Regents Park Publishers

Operations Management

T4LM1

Forecasting Methods

Outline – Continued

- **Forecasting Approaches**
  - **Overview of Qualitative Methods**
  - **Overview of Quantitative Methods**
- **Time-Series Forecasting**
  - **Decomposition of a Time Series**
  - **Naive Approach**

Outline – Continued

- **Time-Series Forecasting (cont.)**
  - **Moving Averages**
  - **Exponential Smoothing**
  - **Exponential Smoothing with Trend Adjustment**
  - **Trend Projections**
  - **Seasonal Variations in Data**
  - **Cyclical Variations in Data**

Outline – Continued

- **Associative Forecasting Methods: Regression and Correlation Analysis**
  - **Using Regression Analysis for Forecasting**
  - **Standard Error of the Estimate**
  - **Correlation Coefficients for Regression Lines**
  - **Multiple-Regression Analysis**

What is Forecasting?

What is Forecasting?

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

Forecasting Time Horizons

- Short-range forecast
  - Up to 1 year, generally less than 3 months
  - Purchasing, job scheduling, workforce levels, job assignments, production levels
- Medium-range forecast
  - 3 months to 3 years
  - Sales and production planning, budgeting
- Long-range forecast
  - 3^+ years
  - New product planning, facility location, research and development

Distinguishing Differences

- **Medium/long range forecasts deal with more comprehensive issues and support management decisions regarding planning and products, plants and processes**
- **Short-term forecasting usually employs different methodologies than longer-term forecasting**
- **Short-term forecasts tend to be more accurate than longer-term forecasts**

Types of Forecasts

- Economic forecasts
  - Address business cycle – inflation rate, money supply, housing starts, etc.
- Technological forecasts
  - Predict rate of technological progress
  - Impacts development of new products
- Demand forecasts
  - Predict sales of existing products and services

Strategic Importance of Forecasting

- **Human Resources – Hiring, training, laying off workers**
- **Capacity – Capacity shortages can result in undependable delivery, loss of customers, loss of market share**
- **Supply Chain Management – Good supplier relations and price advantages**

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
6. Make the forecast
7. Validate and implement results

The Realities!

- Forecasts are seldom perfect
- 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**

Qualitative Methods

Overview of Qualitative Methods

1. **Jury of executive opinion**

   Pool opinions of high-level experts, sometimes augment by statistical models. Internal staff.

2. **Delphi method**

   Panel of external experts, queried iteratively.

Overview of Qualitative Methods

3. **Sales force composite**

   Estimates from individual salespersons are reviewed for reasonableness, then aggregated

Consumer Market Survey

   Ask the customer. Not very reliable.

Jury of Executive Opinion

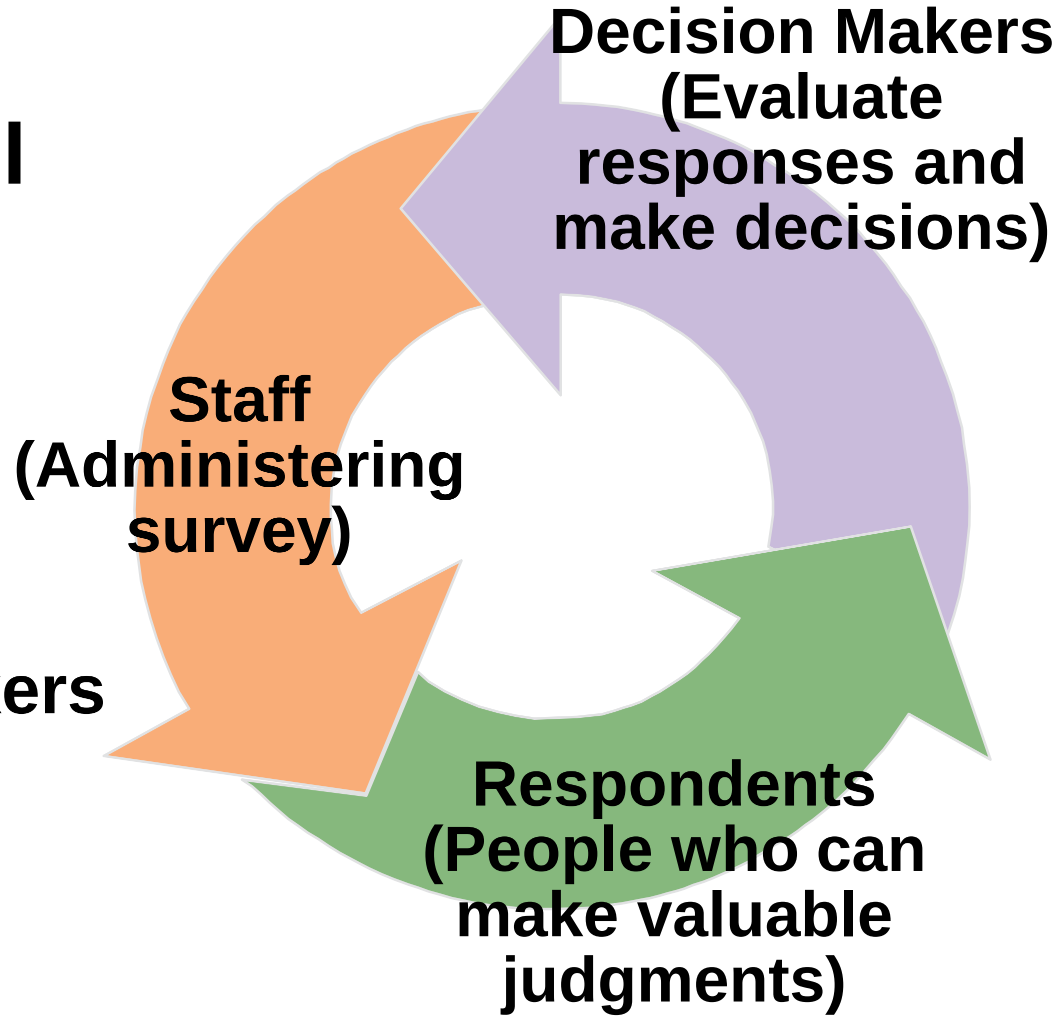
- Involves small group of high-level experts and managers
- Group estimates demand by working together
- Combines managerial experience with statistical models
- Relatively quick
- 'Group-think' disadvantage

