CHAPTER 4 - DEMAND FORECASTING & COLLABORATIVE PLANNING, FORECASTING, & REPLENISHMENT

Principles of Supply Chain Management:

A Balanced Approach

Learning Objectives

You should be able to:

- Explain the role of demand forecasting in a supply chain.
- Identify the components of a forecast
- Compare and contrast qualitative and quantitative forecasting techniques
- Assess the accuracy of forecasts
- Explain collaborative planning, forecasting, and replenishment

Chapter Five Outline

- Introduction
- Matching Supply and Demand
- Forecasting Techniques
  - Qualitative Methods
  - Quantitative Methods
- Forecast Accuracy
- Collaborative Planning, Forecasting, and Replenishment
- Software Solutions

Introduction

- Forecasting provides an estimate of future demand
- The goal is to minimize forecast error.
- Factors that influence demand and whether these factors will continue to influence demand must be considered when forecasting.
- Improved forecasts benefit all trading partners in the supply chain.
- Better forecasts result in lower inventories, reduced stock-outs, smoother production plans, reduced costs, and improved customer service.

Matching Supply and Demand

- Suppliers must accurately forecast demand so they can produce & deliver the right quantities at the right time at the right cost.
- Suppliers must find ways to better match supply and demand to achieve optimal levels of cost, quality, and customer service to enable them to compete with other supply chains.
- Problems that affect product & delivery will have ramifications throughout the chain.

Forecasting Techniques

- ***Qualitative forecasting*** is based on opinion and intuition.

- ***Quantitative forecasting*** uses mathematical models and historical data to make forecasts.

- ***Time series*** models are the most frequently used among all the forecasting models.

Forecasting Techniques- Cont.

Qualitative Forecasting Methods

Generally used when data are limited, unavailable, or not currently relevant. Forecast depends on skill & experience of forecaster(s) & available information.

Four qualitative models used are:

1. **Jury of executive opinion**
2. **Delphi method**
3. **Sales force composite**
4. **Consumer survey**

Forecasting Techniques- Cont.

Quantitative Methods

- ***Time series forecasting-*** based on the assumption that the future is an extension of the past. Historical data is used to predict future demand.
- ***Associative forecasting-*** assumes that one or more factors (independent variables) predict future demand.

It is generally recommended to use a combination of quantitative and qualitative techniques.

Forecasting Techniques- Cont.

Components of Time Series- Data should be plotted to detect for the following components:

- **Trend variations:** either increasing or decreasing
- **Cyclical variations:** wavelike movements that are longer than a year
- **Seasonal variations:** show peaks and valleys that repeat over a consistent interval such as hours, days, weeks, months, years, or seasons
- **Random variations:** due to unexpected or unpredictable events

Forecasting Techniques- Cont.

Time Series Forecasting Models

- ***Simple Moving Average Forecasting Model***. Simple moving average forecasting method uses historical data to generate a forecast. Works well when demand is fairly stable over time.

$$F_{t+1} = \frac{\sum_{i=t-n+1}^{t} A_i}{n}$$

where

F_{t+1} = forecast for Period $t + 1$,
n = number of periods used to calculate moving average, and
A_i = actual demand in Period i.

