Forecasting

Industrial Management

IPE 4102

Learning Objectives

- ❑ List features common to all forecasts
- ❑ Explain why forecasts are generally wrong
- ❑ List elements of a good forecast
- ❑ Outline the steps in the forecasting process
- ❑ Summarize forecast errors and use summaries to make decisions
- ❑ Describe four qualitative forecasting techniques
- ❑ Use a naïve method to make a forecast
- ❑ Prepare a moving average forecast
- ❑ Prepare a weighted-average forecast
- ❑ Prepare an exponential smoothing forecast
- ❑ Prepare a linear trend forecast
- ❑ Prepare a trend-adjusted exponential smoothing forecast
- ❑ Compute and use seasonal relatives
- ❑ Compute and use regression and correlation coefficients
- ❑ Construct control charts and use them to monitor forecast errors
- ❑ Describe the key factors and trade-offs to consider when choosing a forecasting technique

Forecast

- A statement about the future value of a variable of interest such as demand.
- Forecasting is used to make *informed* decisions.
- Long-range
- Short-range

Forecasts

Forecasts affect decisions and activities throughout an organization

- Accounting, finance
- Human resources
- Marketing
- MIS
- Operations
- Product / service design

Uses of Forecasts

Accounting	Cost/profit estimates
Finance	Cash flow and funding
Human Resources	Hiring/recruiting/training
Marketing	Pricing, promotion, strategy
MIS	IT/IS systems, services
Operations	Schedules, MRP, workloads
Product/service design	New products and services

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Features Common to All Forecasts

Techniques assume some underlying causal system that existed in the past will persist into the future

Forecasts are not perfect

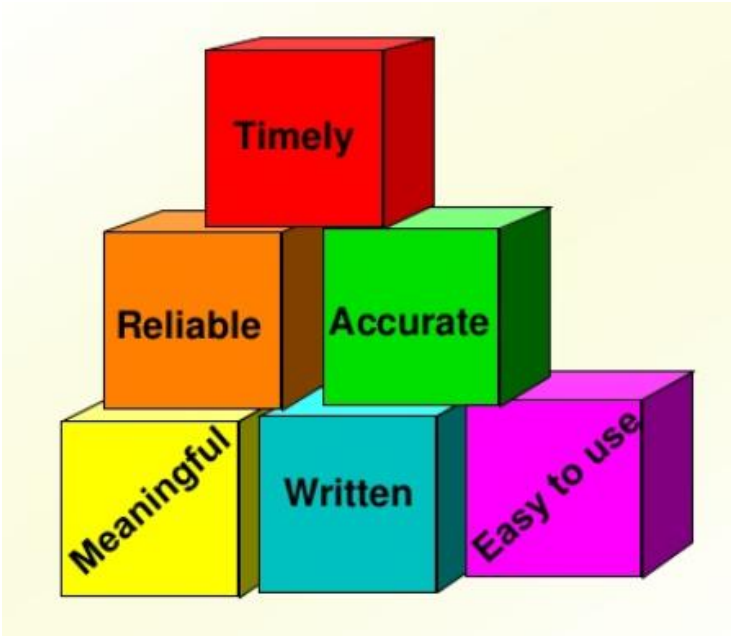
Forecasts for groups of items are more accurate than those for individual items