Sales Force Composite

- **Each salesperson projects his or her sales**
- **Combined at district and national levels**
- **Sales reps know customers' wants**
- **Tends to be overly optimistic**

Delphi Method

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



Quantitative Methods

Overview of Quantitative Approaches

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

5. Linear regression

time-series models

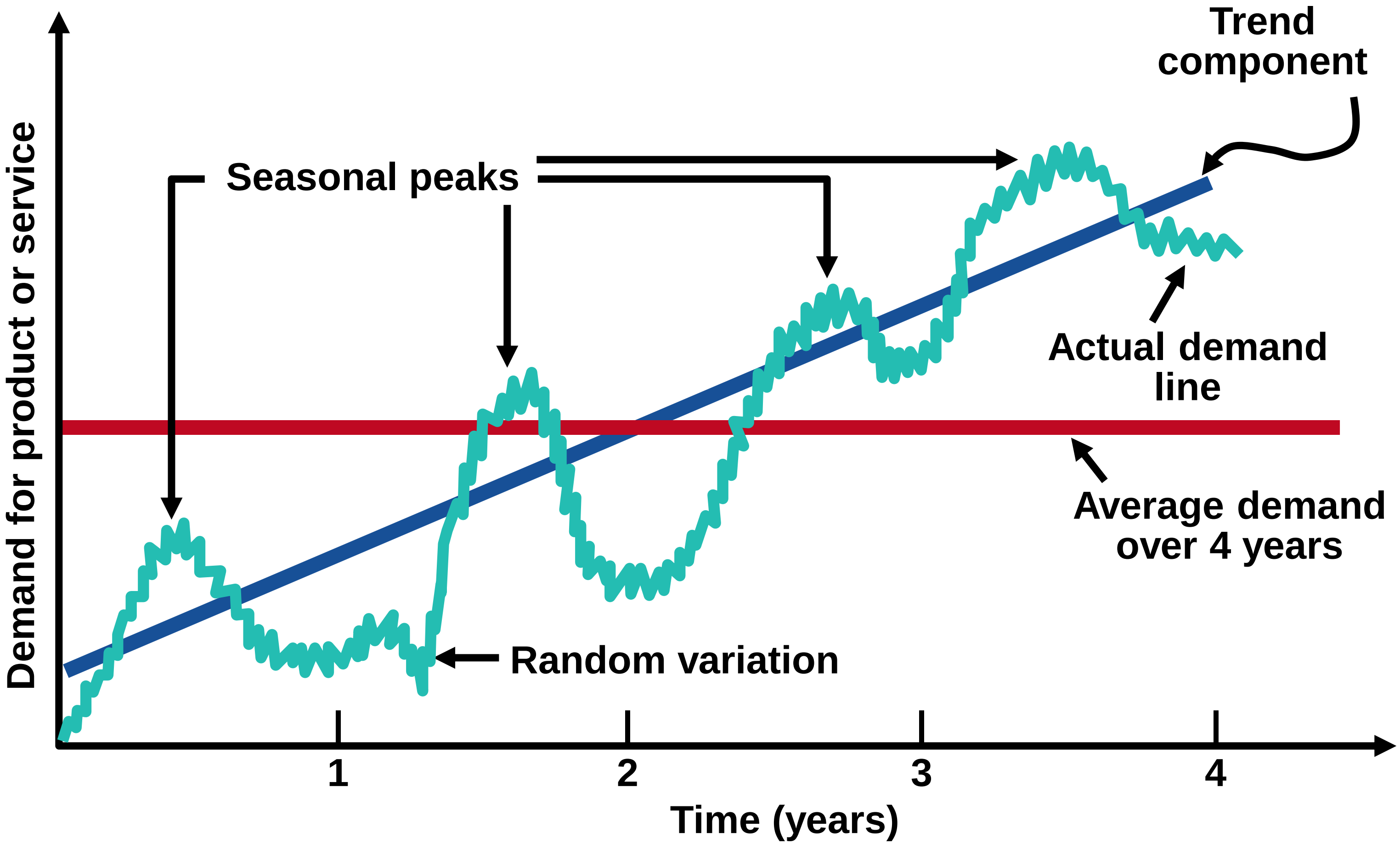
associative model

Time- series Forecasting

Time Series Forecasting

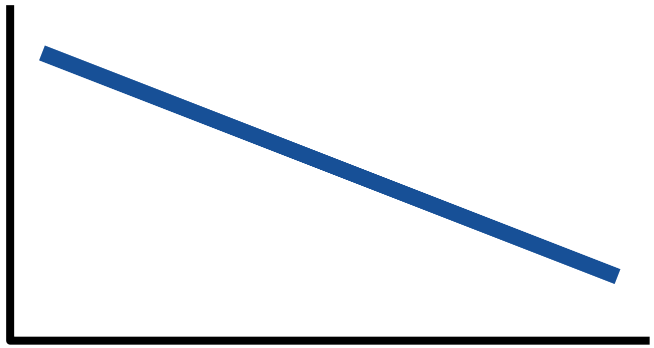
- **Set of evenly spaced numerical data**
