Supply Chain Engineering

Models and Applications

by

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Chapter 2

Planning Production in Supply Chains

Forecasting References

Read:

- Chapter 2, SCE book

References:

- "Forecasting: An Upward Trend?" by Yurkiewicz, OR/MS Today, Vol.39, #3, pp.52-61, 2012.
- "Forecasting practices in US corporations: Survey results" by Sanders and Manrodt, Interfaces, pp.92-100, March-April 1994.
- "Forecasting software in practice" by Sanders & Manrodt, Interfaces, V.33,pp.90-93, Dec.2003.
- www.forecastingprinciples.com

Chapter 2 – Part 1

Forecasting

Topics

- Forecasting Process
- Qualitative Forecasting Methods
- Time Series Forecasting Methods
- Forecasting for Multiple Periods
- Forecasting Errors
- Forecasting Software
- Forecasting in Practice

Demand Forecasting

- A forecast is an inference of what is likely to happen in the future.
- It is best estimate based on available information.
- Forecasts of future demand are essential to supply chain engineering decisions.
- Forecasting is different than estimating probability distribution of demand.

Stationarity Assumption in OR models

- Most stochastic OR models (except Simulation) assume stationarity of data for simplicity, i.e., the underlying probability distribution does not change over time.
- In reality, demand data is not stationary due to seasonal fluctuations, growth etc.
- Forecasting handles non-stationary data by estimating the mean of the probability distributions at a given time.

Use of Demand Forecasts in SCE Decisions

- Strategic
  - Long term forecast (several years)
  - Example: Facility and capacity planning
- Tactical
  - Medium range forecast (yearly)
  - Example: Aggregate Planning, Inventory policy, labor needs, production scheduling
- Operational
  - Short term forecast, low variability
  - Day-to-day operations

Demand Forecasts

- Do both Push and Pull systems need demand forecasting?
- Use of Demand Forecasts by Function
  - Production
  - Marketing
  - Finance
  - Personnel

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

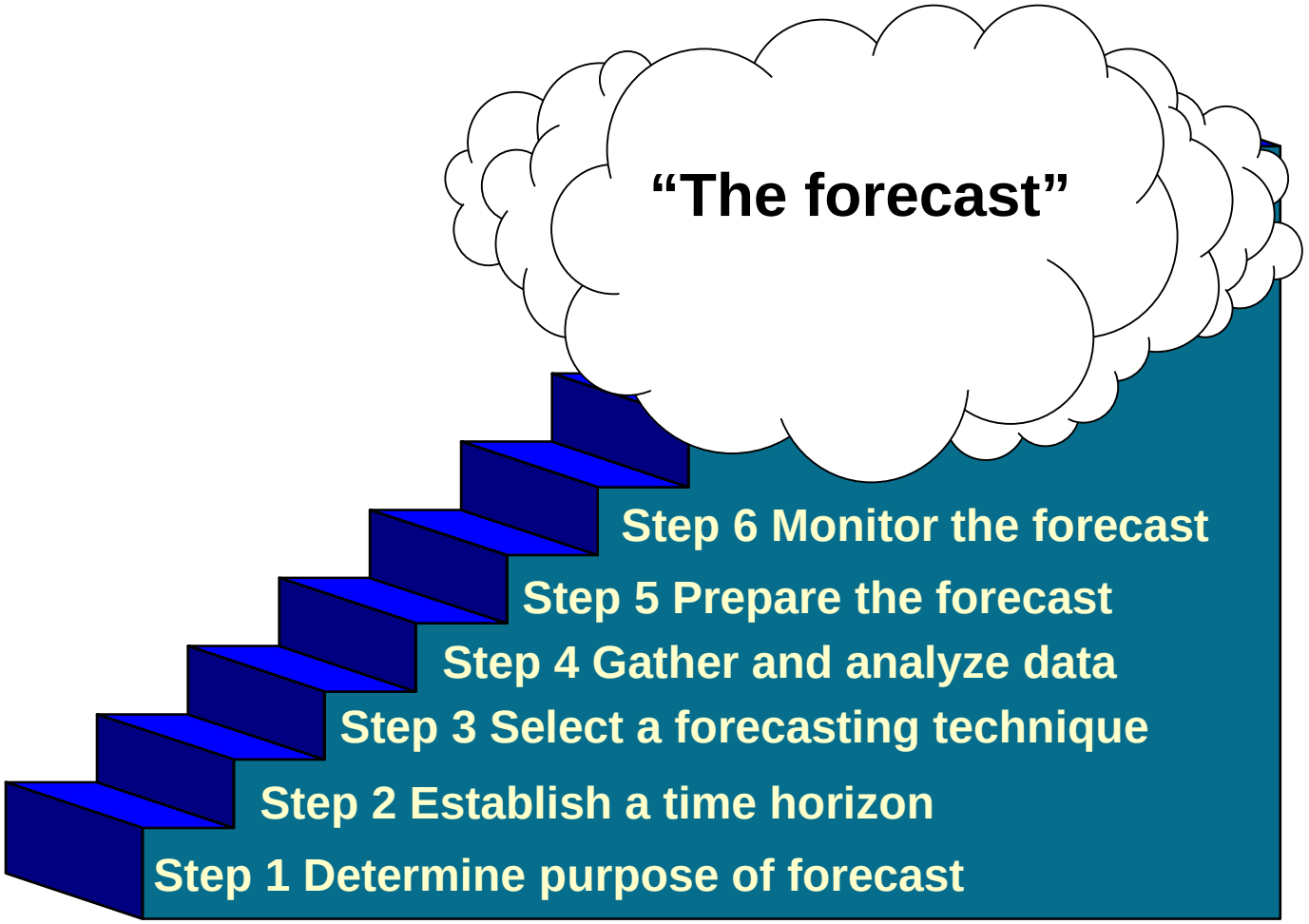
Elements of Good Forecast

- Timeliness
- Reliability
- Accuracy
- Regular reviews
- Equal chance of being over and under
- Good documentation
- Easy to use

Laws of Forecasting

- More accurate at the aggregate level
  - Sales of product categories versus SKUs
- Short term forecasts are more accurate than long term forecasts.
  - Weekly forecasts for the next month versus yearly forecasts for the next 5 years
- Forecasts are dynamic and change always
  - Monitoring and updating are essential