Forecast accuracy decreases as the forecasting horizon increases

Elements of a Good Forecast

The forecast

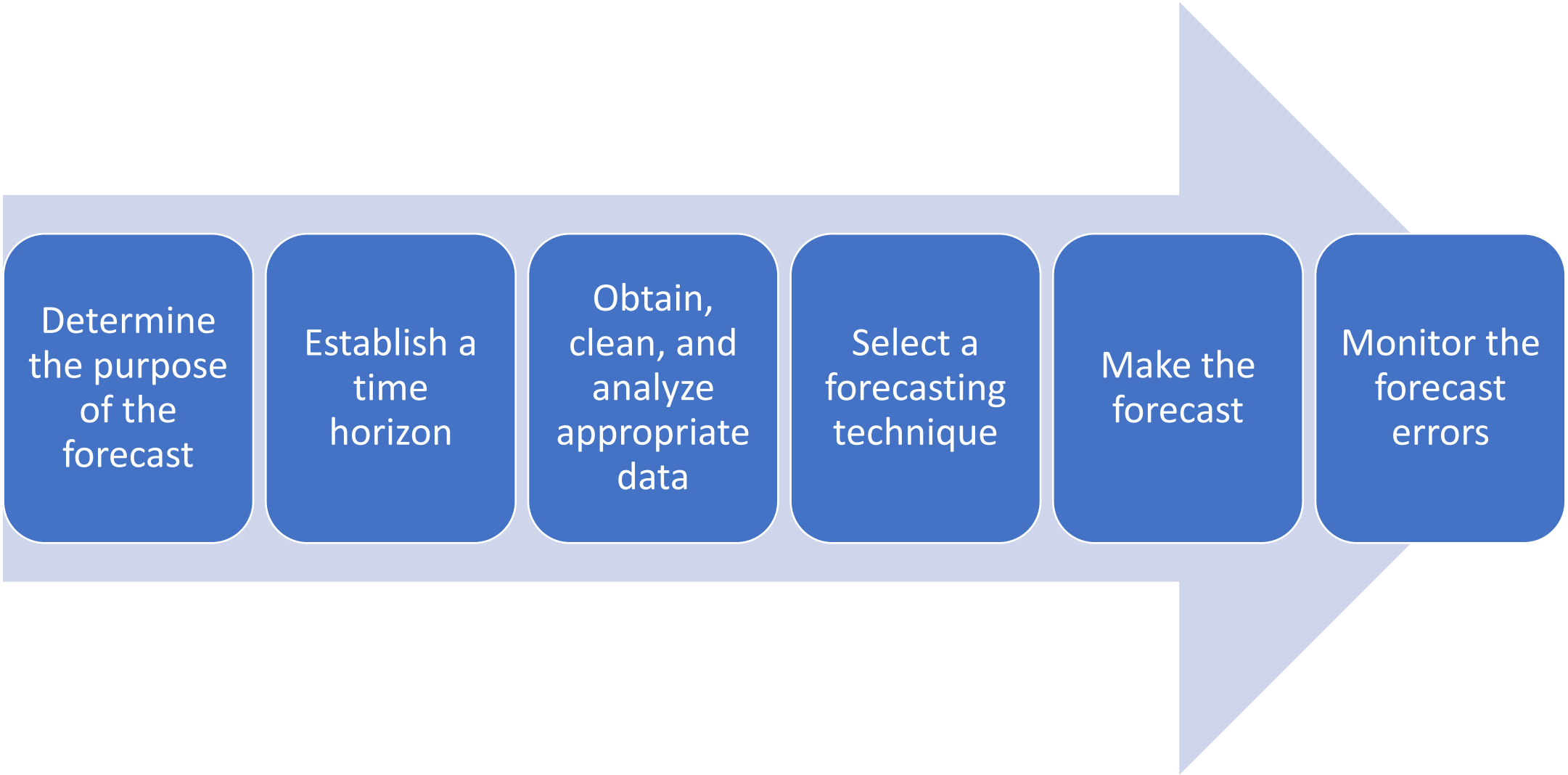
- should be ***timely***
- should be ***accurate***
- should be ***reliable***
- should be expressed in ***meaningful units***
- should be *in* ***writing***
- technique should be ***simple*** *to understand and use*
- should be ***cost-effective***



Forecasting & Supply Chain

- Inaccurate forecasts can lead to shortages and excesses throughout the supply chain.
- Organizations should develop the best possible forecasts.
- Organizations should do collaborative planning and forecasting with major supply chain partners.

Steps in the Forecasting Process



Forecast Accuracy Metrics

$$MAD = \frac{\sum |Actual_t - Forecast_t|}{n}$$

MAD weights all errors evenly

$$MSE = \frac{\sum (Actual_t - Forecast_t)^2}{n-1}$$

MSE weights errors according to their squared values

$$MAPE = \frac{\sum \frac{|Actual_t - Forecast_t|}{Actual_t} \times 100}{n}$$

MAPE weights errors according to relative error

Example

Compute MAD, MSE, and MAPE for the following data, showing actual and forecasted numbers of accounts serviced.