  - **Obtained by observing response variable at regular time periods**
- **Forecast based only on past values, no other variables important**
  - **Assumes that factors influencing past and present will continue influence in future**

Components of Demand



Trend Component

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



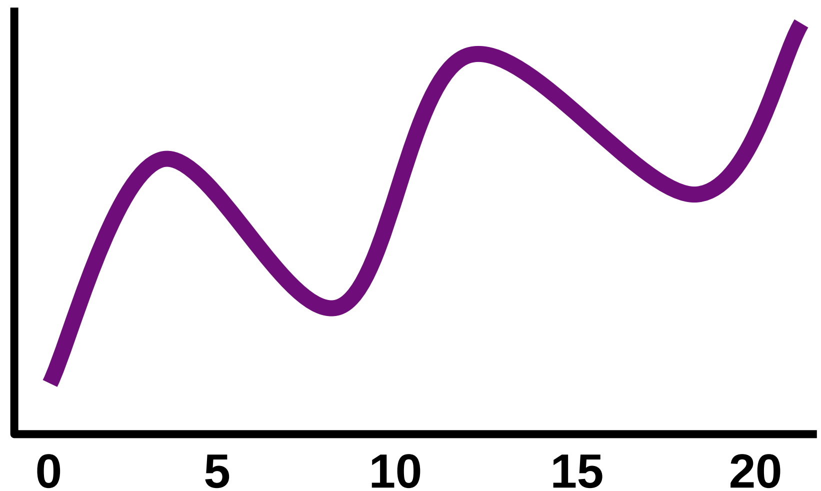
Seasonal Component

- Regular pattern of up and down fluctuations
- Due to weather, customs, etc.
- Occurs within a single year

Period	Length	Number of Seasons
Week	Day	7
Month	Week	4-4.5
Month	Day	28-31
Year	Quarter	4
Year	Month	12
Year	Week	52