Steps in Forecasting Process



Forecasting Methods

- ***Qualitative***—appropriate when lacking historical data and have expert input
- ***Time series***—use historical information and possibly incorporate trends and seasonality (e.g., moving average, exponential smoothing—single or double)
- ***Causal***—use when demand-correlated environmental factors are suspected (e.g., regression)
- ***Simulation***—use for combining time series and causal methods (e.g., “what if” analysis)

Qualitative Methods

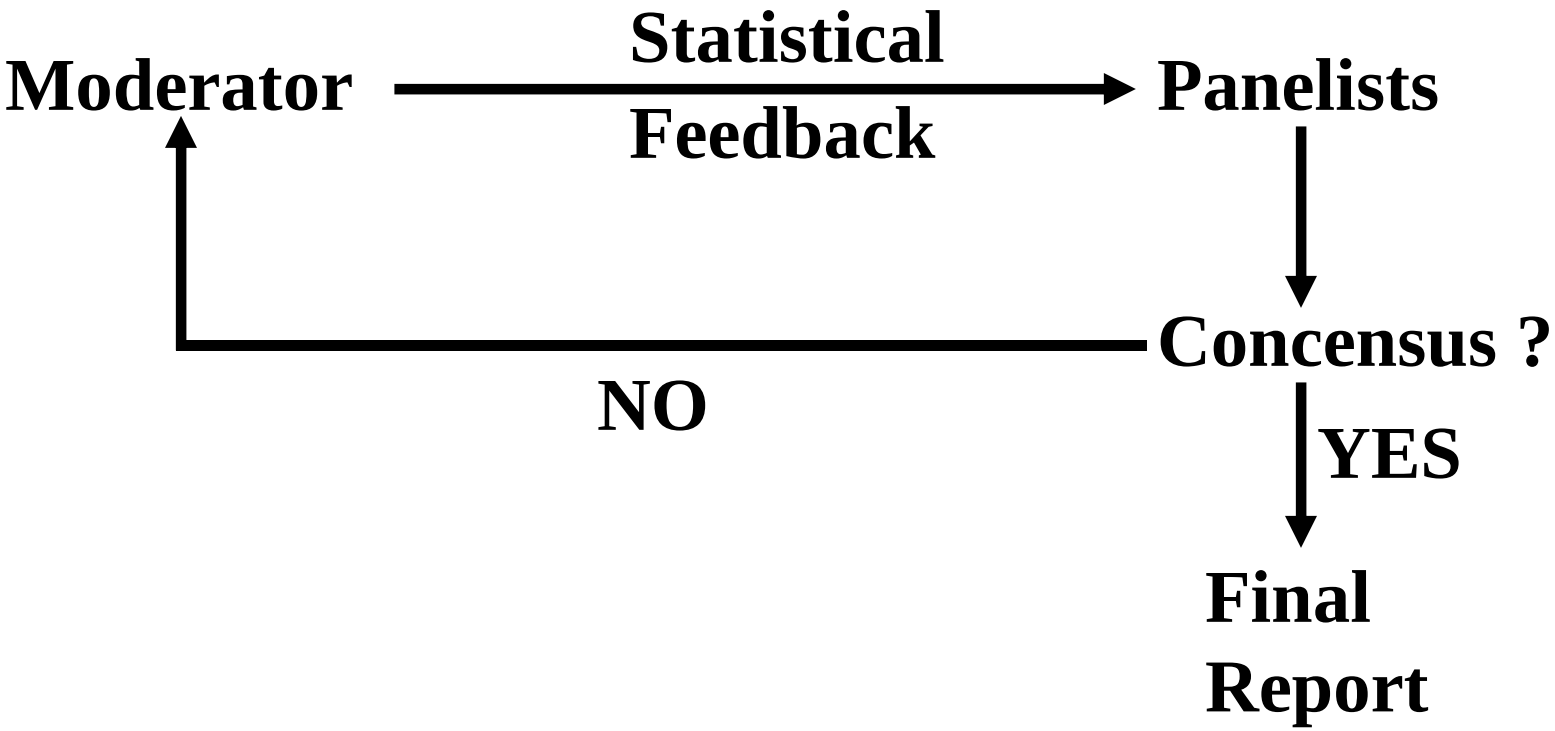
Useful for new products and as a supplement to Quantitative methods

- Executive Committee Consensus
- Survey of Sales Force
- Customer Surveys
- Delphi Method

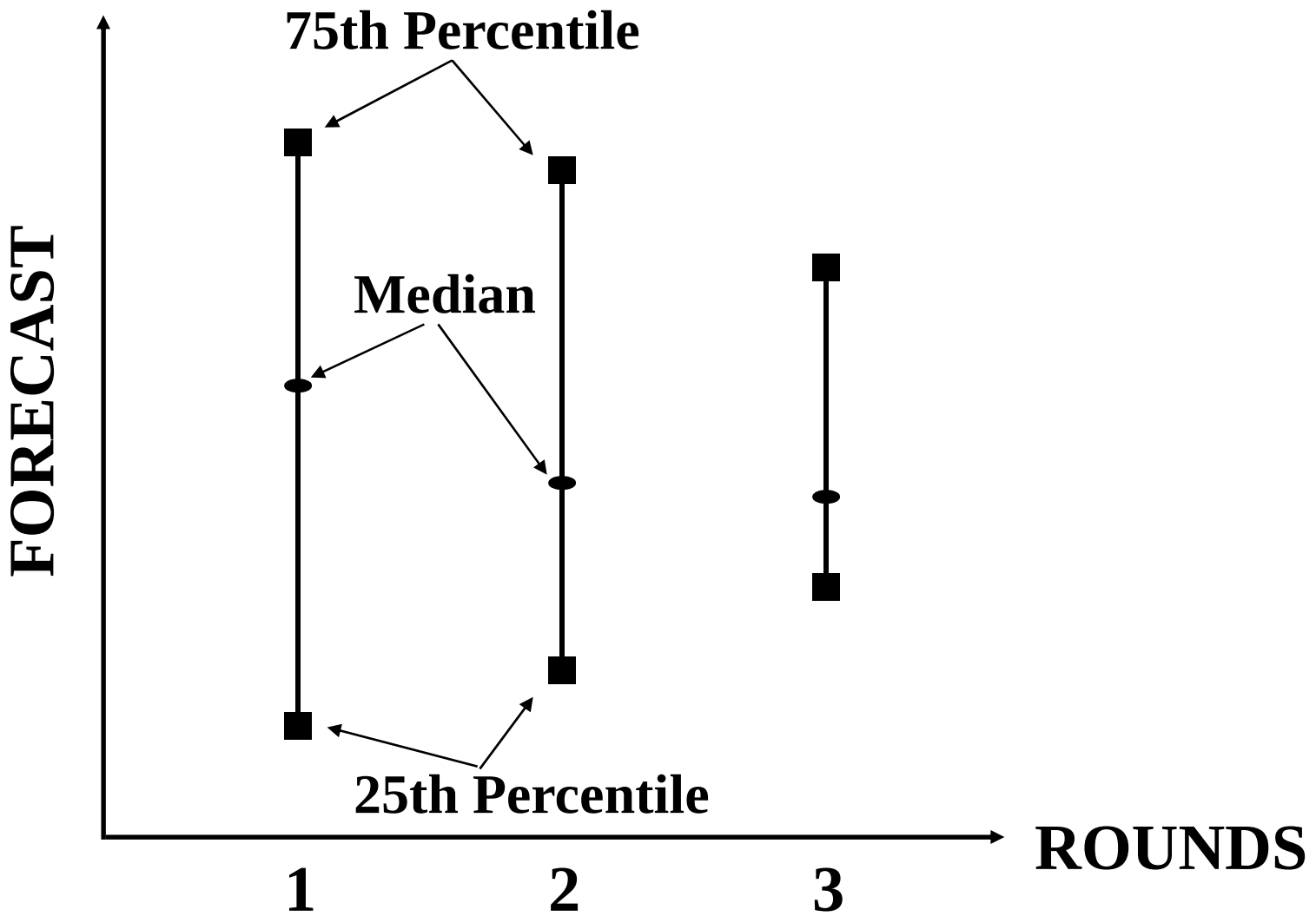
Delphi Method:

- Developed by RAND Corp. in 1969
- Used more as a forecasting tool based on expert opinion

Delphi Process:



Statistical summary of Delphi rounds:



Delphi Method:

Provides

- **Anonymity**
- **Interaction with controlled feedback**
- **Statistical group response (not majority view)**

Avoids

- **Dominance of authoritative figures**
- **Bandwagon effect**
- **Persuasiveness**

It used to be a time consuming process; but with electronic communication, it can be done quickly.

Quantitative Methods

- Based on the assumption that the “forces” that generated the past demand will generate the future demand, i.e., history will tend to repeat itself
- Analysis of the past demand pattern provides a good basis for forecasting future demand
- Majority of quantitative approaches fall in the category of **Time Series Models.**

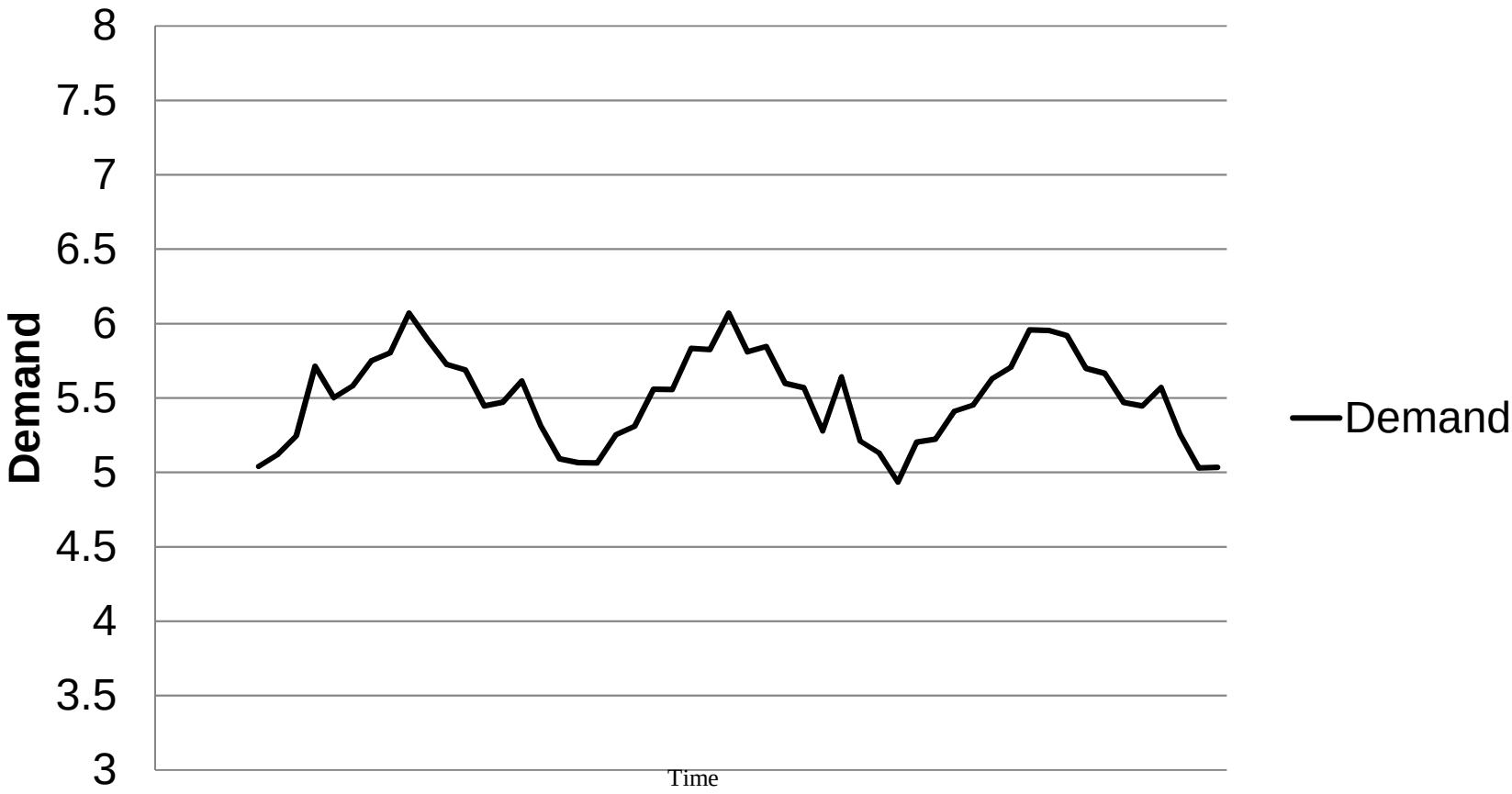
Time Series Models

- A Time Series is a set of values for a sequence of random variables over time.
- Give the observed demand for ‘n’ periods, determine the forecasted demand for period ‘n+1’
- Assumes the future is related to the past.