Period	Actual	Forecast	(A − F) Error	|Error|	Error^2	[|Error| ÷ Actual] × 100
1	217	215	2	2	4	.92%
2	213	216	−3	3	9	1.41
3	216	215	1	1	1	.46
4	210	214	−4	4	16	1.90
5	213	211	2	2	4	.94
6	219	214	5	5	25	2.28
7	216	217	−1	1	1	.46
8	212	216	−4	4	16	1.89
			−2	22	76	10.26%

Example

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8	212	216	–4	4	16	1.89
			–2	22	76	10.26%

$$\text{MAD} = \frac{\Sigma|e|}{n} = \frac{22}{8} = 2.75$$

$$\text{MSE} = \frac{\Sigma e^2}{n-1} = \frac{76}{8-1} = 10.86$$

$$\text{MAPE} = \frac{\Sigma\left[\frac{|e|}{\text{Actual}} \times 100\right]}{n} = \frac{10.26\%}{8} = 1.28\%$$

Types of Forecasts

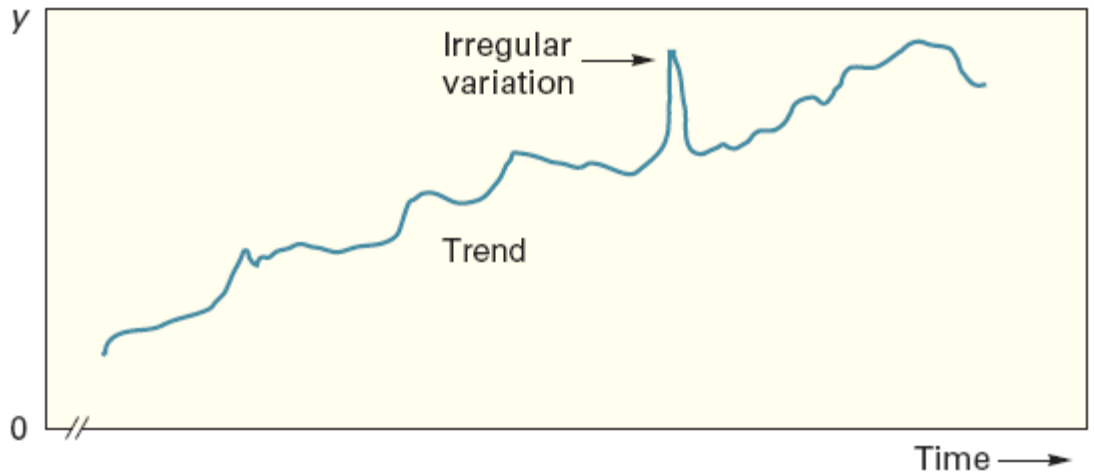
Judgmental	• uses subjective inputs
Time series	• uses historical data assuming the future will be like the past
Associative models	• uses explanatory variables to predict the future

Qualitative Forecasts

- Forecasts that use subjective inputs such as opinions from consumer surveys, sales staff, managers, executives, and experts
  - Executive opinions
    - a small group of upper-level managers may meet and collectively develop a forecast
  - Sales force opinions
    - members of the sales or customer service staff can be good sources of information due to their direct contact with customers and may be aware of plans customers may be considering for the future
  - Consumer surveys
    - since consumers ultimately determine demand, it makes sense to solicit input from them
    - consumer surveys typically represent a *sample* of consumer opinions
  - Other approaches
    - managers may solicit 0pinions from other managers or staff people or outside experts to help with developing a forecast.
    - the **Delphi method** is an iterative process intended to achieve a consensus