SMA-Example

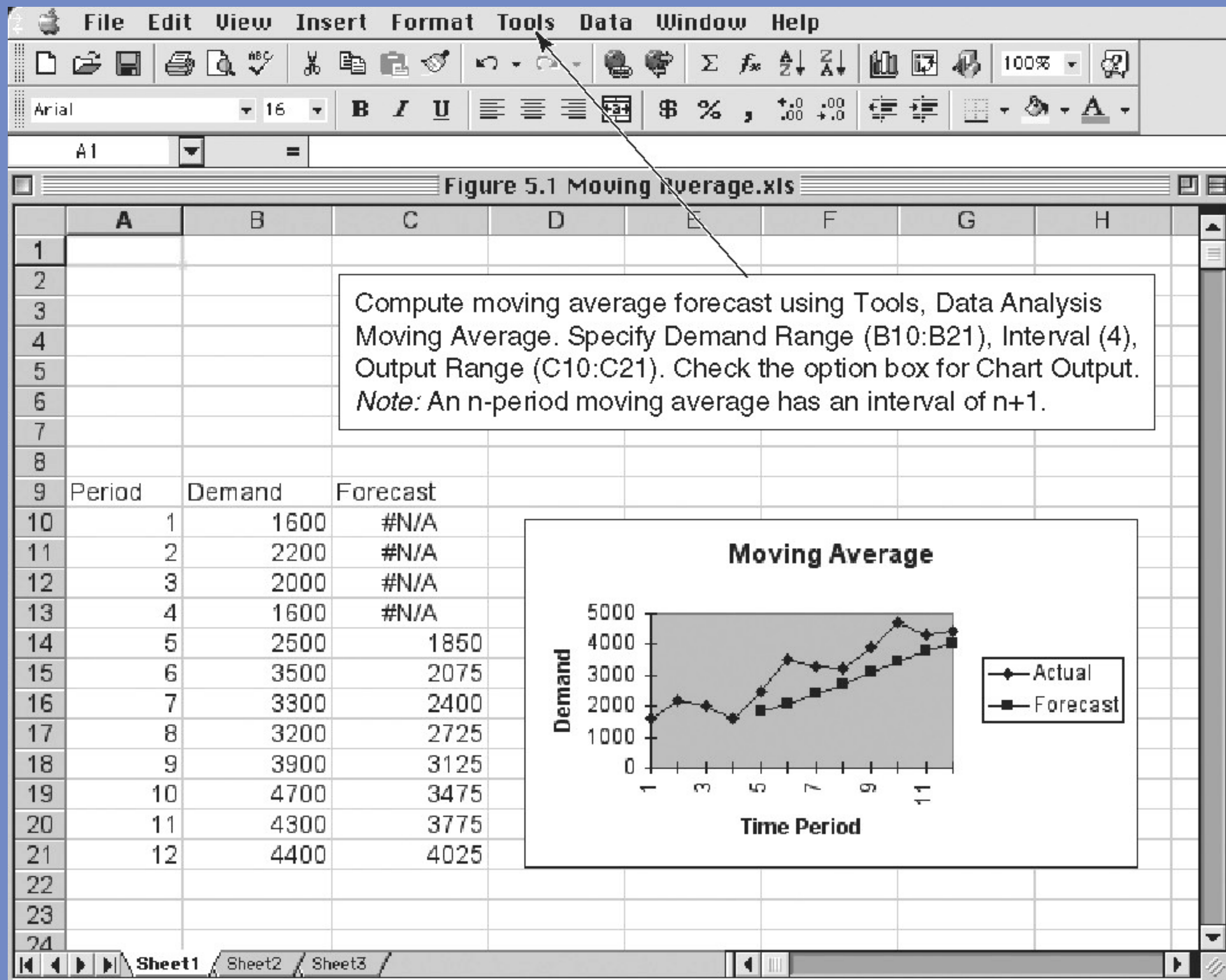
PERIOD	DEMAND
1	1600
2	2200
3	2000
4	1600
5	2500
6	3500
7	3300
8	3200
9	3900
10	4700
11	4300
12	4400

Using the data provided, calculate the forecast for period 5 using a four-period simple moving average.

SOLUTION

$$F_5 = \text{forecast for period } 5 = \frac{1600 + 2200 + 2000 + 1600}{4} = 1850$$

Forecasting Techniques- Cont.



Period	Demand	Forecast
1	1600	#N/A
2	2200	#N/A
3	2000	#N/A
4	1600	#N/A
5	2500	1850
6	3500	2075
7	3300	2400
8	3200	2725
9	3900	3125
10	4700	3475
11	4300	3775
12	4400	4025

Forecasting Techniques- Cont.

Time Series Forecasting Models

- ***Weighted Moving Average Forecasting Model-*** based on an n-period weighted moving average, follows:

$$F_{t=1} = \sum_{i=t-n+1}^{t} w_i A_i$$

where

F_{t+1} = forecast for Period $t + 1$,
n = number of periods used in determining the moving average,
A_i = actual demand in Period i, and
w_i = weight assigned to Period i (with $\Sigma w_i = 1$).