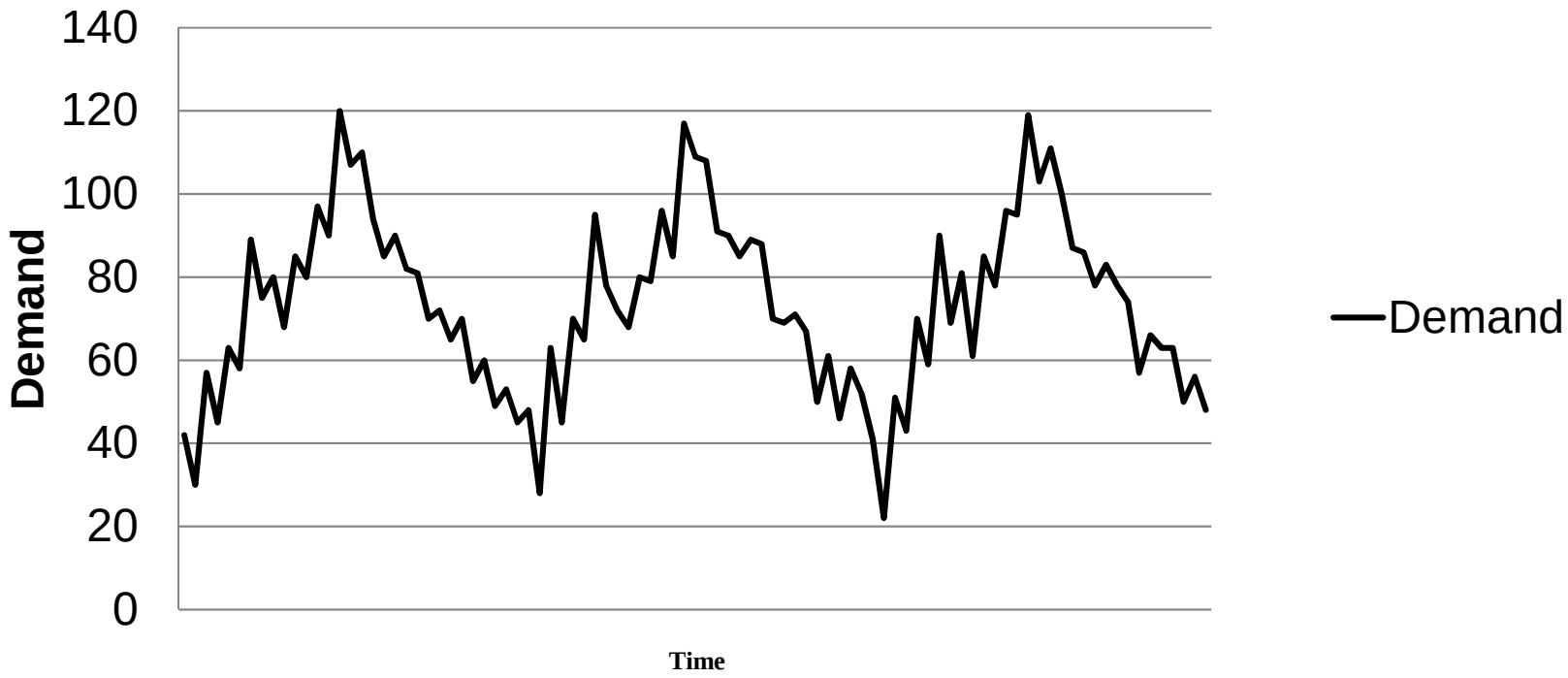
Components of Time Series Data

- Actual Demand = Systematic component + Random component (noise)
- Systematic component may include
  - Constant Level
  - Constant Level + Seasonality (predictable)
  - Constant Level + Trend (growth or decline)
  - Constant Level + Seasonality and Trend