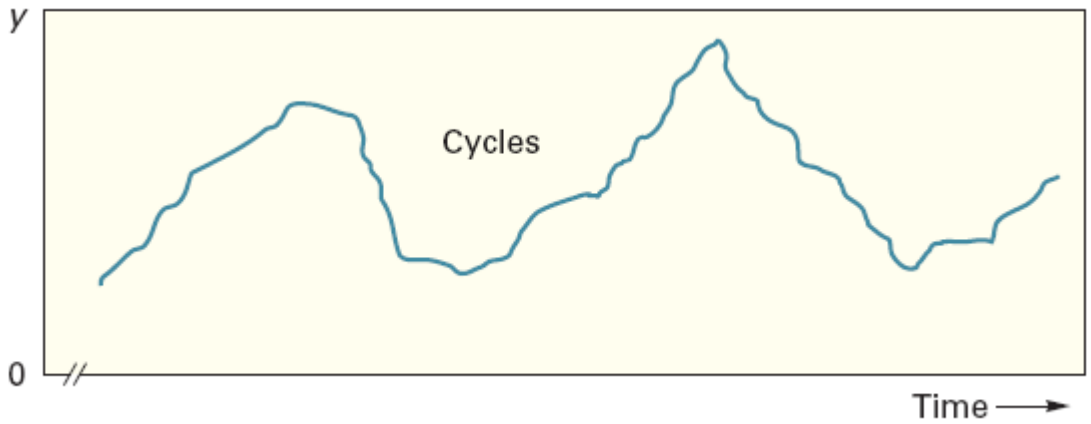
Time-Series Forecasting

- Trends
  - Population shifts
  - Changing incomes
  - Cultural changes
- **Irregular variations**
  - Weather conditions
  - Strikes
  - Major change in product



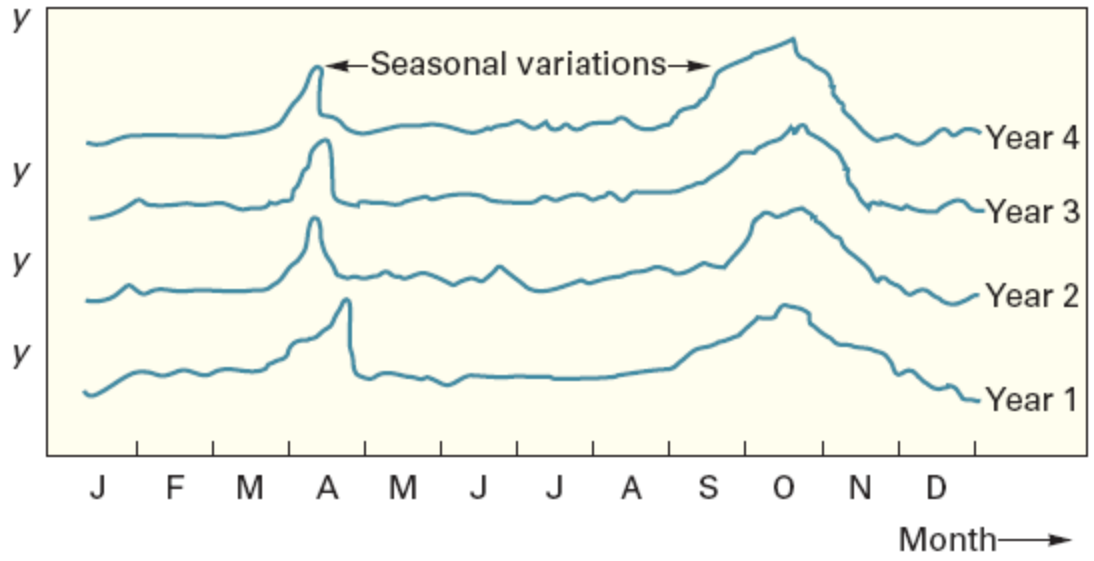
Time-Series Forecasting

- Cyclical
  - Variety of conditions:
    - Economic
    - Political
    - agricultural

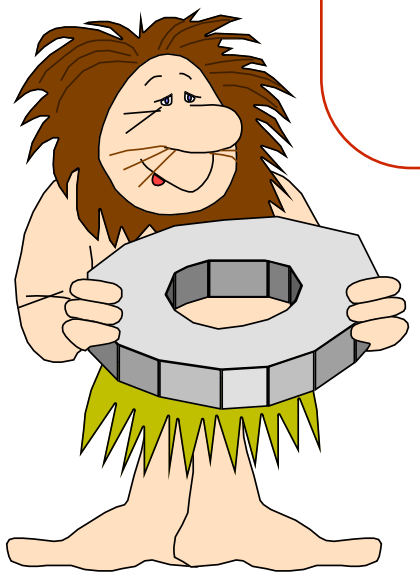


Time-Series Forecasting

- Seasonality
  - Restaurants
  - supermarkets



Naive Forecasts



Uh, give me a minute.... We sold 250 wheels last week.... Now, next week we should sell....

The forecast for any period equals the previous period's actual value.