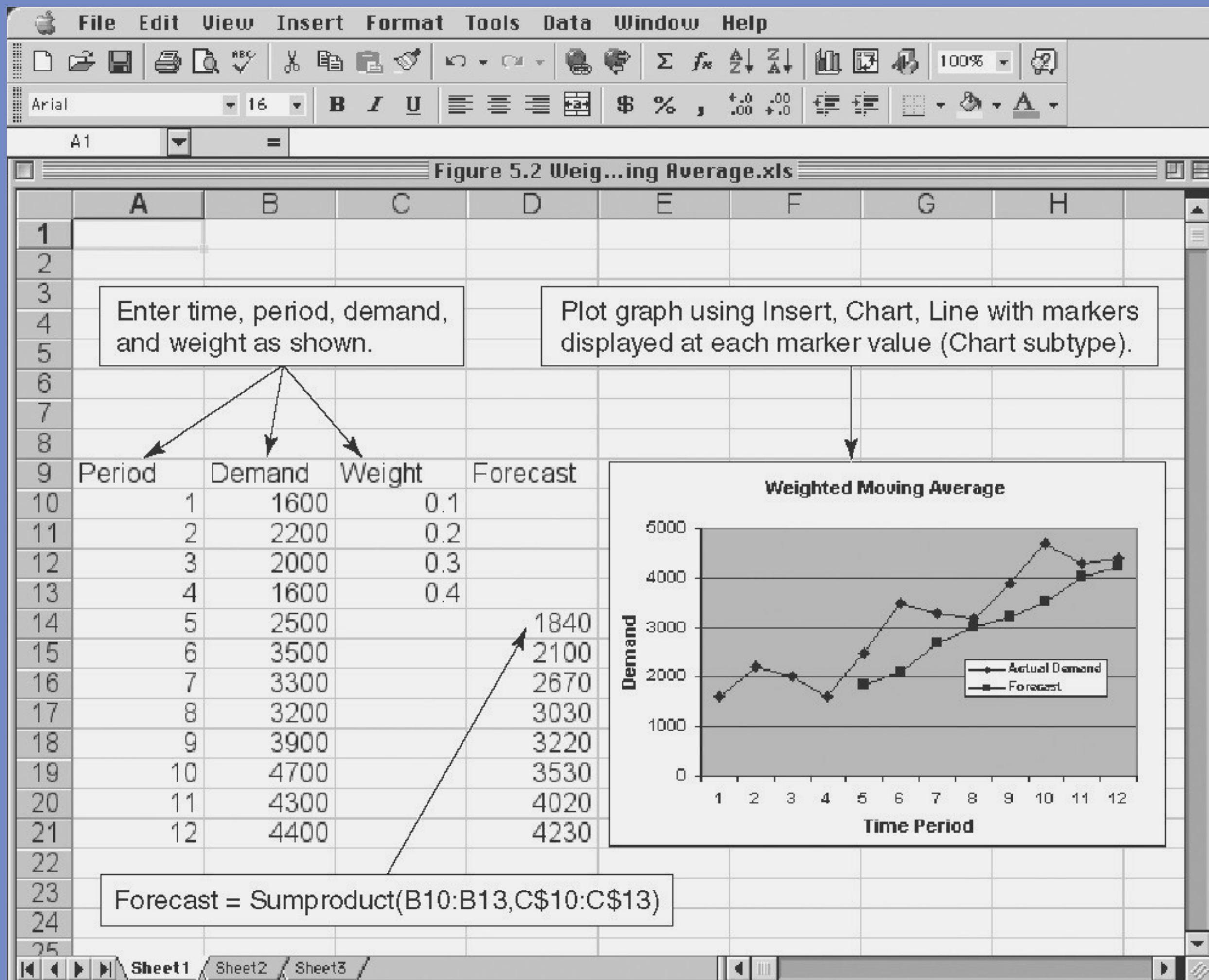
WMA-Example

Calculate the forecast for period 5 using a four-period weighted moving average for the same data (previous example). The weights of 0.4, 0.3, 0.2 and 0.1 are assigned to the most recent, second most recent, third most recent and fourth most recent periods respectively,

SOLUTION

$$F_5 = 0.1(1600) + 0.2(2200) + 0.3(2000) + 0.4(1600) = 1840$$

Forecasting Techniques- Cont.



Forecasting Techniques- Cont.

Time Series Forecasting Models

– ***Exponential Smoothing Forecasting Model-*** a weighted moving average in which the forecast for the next period's demand is the current period's forecast adjusted by a fraction of the difference between the current period's actual demand and its forecast. ***Only two data points are needed***.

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

Where

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

F_t = forecast for Period t

A_t = actual demand for Period t

α = a smoothing constant ($0 \le \alpha \le 1$).

Exponential Smoothing-Example

Based on the data for previous example, calculate the forecast for period 3 using exponential smoothing method. Assume that the forecast for period 2 is 1600 and use a smoothing constant (α) of 0.3.

SOLUTION

Given: $F_2 = 1600$, $\alpha = 0.3$

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

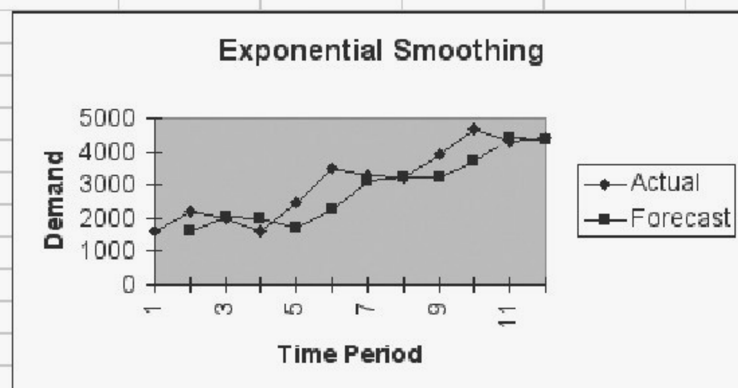
$$F_3 = F_2 + \alpha(A_2 - F_2) = 1600 + 0.3(2200 - 1600) = 1780$$

Thus, the forecast for week 3 is 1780.

Forecasting Techniques- Cont.

Compute exponential smoothing forecast using Tools, Data Analysis, Exponential Smoothing. Specify Demand Range (B10:B21), Damping Factor (0.3), Output Range (C10:C21). Check the option box for Chart Output.
Note: The forecast for Period 2 is the actual demand for Period 1 (naïve method).

Period	Demand	Forecast
1	1600	#N/A
2	2200	1600
3	2000	2020
4	1600	2006
5	2500	1721.8
6	3500	2266.54
7	3300	3129.962
8	3200	3248.989
9	3900	3214.697
10	4700	3694.409
11	4300	4398.323
12	4400	4329.497



Forecasting Techniques- Cont.