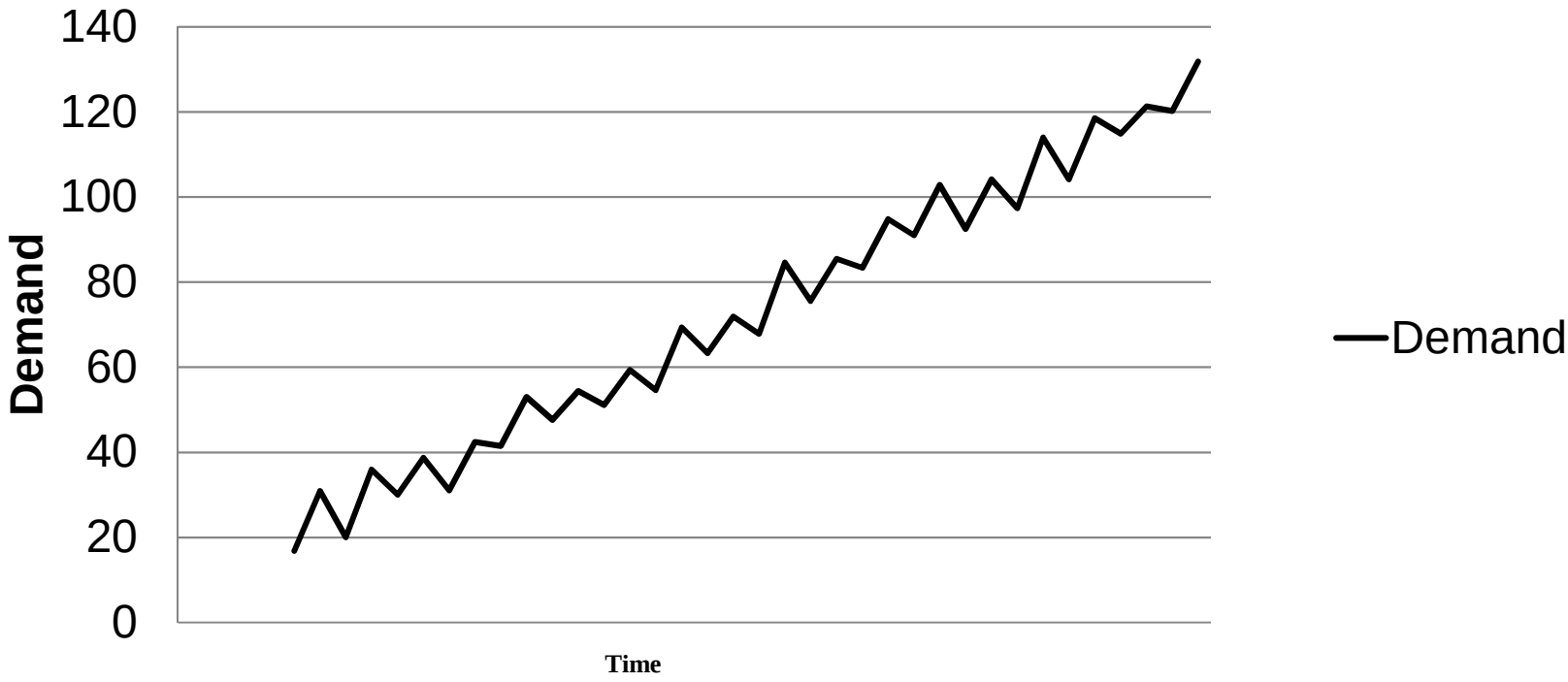
Constant Level



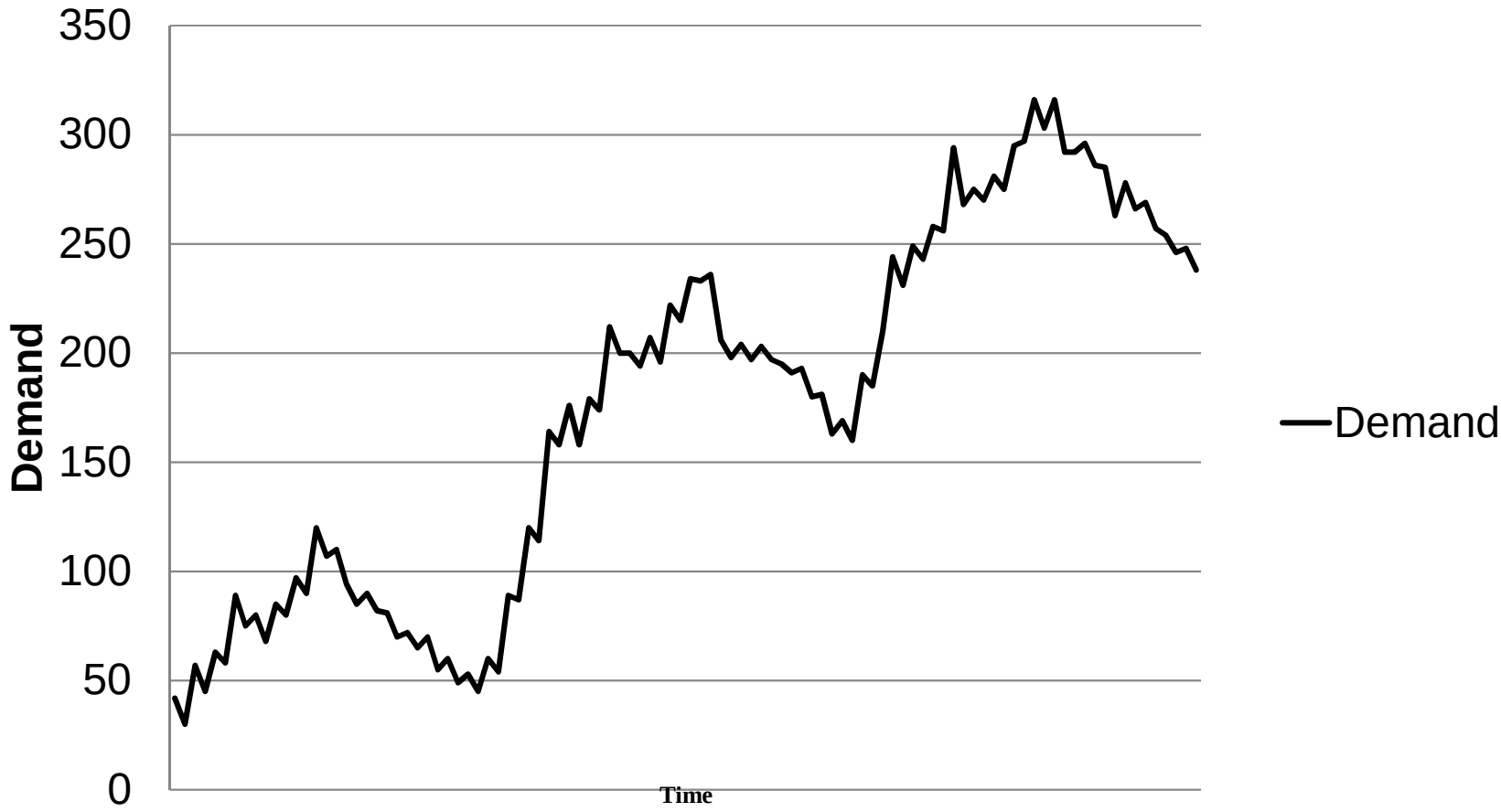
Constant Level with Seasonality



Constant Level with Trend



Constant Level with Trend and Seasonality



Quantitative Forecasting Methods

- Last Value Method (Naïve Method)
- Averaging Method
- Moving Average Method
- Weighted Moving Average Method
- Exponential Smoothing method
- Incorporating Seasonality
- Exponential Smoothing with Trend (Holt's Model)
- Exponential Smoothing with Trend and Seasonality (Winters' Model)

Quantitative Methods

- Last Value Method: Most recent observed value is the new forecast
- Averaging Method: All the past data are averaged to get the new forecast
- m-period Moving Average: Only the last ‘m’ values of past data are averaged for the new forecast
- Weighted Moving Average: The most recent values are given higher weights in the moving average

Moving Average Method

Demand	Forecast (3-period)	Forecast (4-period)
270	start-up	start-up
241	↓	↓
331		
299	280.6	
360	290.3	285.3
340	330	307.8
	333	332.5

Weighted Moving Average Method

Demand	Forecast (.2, .3, .5)	Forecast (.1, .2, .3, .4)
270	start-up	start-up
241	↓	↓
331	↓	↓
299	291.8	↓
360	297	294.1
340	335.9	324
	337.8	336.9

How to determine weights for Weighted Moving Average Method?

- By Hit and Trial
- By Linear Programming Method
- Example 2.1, Ch. 2, SCE Book

Exponential Smoothing Method

- It is basically a weighted averaging method with weights decreasing exponentially on the older demands.
- Requires choosing a smoothing constant, called ‘α’, between 0 and 1.