Time-Series Forecasting - Naïve Forecast

- **Naïve Forecast**
  - Uses a single previous value of a time series as the basis for a forecast
    - The forecast for a time period is equal to the previous time period's value
  - Can be used with
    - a stable time series
    - seasonal variations
    - trend

Time-Series Forecasting - Naïve Forecast

Period	Actual	Change from Previous Value	Forecast
1	50		
2	53	+3	
3			53 + 3 = 56

Time-Series Forecasting - Naïve Forecast

- **Advantages:**
  - Virtually no cost
  - Quick and easy to prepare
  - Data analysis is nonexistent
  - Easily understandable
  - Cannot provide high accuracy
  - Can be a standard for accuracy

The main observation is its inability to provide accurate forecasts.

Uses for Naïve Forecasts

- Stable time series data
  - F(t) = A(t-1)
- Seasonal variations
  - F(t) = A(t-n)
- Data with trends
  - F(t) = A(t-1) + (A(t-1) – A(t-2))

Moving Average

- Technique that averages a number of the most recent actual values in generating a forecast

$$F_t = \text{MA}_n = \frac{\sum_{i=1}^{n} A_{t-i}}{n} = \frac{A_{t-n} + \ldots + A_{t-2} + A_{t-1}}{n}$$

where

F_t = Forecast for time period t

MA_n = n period moving average

A_{t-i} = Actual value in period $t-i$

n = Number of periods in the moving average

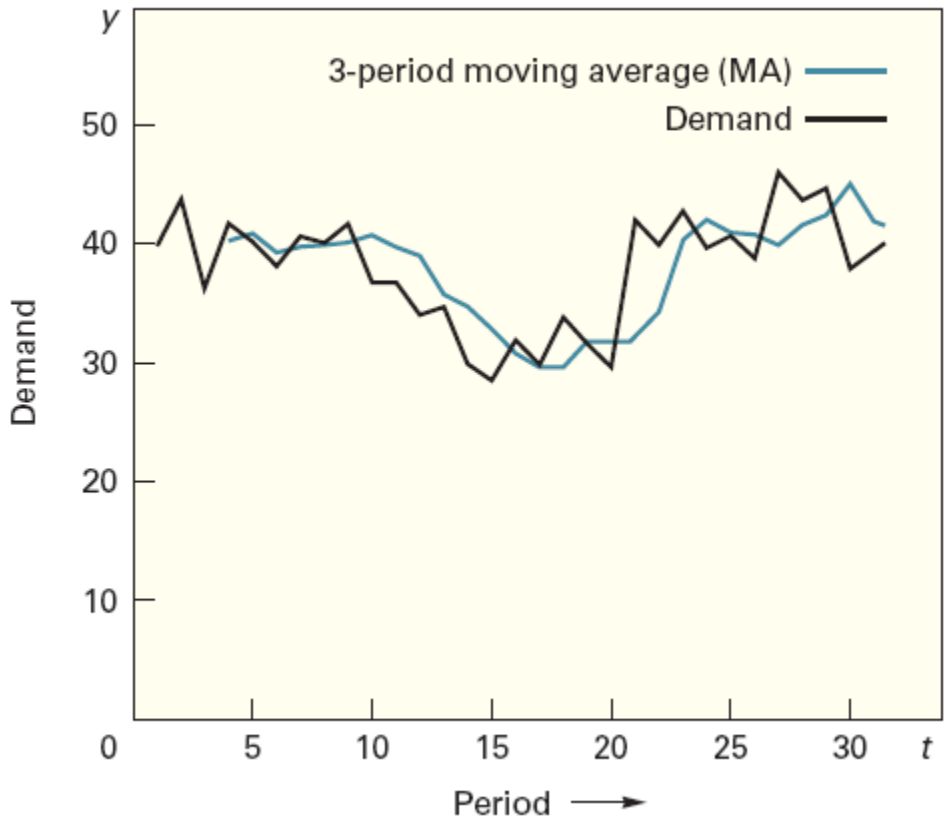
Moving Average

Compute a three-period moving average forecast given demand for shopping carts for the last five periods.

Period	Demand	
1	42	
2	40	
3	43	} the 3 most recent demands
4	40	
5	41	

$$F_6 = \frac{43 + 40 + 41}{3} = 41.33$$

A three-period moving average forecast against actual demand



Moving Average

- Advantages
  - ❖ easy to compute
  - ❖ easy to understand
- Disadvantages
  - ❖All values in the average are weighted equally

Weighted Moving Average

- The most recent values in a time series are given more weight in computing a forecast
  - The choice of weights, *w*, is somewhat arbitrary and involves some trial and error

$$F_t = w_t(A_t) + w_{t-1}(A_{t-1}) + \ldots + w_{t-n}(A_{t-n})$$

where

w_t = weight for period t, w_{t-1} = weight for period $t-1$, etc.