Time Series Forecasting Models

- ***Trend-Adjusted Exponential Smoothing forecasting Model***. a trend component in the time series shows a systematic upward or downward trend in the data over time.

$$F_t = \alpha A_t + (1 - \alpha)(F_{t+1} + T_{t-1}),$$

$$T_t = ß(F_t - F_{t-1}) + (1 – ß)T_{t-1},$$

and the trend-adjusted forecast,

$$TAF_{t+m} = F_t + mT_t$$

- where

F_t = exponentially smoothed average in Period t

A_t = actual demand in Period t

T_t = exponentially smoothed trend in Period t

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

ß = smoothing constant for trend ($0 \leq ß \leq 1$)

Forecasting Techniques- Cont.

Time Series Forecasting Models

– ***Linear Trend Forecasting Model***. The trend can be estimated using simple linear regression to fit a line to a time series.

$$\hat{Y} = b_0 + b_1 x$$

– where

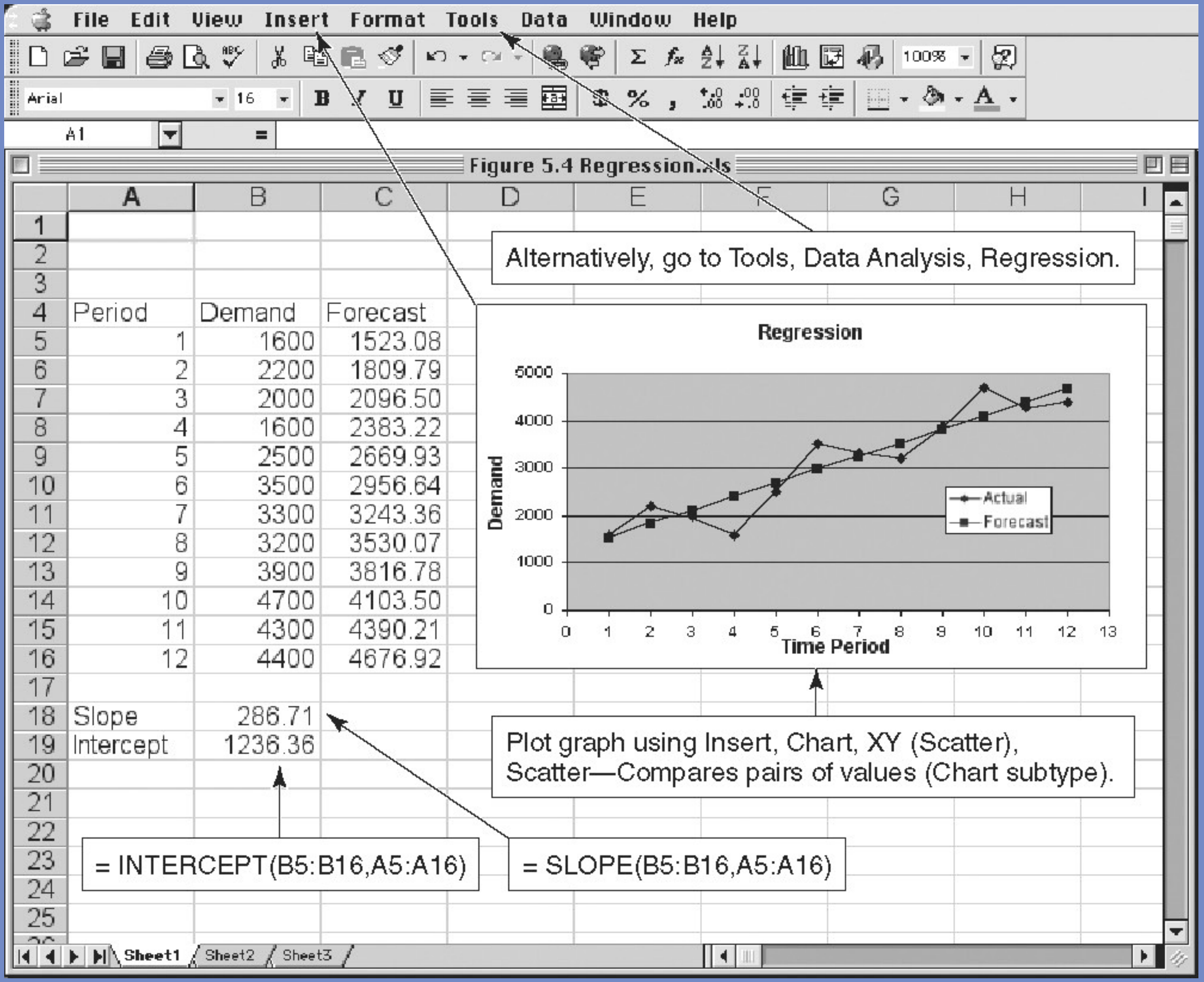
$\hat{Y}$ = forecast or dependent variable

x = time variable

B_0 = intercept of the line

b_1 = slope of the line

Forecasting Techniques- Cont.



Forecasting Techniques- Cont.