Then,

$$\mathbf{F_{n+1} = \alpha D_n + (1 - \alpha) F_n}$$

Exponential Smoothing — *Continued*

$$F_{n+1} = \alpha D_n + (1 - \alpha) F_n$$

n	D_n	F_n ($\alpha = 0.2$)
1	270	307 (from averaging)
2	241	299.6
3	331	287.9
4	299	296.5
5	360	297
6	340	309.6
7	-	315.7

Exponential Smoothing Method

Advantages:

- To forecast you only need last period's actual demand and its forecast.
- Reacts more quickly to changes in data compared to averaging methods.

Exponential Smoothing Method

Drawbacks:

- Difficulty in choosing ‘alpha’
  - Practical value between 0.1 and 0.4
- Lags behind continuing trend; however, method can be modified for trend and seasonal variations.

Incorporating Seasonality in Forecasting

1. Compute Seasonal factor for the period = Average for the period/overall average
2. Compute deseasonalized data = Actual/seasonal factor
3. Select a time series forecasting method.
4. Apply the method to deseasonalized data to get deseasonalized forecast.
5. Actual forecast = deseasonalized forecast * seasonal factor for the period

Example for Incorporating Seasonality (Example 2.3, Ch. 2, SCE Book)

- PC sales by quarter given for 2008, 2009 and 2010
- PC sales are high in the 4^{th} quarter due to Christmas season
- PC sales are also high in the 3^{rd} quarter due Back-to-school sales
- Determine the forecast for the first quarter of 2011 incorporating seasonality

Time Series Forecasting with Trend

How to incorporate Trend in the Forecast?

- Simple Trend Model Using Regression
  - Example 2.4
- Exponential Smoothing with Trend (Holt's Model)
  - Examples 2.5 and 2.6
- Exponential Smoothing with Trend and Seasonality (Winters' model)
  - Example 2.7

Forecasting for Multiple Periods

- Constant level model
  - F(n+i) = F(n+1) for i=1, 2, 3…….
  - In other words, the best forecast for n+2, n+3, etc is F(n+1).
- Under Seasonality
  - F(n+i) = Deseasonalized forecast for (n+1) * SI(n+i) for i=1,2…. where SI(n+i) is the seasonality index for period n+i.
- Under Trend (Holt's Model)
  - F(n+i) = L(n+1) + (i) T(n+1) for i = 1,2,….
- Under Trend and seasonality (Winters' model)
  - F(n+i) = [L(n+1) + (i) T(n+1)] SI(n+i) for i=1, 2,…..

How to Choose the Right Forecasting Method

- Use Forecast errors as a measure of performance of a method.
- Studies have shown that it is better to use multiple methods and average their forecasts as the forecast.

Forecast Errors

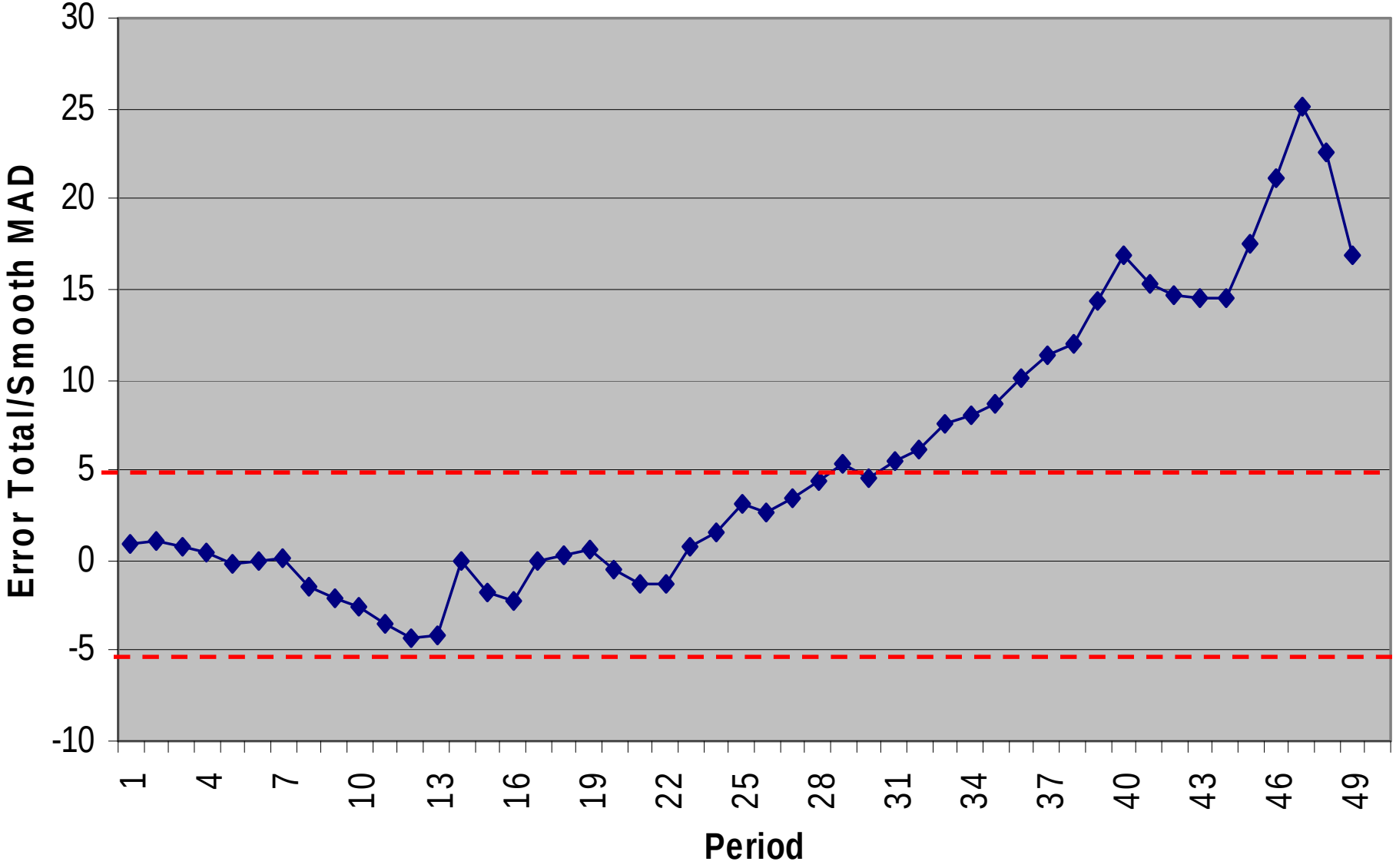
- Mean Absolute Deviation (MAD)
- Mean Squared Error (MSE)
- Standard Deviation of Forecast Error
- Bias
- Mean Absolute Percentage Error (MAPE)
- Tracking Signal (TS)