A_t = the actual value for period t, A_{t-1} = the actual value for period $t-1$, etc.

Weighted Moving Average

- For the given the following demand data, compute a weighted average forecast using a weight of .40 for the most recent period, .30 for the next most recent, .20 for the next, and .10 for the next.

Period	Demand
1	42
2	40
3	43
4	40
5	41

$$F_6 = .10(40) + .20(43) + .30(40) + .40(41) = 41.0$$

Exponential Smoothing

- A weighted averaging method that is based on the previous forecast plus a percentage of the forecast error

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

where

F_t = Forecast for period t

F_{t-1} = Forecast for the previous period

α = Smoothing constant

A_{t-1} = Actual demand or sales from the previous period

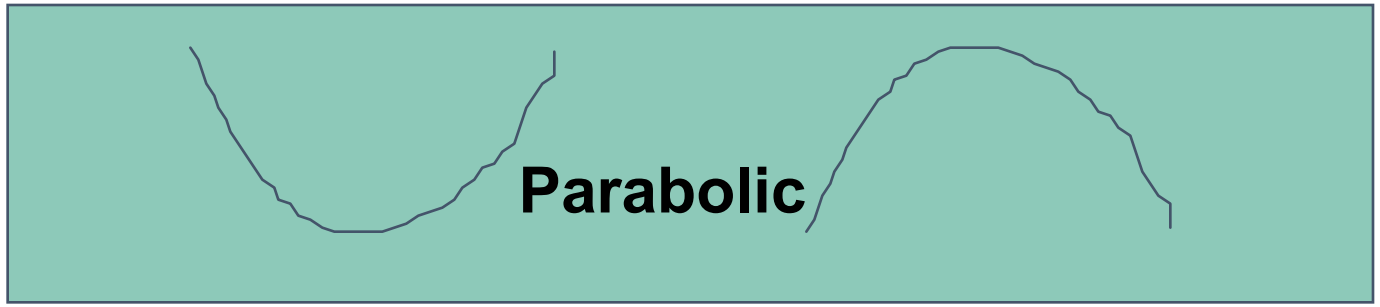
Other forecasting method