Associative Forecasting Models- One or several external variables are identified that are related to demand

- ***Simple regression***. Only one explanatory variable is used and is similar to the previous trend model. The difference is that the *x* variable is no longer a time but an explanatory variable.

$$\hat{Y} = b_0 + b_1 x$$

- where

  $\hat{Y}$ = forecast or dependent variable

  x = explanatory or independent variable

  b_0 = intercept of the line

  b_1 = slope of the line

Least Squares Method

Equations to calculate the regression variables

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

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

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

LSM-Example

Year	Time Period (x)	Electrical Power Demand	x^2	xy
2001	1	74	1	74
2002	2	79	4	158
2003	3	80	9	240
2004	4	90	16	360
2005	5	105	25	525
2005	6	142	36	852
2007	7	122	49	854
	$\sum x = 28$	$\sum y = 692$	$\sum x^2 = 140$	$\sum xy = 3{,}063$
	$\bar{x} = 4$	$\bar{y} = 98.86$		

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

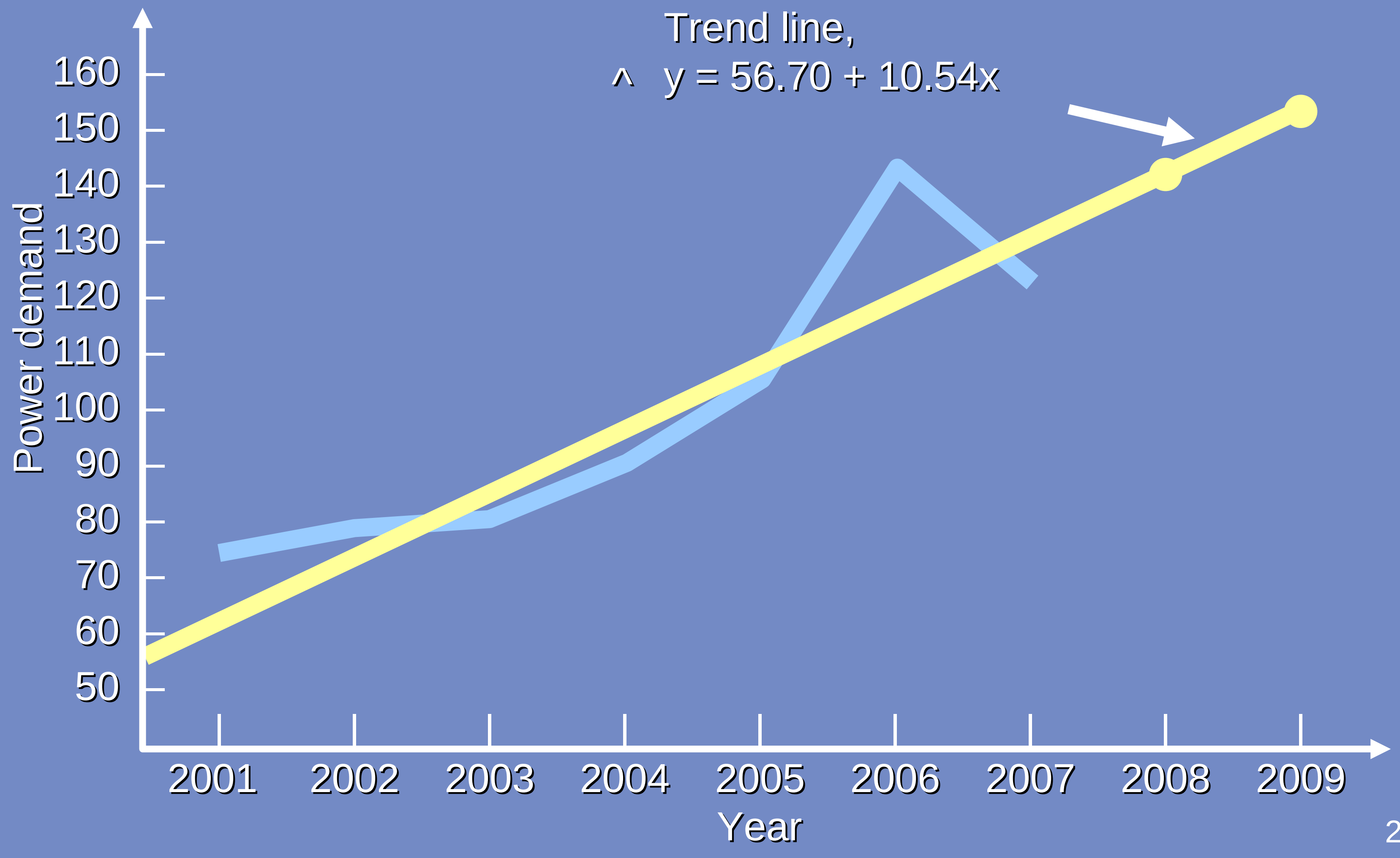
$$a = \bar{y} - b\bar{x} = 98.86 - 10.54(4) = 56.70$$

Example-Cont.

The trend line is

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

Example-Cont.