Monitoring Forecast Accuracy

- **Tracking Signal (TS**) is the most commonly used technique for monitoring forecasts
  - Tracking signal is used to detect changes in the pattern
  - When the tracking signal goes outside the set limits the forecaster can be notified
- Tracking Signal is given by :

$$TS_n = Bias_n / MAD_n \quad \text{for } n=1,2,3$$

Tracking Signal



Uses of Forecast Errors

- To select a method by retrospective testing on past data.
- To select the parameters of a particular method.
- To monitor how well the selected method is performing

Forecasting Software

- Over 30 software packages costing $0 to $25,000.
- Three types of software available
  - Automatic (most expensive)
  - Semi automatic (moderate cost)
  - Manual (cheap)
- Some are stand alone dedicated software, others are add-on to MS Excel, SAS, Minitab
- For details refer to: “Forecasting: An Upward Trend?” by Yurkiewicz, OR/MS Today, Vol.39, No.3, pp. 52-61, 2012.

Forecasting in Practice
(Company Surveys)

References:

"Forecasting Software in Practice: Uses, Satisfaction and Performance" by Sanders and Manrodt, Interfaces, Vol,33, pp. 90-93, Sep. – Oct. 2003

"Forecasting practices in US corporations: Survey results" by Sanders and Manrodt, Interfaces, Vol. 24, pp.92-100, March-April 1994.

Observations in Practice:

- Simpler forecasting methods are more frequently used because they are easy to understand and communicate
- Several studies have found that complex forecasting procedures seldom give better results.

Forecasting in Practice*

	Forecast Period			
Forecasting Technique	**Immediate <1 Month**	**Short 1-6 month**	**Medium 6-12 months**	**Long > 12 months**
Judgmental				
Managers opinion	**27.9**	**39.8**	**37.1**	**9.3**
Executive Opinion	**17.5**	**28.9**	**40.1**	**26.2**
Sales force	**28.6**	**17.5**	**33.1**	**8.7**
Quantitative				
Moving Average	**17.7**	**33.5**	**28.3**	**8.7**
St. line projection	**7.6**	**13.2**	**12.5**	**8.2**
Naïve	**16**	**18.5**	**13.8**	**0**
Expon. Smoothing	**12.9**	**19.6**	**16.8**	**4.2**
Regression	**13.4**	**25.1**	**26.4**	**16.5**
Simulation	**3.4**	**7.8**	**11.2**	**8.3**
Classical decomposition	**0**	**6.8**	**11.9**	**9.3**
Box-Jenkins	**2.4**	**2.4**	**4.9**	**3.4**

* % of managers that reported different techniques for different time horizons.

Real World Applications

- Taco Bell
- Dell Computers
- FedEx
- National Car Rental
- Nabisco
- National Broadcasting Company

Chapter 2 – Part 2

Aggregate Planning

Topics

- Production Planning Process
- Aggregate Planning Strategies
- Linear Programming Model for Aggregate Planning
- Nonlinear Programming Model for Aggregate Planning
- Aggregate Planning as a Transportation Problem
- Managerial Issues

Aggregation
Why?

Aggregation refers to the idea of focusing on overall capacity, rather than individual products or services.

Aggregation is done according to:

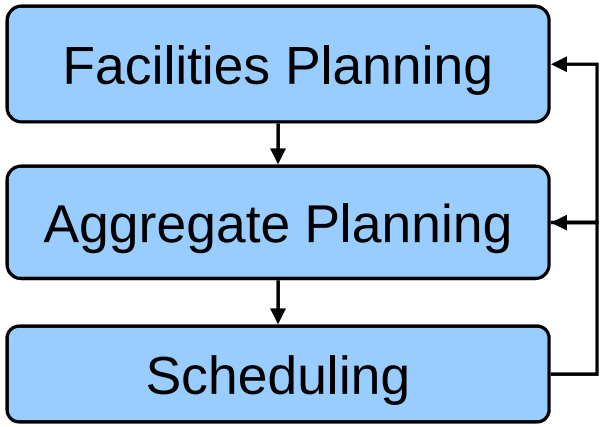
- Products
- Labor
- Time

Production Planning

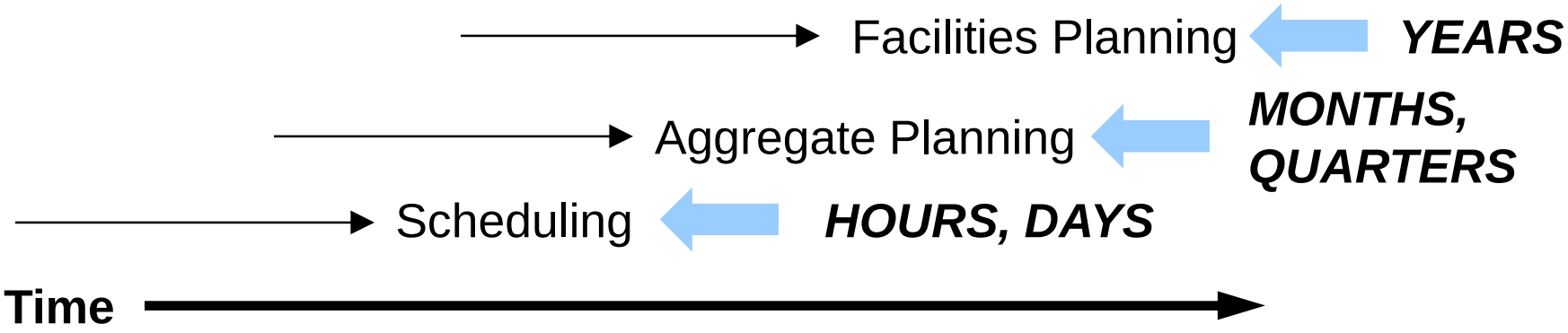
- Long Range Planning ← ***1 - 5 years***
  - Strategic planning
- Medium Range Planning ← ***2 - 18 months***
  - Employment, output, and inventory levels
- Short Range Planning ← ***0 - 2 months***
  - Job (order) scheduling, machine loading, and job sequencing