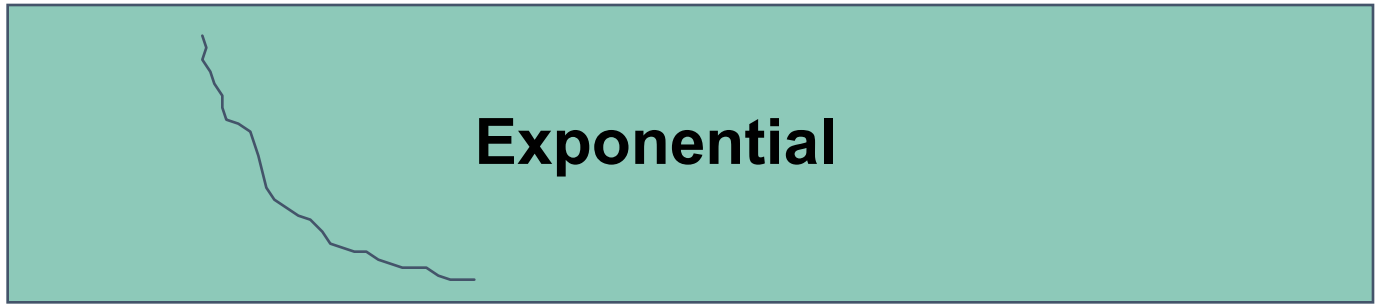
- Focus forecasting
- Diffusion models

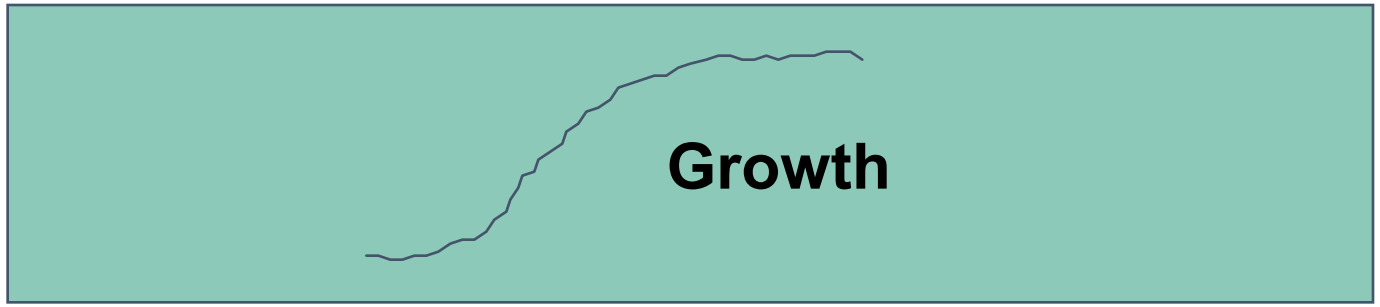
Techniques for Trend

- linear
- Non-linear

Common Nonlinear Trends

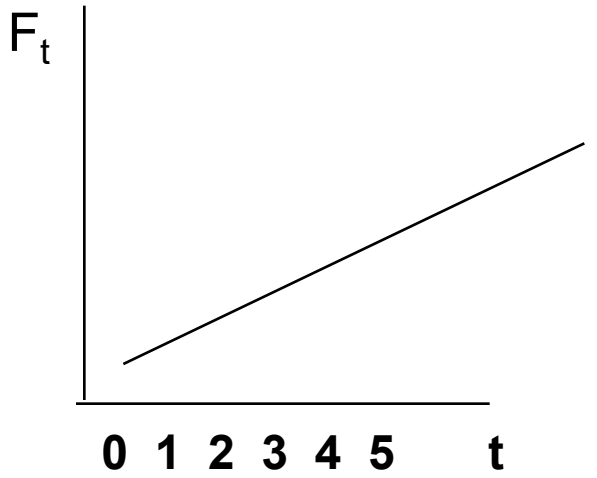






Linear Trend Equation

$$F_t = a + bt$$



- F_t = Forecast for period t
- t = Specified number of time periods
- a = Value of F_t at t = 0
- b = Slope of the line

Calculating a and b

$$b = \frac{n\sum(ty) - \sum t \sum y}{n\sum t^2 - (\sum t)^2}$$

$$a = \frac{\sum y - b\sum t}{n}$$

Linear Trend Equation Example

t Week	t^2	y Sales	ty
1	1	150	150
2	4	157	314
3	9	162	486
4	16	166	664
5	25	177	885
$\Sigma t = 15$ $(\Sigma t)^2 = 225$	$\Sigma t^2 = 55$	$\Sigma y = 812$	$\Sigma ty = 2499$

Linear Trend Calculation

$$b = \frac{5\,(2499) - 15(812)}{5(55) - 225} = \frac{12495 - 12180}{275 - 225} = 6.3$$