Forecasting Techniques- Cont.

Associative Forecasting Models-

– ***Multiple regression***. Where several explanatory variables are used to make the forecast.

$$\hat{Y} = b_0 + b_1 x_1 + b_2 x_2 + \ . \ . \ . \ b_k x_k$$

– where

$\hat{Y}$ = forecast or dependent variable

x_k = kth explanatory or independent variable

b_0 = intercept of the line

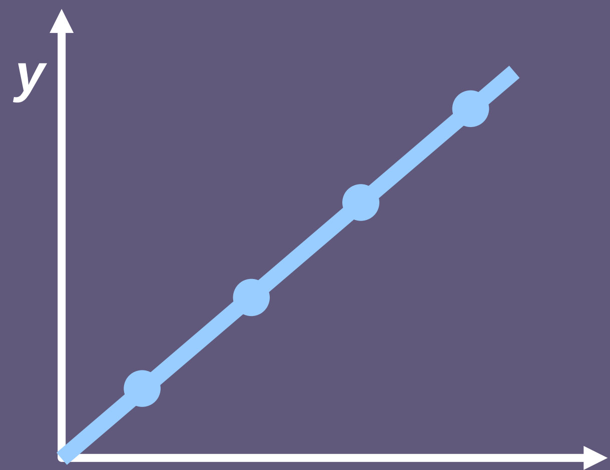
b_k = regression coefficient of the independent variable x_k

Least Squares Requirements

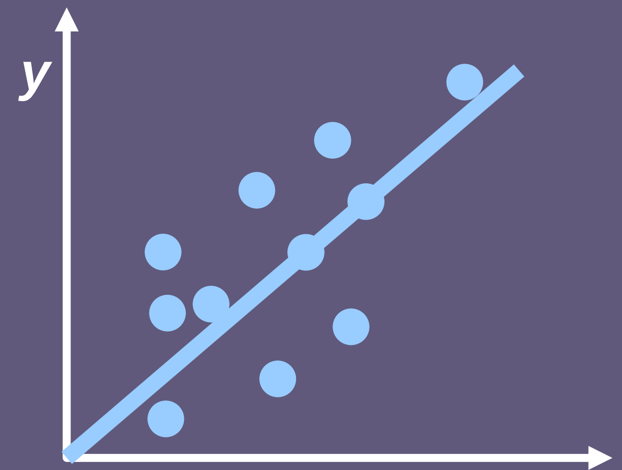
1. We always plot the data to insure a linear relationship
2. We do not predict time periods far beyond the database
3. Deviations around the least squares line are assumed to be random

Correlation

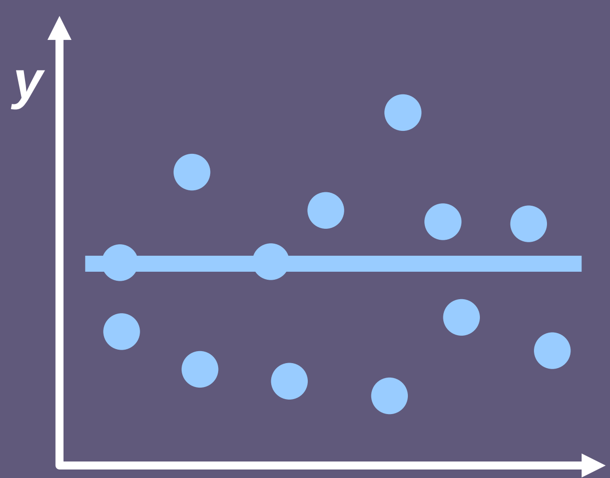
- How strong is the linear relationship between the variables?
- Correlation does not necessarily imply causality!
- Coefficient of correlation, r, measures degree of association
  - Values range from -1 to +1



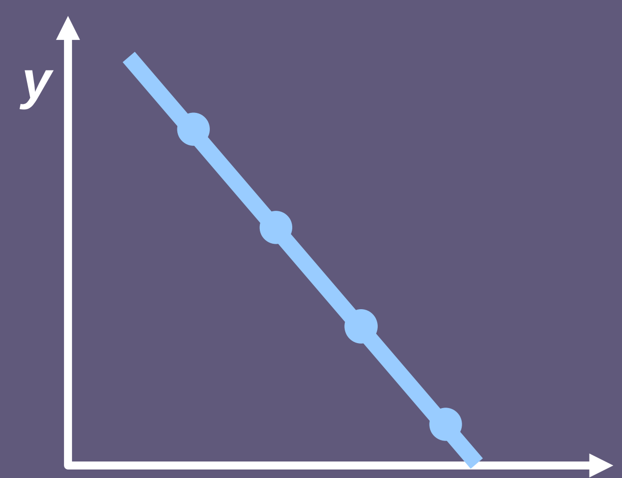
(a) Perfect positive correlation:
r = +1



(b) Positive correlation:
0 < *r* < 1



(c) No correlation:
r = 0



(d) Perfect negative correlation:
r = -1

Correlation Coefficient

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

Coefficient of Determination

- 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

Forecast Accuracy

The formula for ***forecast error***, defined as the difference between actual quantity and the forecast, follows:

Forecast error, $e_t = A_t - F_t$

where

e_t = forecast error for Period t

A_t = actual demand for Period t

F_t = forecast for Period t

Several measures of forecasting accuracy follow:

- ***Mean absolute deviation*** **(MAD)**- a MAD of 0 indicates the forecast exactly predicted demand.
- ***Mean absolute percentage error*** **(MAPE)**- provides perspective of the true magnitude of the forecast error.
- ***Mean squared error*** **(MSE)**- analogous to variance, large forecast errors are heavily penalized
- ***Running sum of forecast error*** **(RSFE)**- sum off all errors for period t.