Managing Capacity
Decision Hierarchy

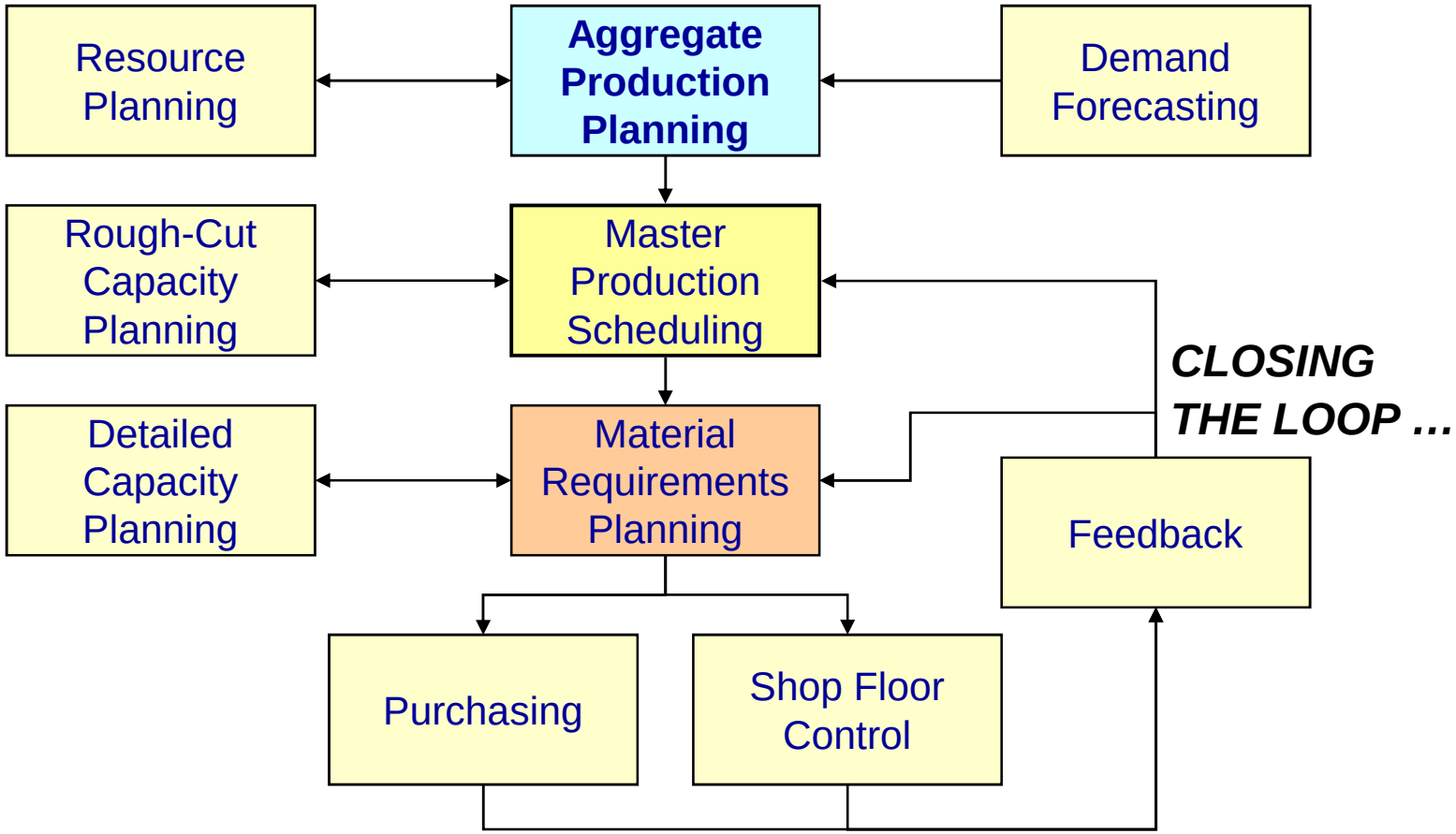
- Decision Linkages



- Decision Time Frame



The Planning Process
Big Picture



Managing Demand … and Supply
Aggregate Planning Issues

Smoothing Demand (*"aggressive"*)

- Provide incentives / promotions to stimulate off-peak demand
- Sell complementary products
- Allow / manage backlogs (reservations)

Smoothing Supply (*"reactive"*)

- Hire / layoff workers
- Use temporary workers
- Use overtime
- Subcontract
- Hold inventory
- Allow shortages

Aggregate Planning Problem

- Given a demand forecast over a planning horizon, develop a plan for production and allocation of resources by making appropriate trade off among capacity, inventory and backlogs.
- It is generally a medium range tactical supply chain planning problem.

Aggregate Planning Strategies

- Chase Strategy
  - Production rates (work force levels) are adjusted to match demands over planning horizon.
- Level Strategy
  - A constant production rate or work force level is maintained over planning horizon.
  - Inventory/backlogs are built and dissipated.
- Mixed Strategy
  - Both inventory and work force levels are allowed to change over the planning horizon.

LP Model for Aggregate Planning (SEC Text, Example 2.13, pp. 65-69)

- Planning horizon 6 months
- Demand forecasts are given
- Both inventory and shortages are allowed.
- All demands met by the end of the 6^{th} month.
- Work force has to be planned.
- Given all cost data, determine the minimum cost plan.

Nonlinear Programming Model for Aggregate Planning

SCE Text, Section 2.16, pp. 70-72

Aggregate Planning Problem as a Transportation Problem

- Transportation model
- Aggregate Planning as a Transportation Problem
- Example 2.15, SCE Text, pp.78-80
- Solution by the Greedy Algorithm

Aggregate Planning Strategies
A Comparison

	Inventory/ Backlogs	Workforce Stability	Control	Production Variability
Level	Can be large and variable	Very Good	Good	Low - None
Hire/Layoff (or Part Time)	Low - None	Poor	Good	Med - Large
Overtime	Low - None	Poor – Good*	Good	Med - Large
Subcontracting	Low - None	Good - V/Good	Questionable	Low – Med

* *It depends* on the constraints…`

Aggregate Production Planning
Managerial Issues

- APP should be tailored to the particular company and situation.
- APP may be constrained by union contracts or company policies.
- Mathematical results typically have to be balanced with managerial judgement and experience.
- Must avoid the tendency to blur the distinction between *production planning* and *production scheduling* (a matter of time scale and level of detail).