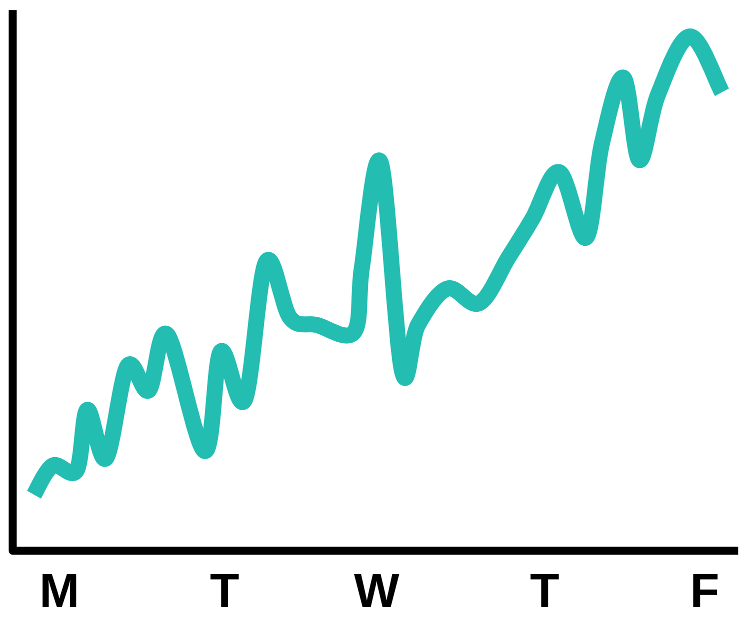
Cyclical Component

- 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 Averages

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 Example

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	$(16 + 19 + 23)/3 = 19\ ^1/_3$

Weighted Moving Average

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

$$\text{Weighted moving average} = \frac{\sum (\text{weight for period } n) \times (\text{demand in period } n)}{\sum \text{weights}}$$

Weighted Moving Average

Month	Actual Shed Sales	3-Month Weighted Moving Average
January	10	
February	12	
March	13	
April	16	$[(3 \times 13) + (2 \times 12) + (1 \times 10)]/6 = 12^1/_6$
May	19	
June	23	
July	26	

Weights Applied:

Last month	3
Two months ago	2
Three months ago	1
Sum of weights	6

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	$[(3 \times 23) + (2 \times 19) + (16)]/6 = 20^1/_2$

Potential Problems With Moving Average

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

Exponential Smoothing

Exponential Smoothing

- **Form of weighted moving average**
  - **Weights decline exponentially**
  - **Most recent data weighted most**
- **Requires smoothing constant (α)**
  - **Ranges from 0 to 1**
  - **Is subjectively chosen (trial and error)**
- **Involves 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 forecast

α = smoothing (or weighting) constant ($0 \leq \alpha \leq 1$)

Exponential Smoothing Example

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

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 (given)

New forecast = 142 + .2(153 – 142)

= 142 + 2.2

= 144.2 ≈

approximatelly144 cars

Measure of Error

Common Measure of Error

Mean Absolute Deviation (MAD)

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

n = number of observations

Absolute Value

Absolute Value= |Actual - Forecast|

Forecast Error

Q	Actual	Forecasted	Absolute Deviation
1	180	175.0	5.00
2	168	175.5	7.50
3	159	174.75	15.75
4	175	173.18	1.82
5	190	173.36	16.64
6	205	175.02	29.98
7	180	178.02	1.98
8	182	178.22	3.78
			82.45