Formulae

$$\text{Mean absolute deviation (MAD)} = \frac{\sum_{t=1}^{n} |e_t|}{n}$$

$$\text{Mean absolute percentage error (MAPE)} = \frac{100}{n} \sum_{t=1}^{n} \left| \frac{e_t}{A_t} \right|$$

$$\text{Mean square error (MSE)} = \frac{\sum_{t=1}^{n} e_t^2}{n}$$

$$\text{Running sum of forecast errors (RSFE)} = \sum_{t=1}^{n} e_t$$

where e_t = forecast error for period t;

A_t = actual demand for period t;

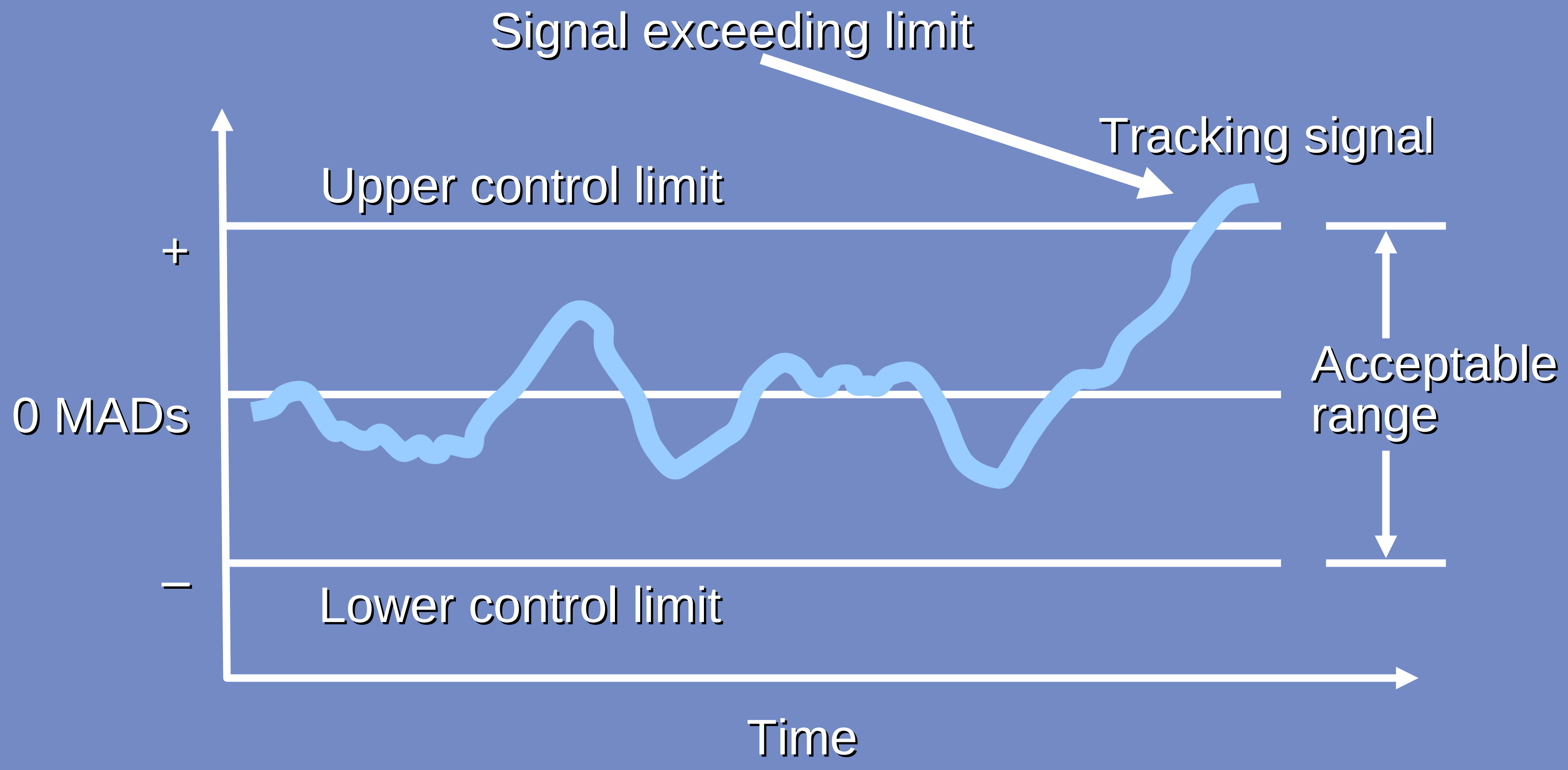
n = number of periods of evaluation.