$$a = \frac{812 - 6.3(15)}{5} = 143.5$$

$$y = 143.5 + 6.3t$$

Linear Trend Calculation

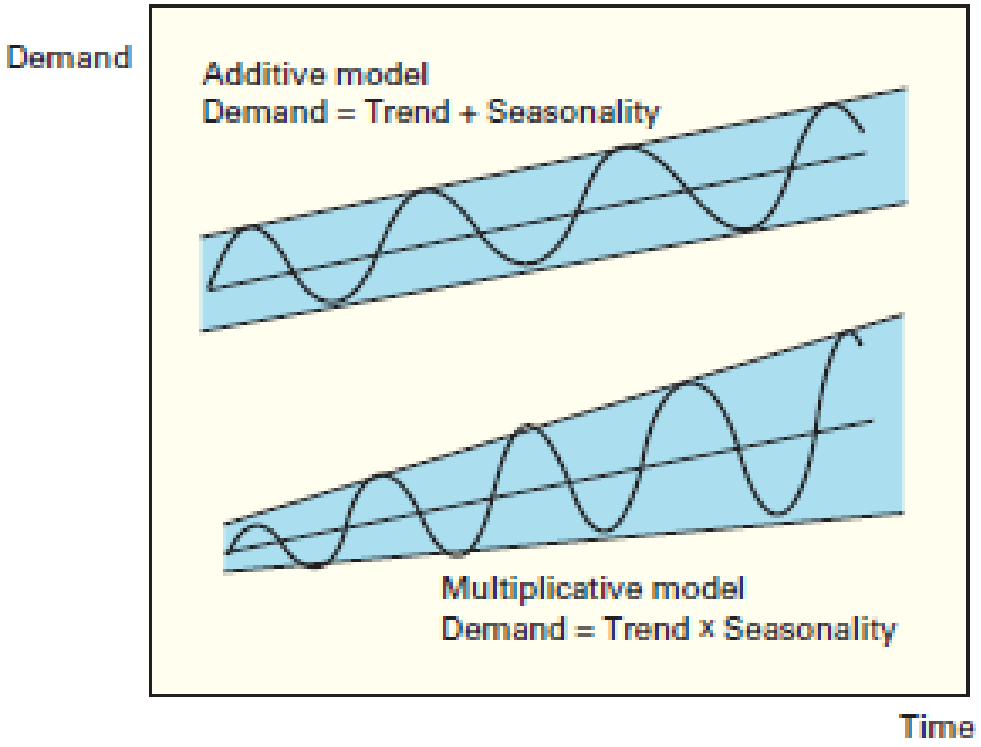
example

Techniques for Seasonality

- Seasonal variations
  - Regularly repeating movements in series values that can be tied to recurring events.
- Seasonal relative
  - Percentage of average or trend
- Centered moving average
  - A moving average positioned at the center of the data that were used to compute it.

Techniques for Seasonality

- Two models:
  - Additive
  - multiplicative



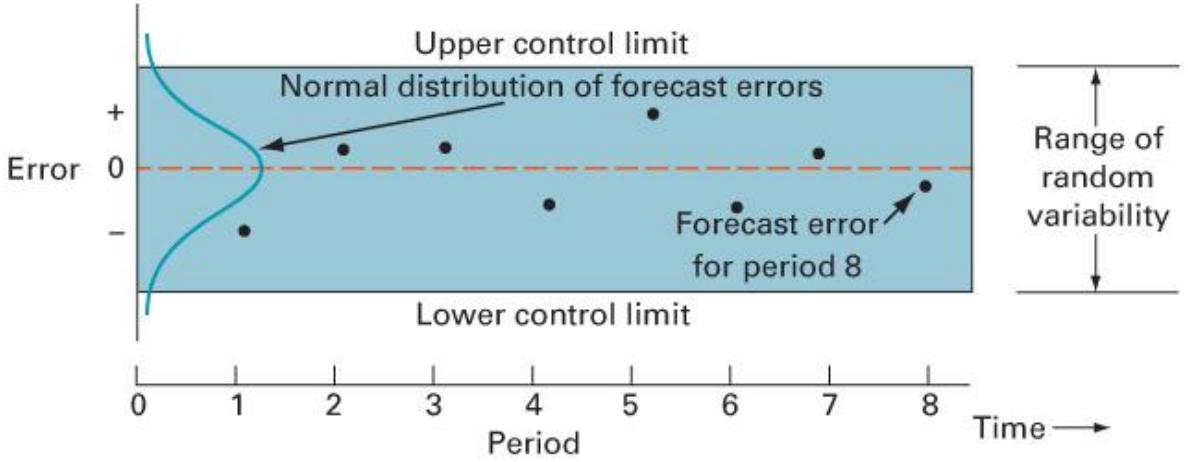
Associative Forecasting

- *Predictor variables* - used to predict values of variable interest
- *Regression* - technique for fitting a line to a set of points
- *Least squares line* - minimizes sum of squared deviations around the line

Simple Linear Regression

- Regression - a technique for fitting a line to a set of data points
  - Simple linear regression - the simplest form of regression that involves a linear relationship between two variables
    - The object of simple linear regression is to obtain an equation of a straight line that minimizes the sum of squared vertical deviations from the line (i.e., the *least squares criterion*)

Control Chart Construction



1. Compute the MSE.
2. Estimate of standard deviation of the distribution of errors

   $s = \sqrt{\text{MSE}}$
3. UCL: $0 + z\sqrt{\text{MSE}}$
4. LCL: $0 - z\sqrt{\text{MSE}}$

   where z = Number of standard deviations from the mean

Choosing a Forecasting Technique

- Factors to consider
  - Cost
  - Accuracy
  - Availability of historical data
  - Availability of forecasting software
  - Time needed to gather and analyze data and prepare a forecast
  - Forecast horizon


Thank you