Forecast Error

$$\text{MAD} = \frac{\sum |\text{deviations}|}{n}$$

= 82.45/8 = 10.31

Trend Projections

Trend Projections

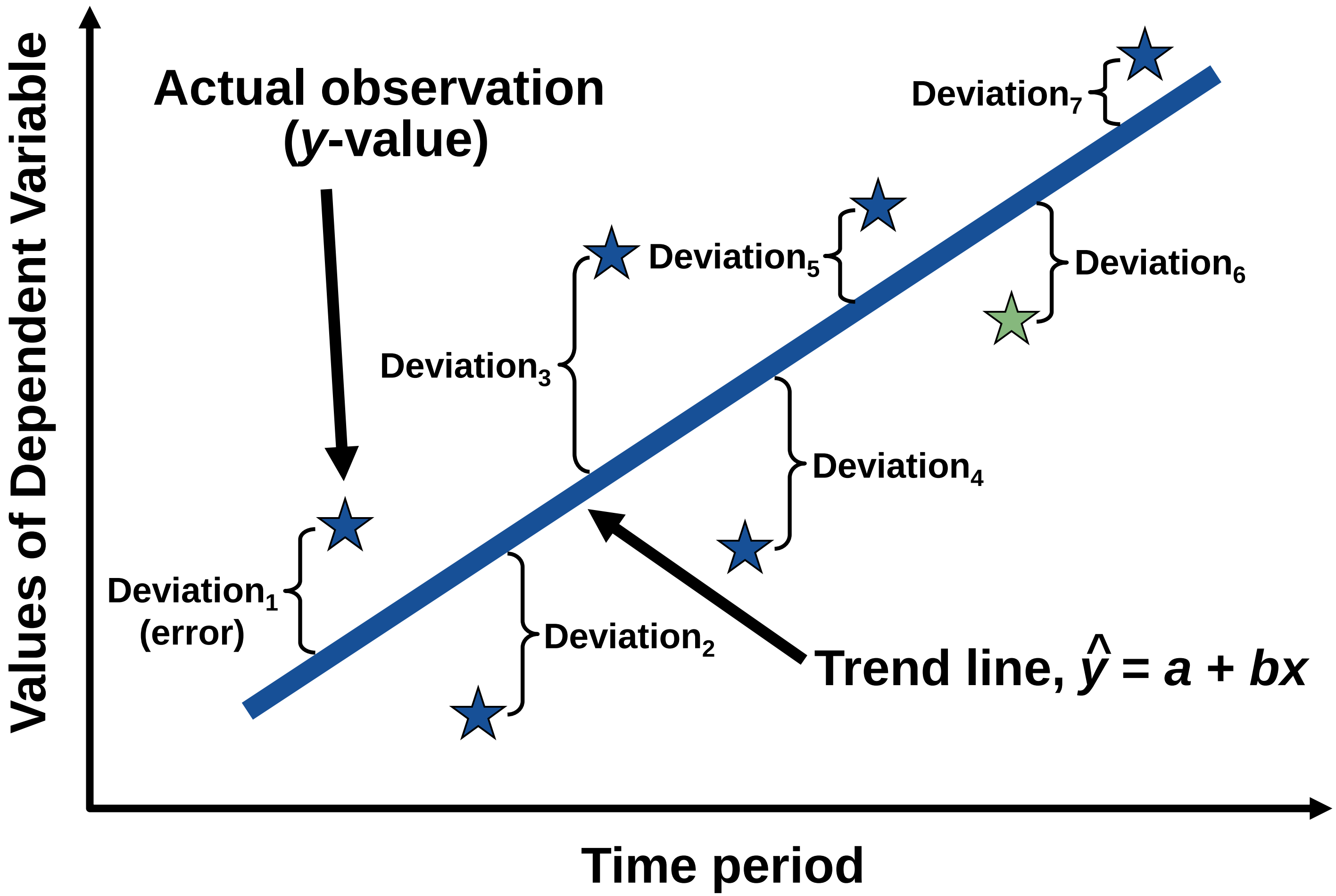
Fitting a trend line to historical data points to project into the medium to long-range

Linear trends can be found using the least squares technique

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

where $\hat{y}$ = computed value of the variable to be predicted (dependent variable)
a = y-axis intercept
b = slope of the regression line
x = the independent variable