Monitoring and Controlling Forecasts

Tracking Signal

- ☑ Measures how well the forecast is predicting actual values
- ☑ Ratio of running sum of forecast errors (RSFE) to mean absolute deviation (MAD)
  - ☑ Good tracking signal has low values
  - ☑ If forecasts are continually high or low, the forecast has a bias error

Tracking Signal



Example

The demand and forecast information for the XYZ Company over a 12-month period is shown in the table below.

PERIOD	DEMAND	FORECAST	PERIOD	DEMAND	FORECAST
1	1600	1523	7	3300	3243
2	2200	1810	8	3200	3530
3	2000	2097	9	3900	3817
4	1600	2383	10	4700	4103
5	2500	2670	11	4300	4390
6	3500	2957	12	4400	4677

Calculate the MAD, MSE, MAPE, RSFE and tracking signal. Assume that the control limit for the tracking signal is ± 3. What can we conclude about the quality of the forecasts?

Example-Cont.

PERIOD	DEMAND	FORECAST	ERROR (e)	ABSOLUTE ERROR	e^2	ABSOLUTE % ERROR
1	1600	1523	77	77	5929	4.8
2	2200	1810	390	390	152,100	17.7
3	2000	2097	–97	97	9409	4.9
4	1600	2383	–783	783	613,089	48.9
5	2500	2670	–170	170	28,900	6.8
6	3500	2957	543	543	294,849	15.5
7	3300	3243	57	57	3249	1.7
8	3200	3530	–330	330	108,900	10.3
9	3900	3817	83	83	6889	2.1
10	4700	4103	597	597	356,409	12.7
11	4300	4390	–90	90	8100	2.1
12	4400	4677	–277	277	76,729	6.3
Total			0	3494	1,664,552	133.9
Average				291.17	138,712.7	11.16
			RSFE	MAD	MSE	MAPE

$$\text{MAD} = 291.2$$

$$\text{MSE} = 138{,}712.7$$

$$\text{MAPE} = 11.2\%$$

$$\text{RSFE} = 0$$

$$\text{Tracking signal} = \frac{RSFE}{MAD} = 0$$

The results indicate no bias and the tracking signal is well within the control limit. However, the forecast are on average 291 units or 11.2% **off** from the actual demand. The situation might require attention to determine the underlaying cause of variation.

Collaborative Planning, Forecasting, and Replenishment

Collaborative Planning, Forecasting, & Replenishment

"Collaboration process whereby supply chain trading partners can jointly plan key supply chain activities from production and delivery of raw materials to production and delivery of final products to end customers"

American Production and Inventory Control Society (APICS).

Objective of CPFR- optimize supply chain through improved demand forecasts, with the right product delivered at right time to the right location, with reduced inventories, avoidance of stock-outs, & improved customer service.

Value of CPFR- broad and open exchange of forecasting information to improve forecasting accuracy when both the buyer and seller collaborate through joint knowledge of base sales, promotions, store openings or closings, & new product introductions.

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Collaborative Planning, Forecasting, and Replenishment

Most firms implement CPFR based on Voluntary Interindustry Commerce Standards Process Model

Step 1: Develop Collaboration Arrangement

Step 2: Create Joint Business Plan

Step 3: Create Sales Forecast

Step 4: Identify Exceptions for Sales Forecast

Step 5: Resolve/Collaborate on Exception Items

Step 6: Create Order Forecast

Step 7: Identify Exceptions for Order Forecast

Step 8: Resolve/Collaborate on Exception Items

Step 9: Order Generation

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Practice Question 1

Data on sales and advertising dollars for the past six months are shown below.

$ SALES (*Y*)	$ ADVERTISING (*X*)
100,000	2000
150,000	3000
125,000	2500
50,000	1000
170,000	3500
135,000	2750

Determine the linear relationship between sales and advertising dollars.

Practice Question 2

The owner of the Chocolate Outlet Store wants to forecast chocolate demand.

Demand for the preceding four years is shown in the following table:

YEAR	DEMAND (POUNDS)
1	68,800
2	71,000
3	75,500
4	71,200

Forecast demand for Year 5 using the following approaches: (1) a three-year moving average; (2) a three-year weighted moving average using .40 for Year 4, .20 for Year 3 and .40 for Year 2; (3) exponential smoothing with $\alpha = .30$, and assuming the forecast for Period 1 = 68,000.

Activate Windows

Practice Question 3

The forecasts generated by two forecasting methods and actual sales are as follows:

MONTH	SALES	FORECAST 1	FORECAST 2
1	269	275	268
2	289	266	287
3	294	290	292
4	278	284	298
5	268	270	274
6	269	268	270
7	260	261	259
8	275	271	275

Compute the MSE, the MAD, the MAPE, the RSFE and the tracking signal for each forecasting method. Which method is better? Why?