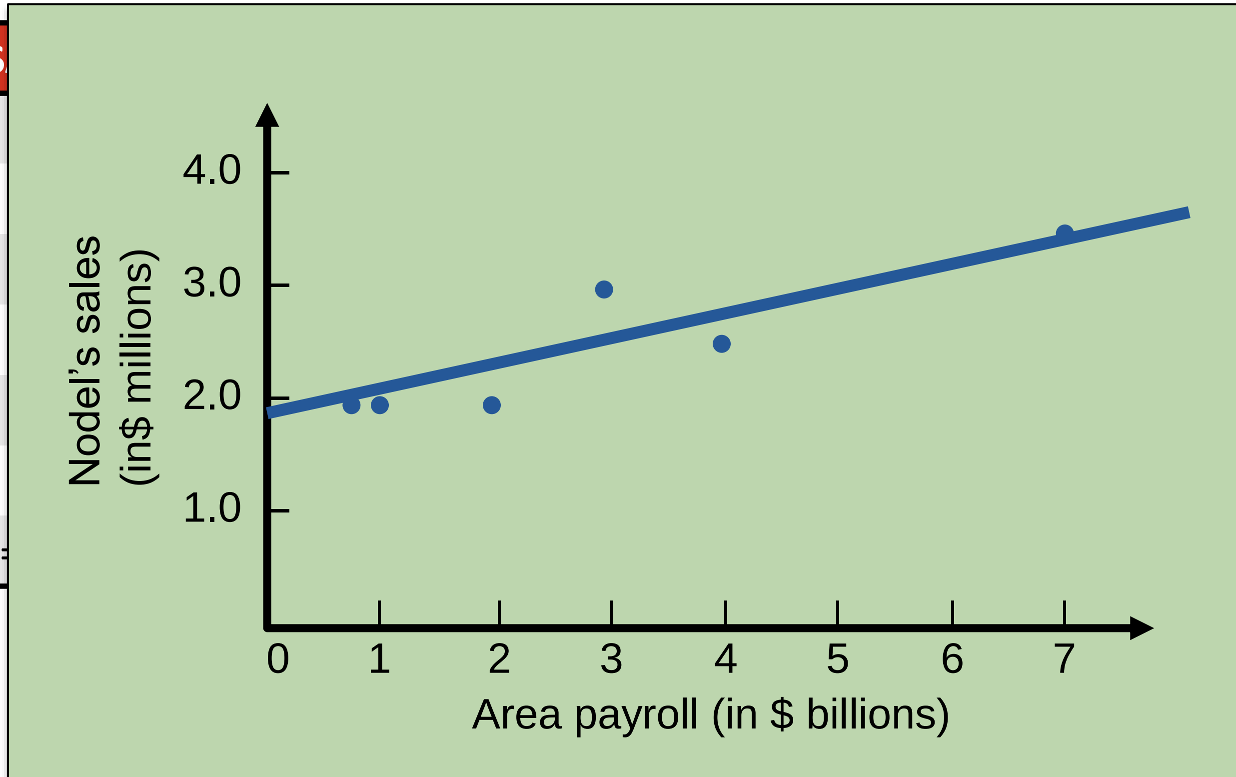
$$\hat{y} = 1.75 + .25x$$

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

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

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

Associative Forecasting Example



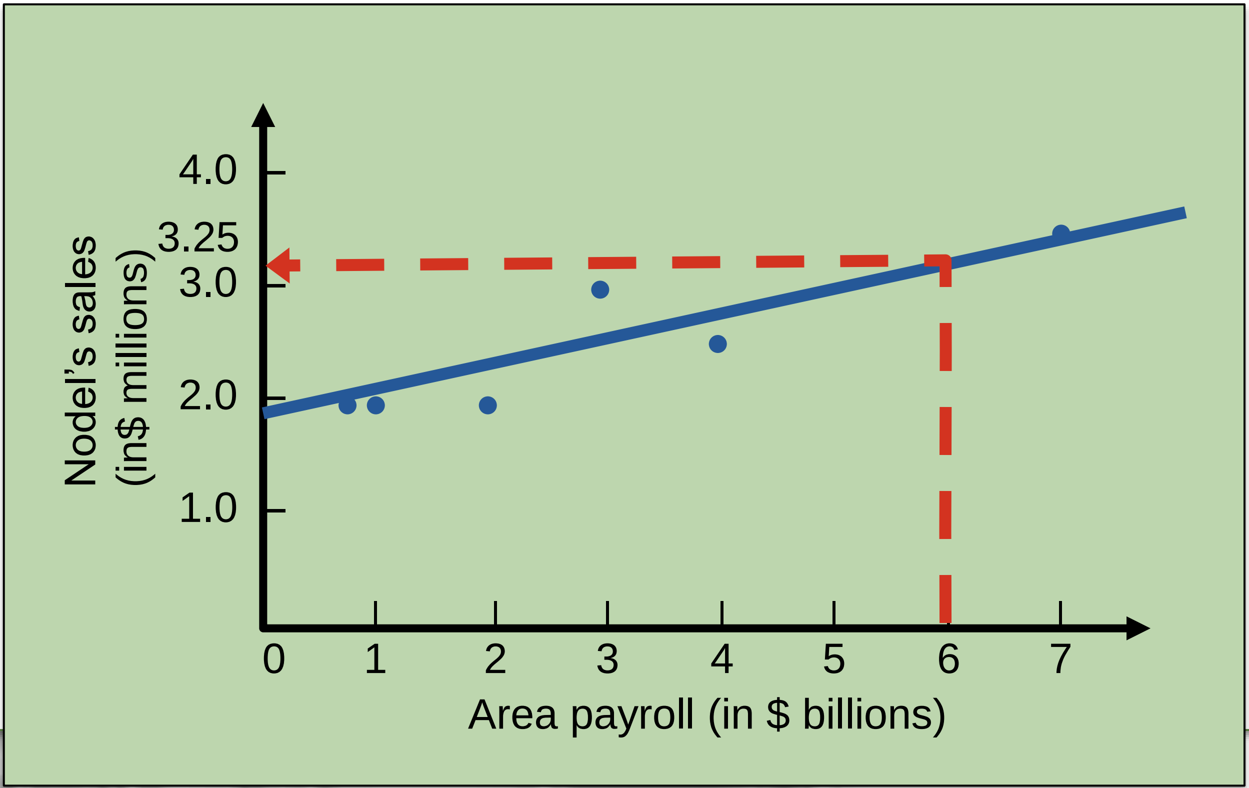
$$b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25$$