Least Squares Method



Least Squares Method

Equations to calculate the regression variables

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

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

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

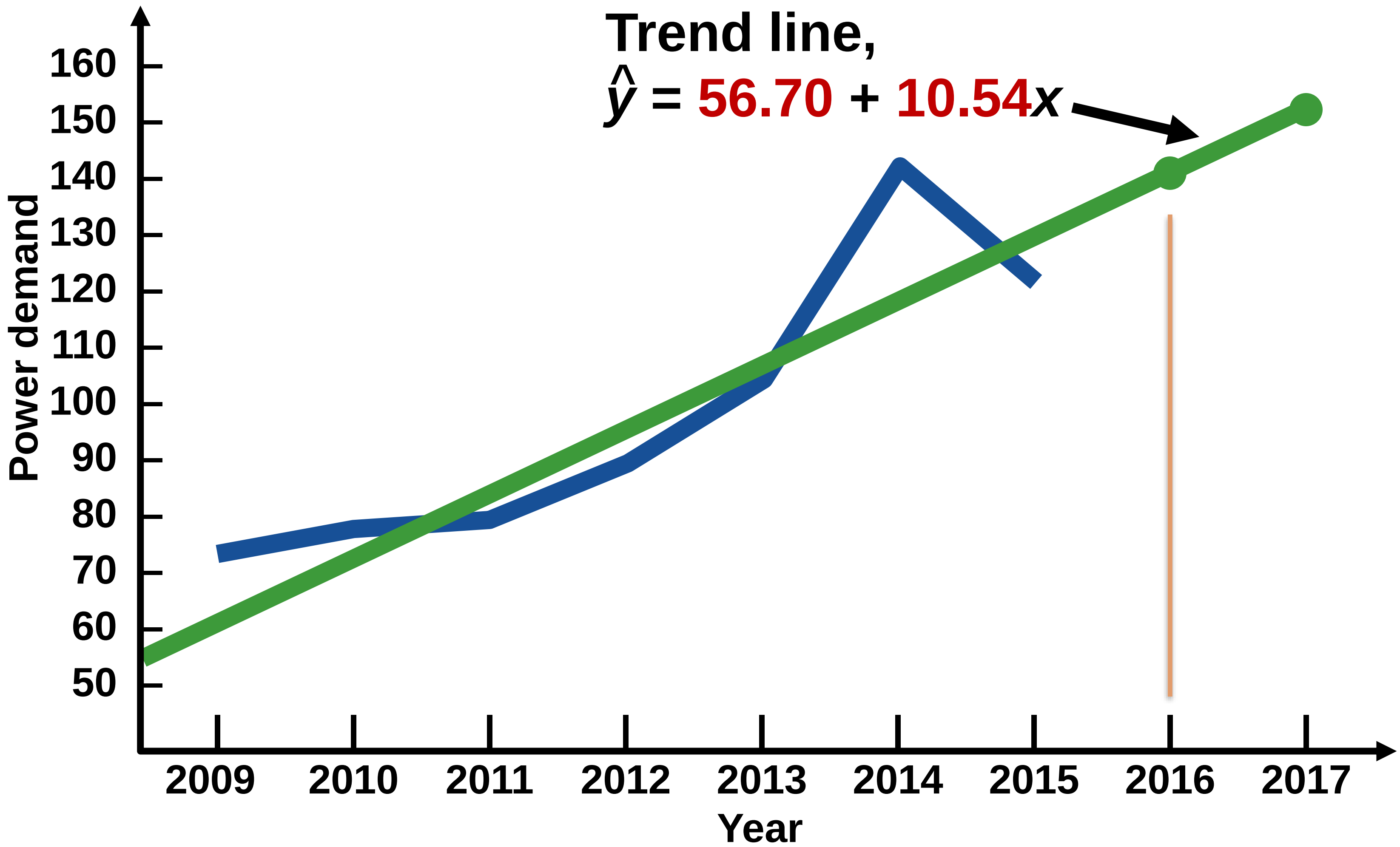
Least Squares Example

Year	Time Period (x)	Electrical Power Demand	x^2	xy
2003	1	74	1	74
2004	2	79	4	158
2005	3	80	9	240
2006	4	90	16	360
2007	5	105	25	525
2008	6	142	36	852
2009	7	122	49	854
	$\sum x = 28$	$\sum y = 692$	$\sum x^2 = 140$	$\sum xy = 3{,}063$
	$\bar{x} = 4$	$\bar{y} = 98.86$		

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

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

Least Squares Example



Correlation

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

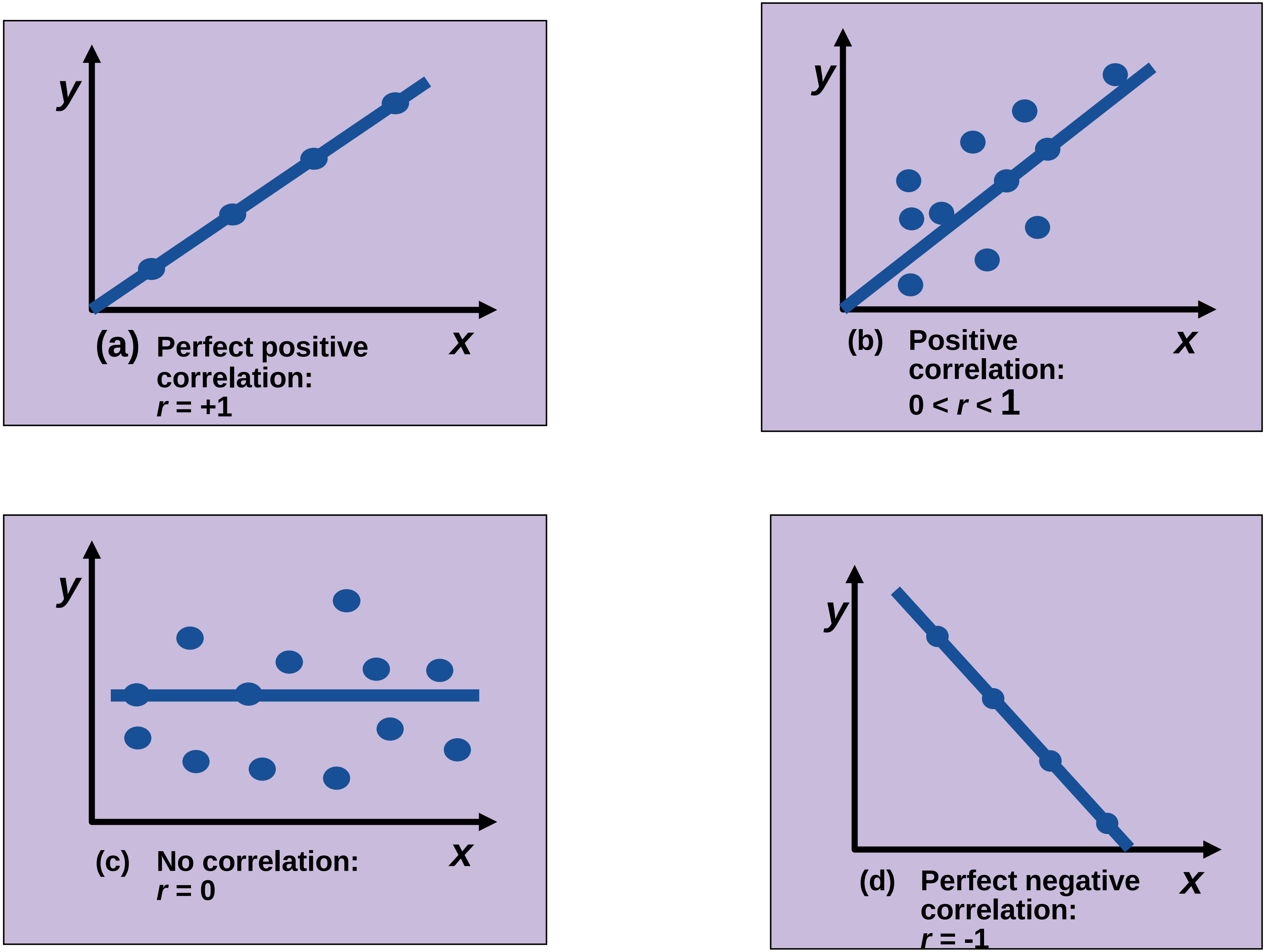
Correlation Coefficient

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

See Sample Problems for Excel based examples

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**


y
x
(a) Perfect positive correlation: r = +1
y
x
(b) Positive correlation: 0 < r < 1
y
x
(c) No correlation: r = 0
y
x
(d) Perfect negative correlation: r = -1

Simple Linear Regression

Simple Linear Regression

Used when changes in one or more independent variables can be used to predict the changes in the dependent variable

Most common technique is linear regression analysis

Simple Linear Regression

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

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

where $\hat{y}$ = computed value of the variable to be predicted (dependent variable)