$$a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

Associative Forecasting Example

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

Sales (in $ millions) = 1.75 + .25(6)
= 1.75 + 1.5 = 3.25



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

Correlation Coefficient

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

Correlation

- 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

For the Nodel Construction example:

$r = .901$

$r^2 = .81$

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

$$\hat{y} = a + b_1 x_1 + b_2 x_2$$

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

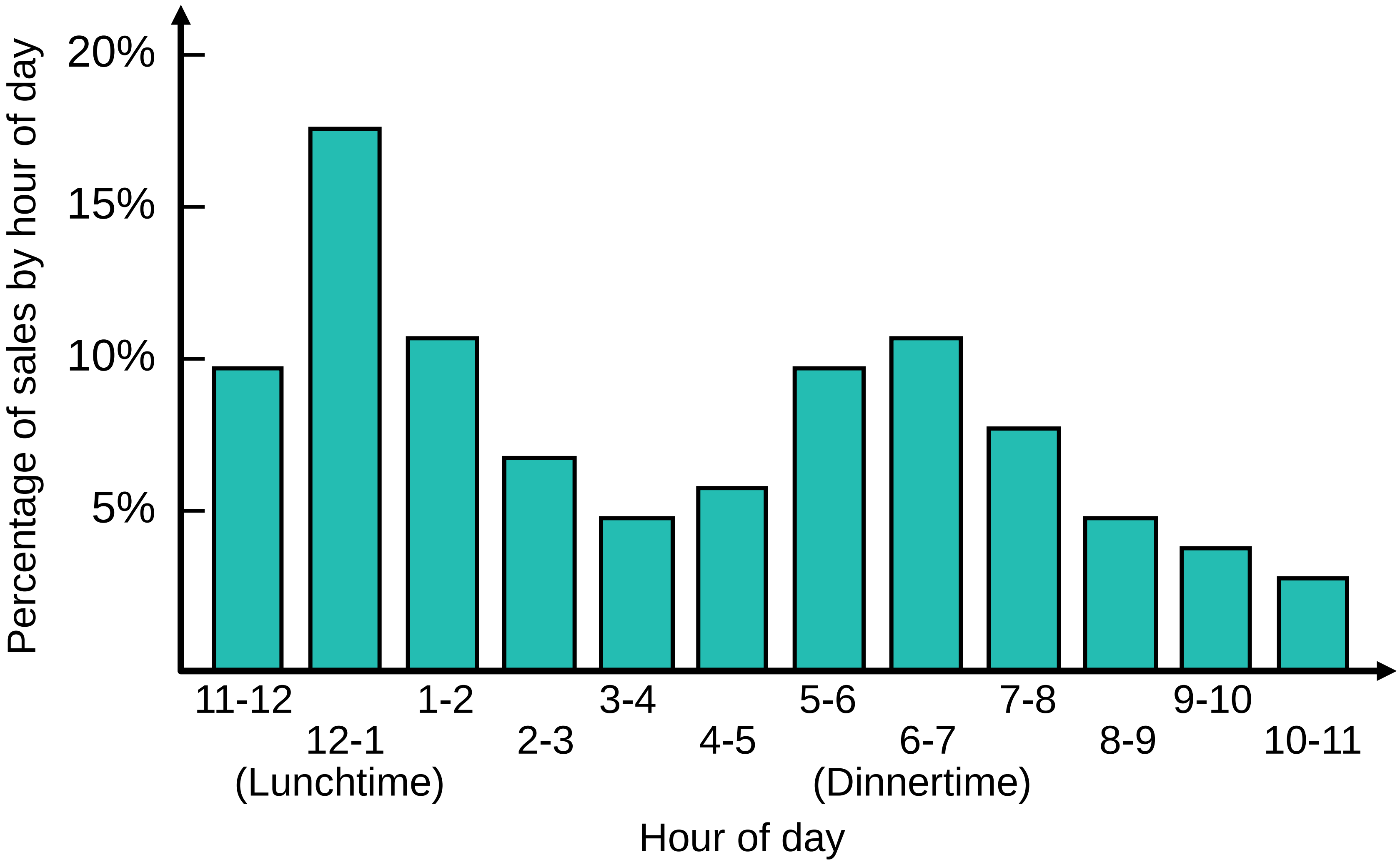
Focus Forecasting

- 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

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

Fast Food Restaurant Forecast



FedEx Call Center Forecast