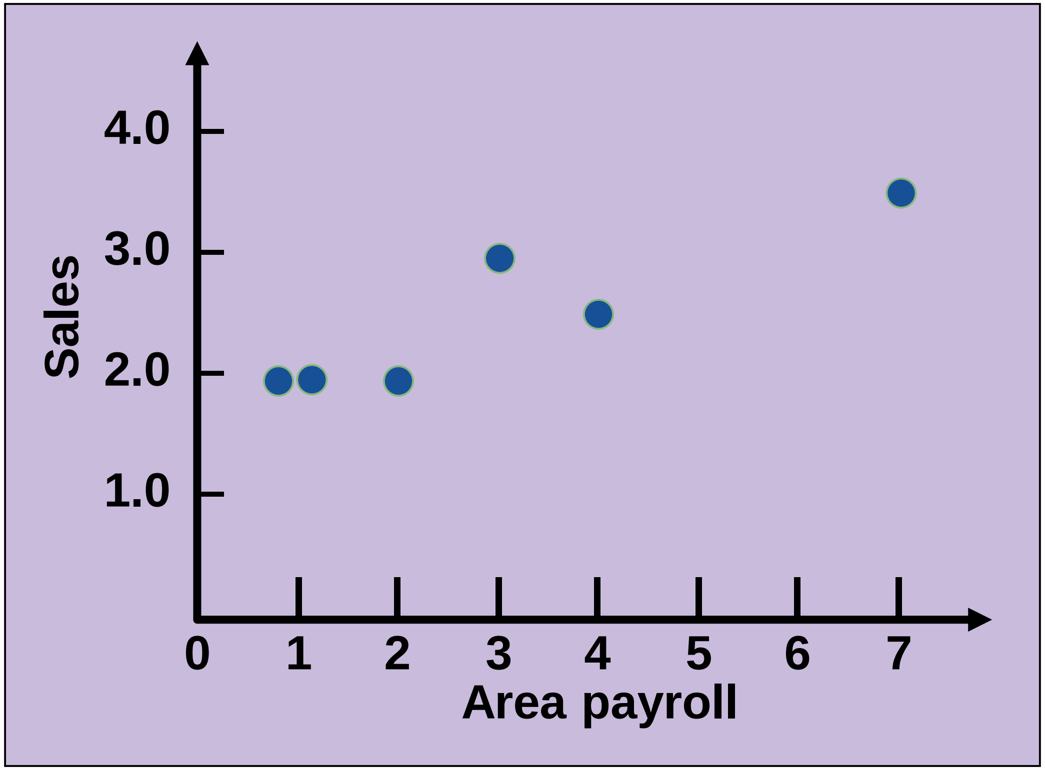
a = y-axis intercept

b = slope of the regression line

x = the independent variable though to predict the value of the dependent variable

Simple Linear Regression

Sales ($ millions), *y*	Area Payroll ($ billions), *x*
2.0	1
3.0	3
2.5	4
2.0	2
2.0	1
3.5	7



Simple Linear Regression

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

$$\bar{x} = \sum x/6 = 18/6 = 3 \qquad b = \frac{\sum xy - n\bar{x}\bar{y}}{\sum x^2 - n\bar{x}^2} = \frac{51.5 - (6)(3)(2.5)}{80 - (6)(3^2)} = .25$$

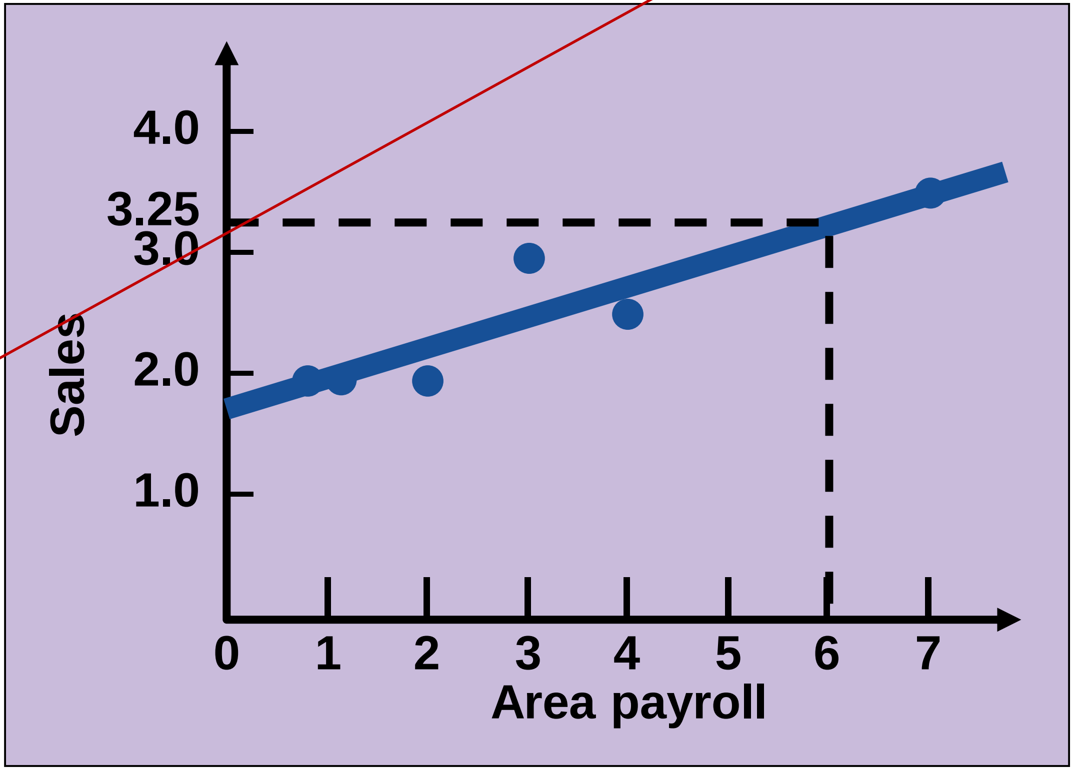
$$\bar{y} = \sum y/6 = 15/6 = 2.5 \qquad a = \bar{y} - b\bar{x} = 2.5 - (.25)(3) = 1.75$$

Simple Linear Regression

$\hat{y} = 1.75 + .25*x$ Sales = 1.75 + .25*(payroll)

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

Sales = 1.75 + .25(6)
Sales = $3,250,000



See Sample Problems for Excel based solutions.

Multiple Linear Regression

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

$$\hat{y} = a + b_1x_1 + b_2x_2 \ldots$$

See Sample Problems for Excel based solutions.

References

[Forecasting at Hard Rock Cafe]

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