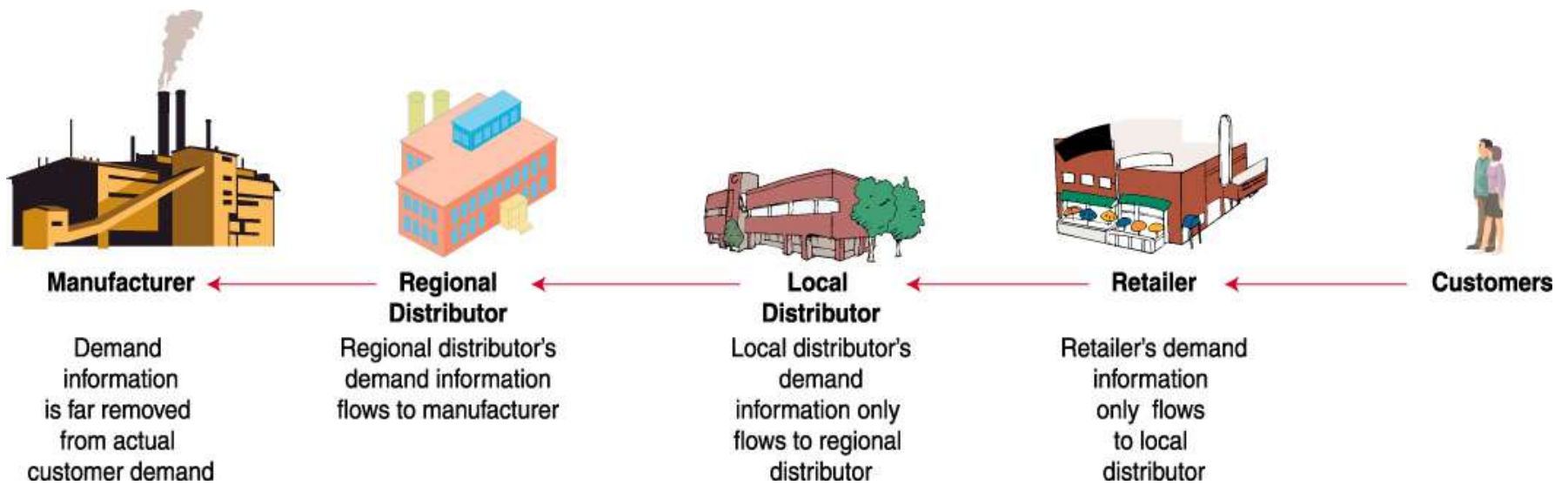
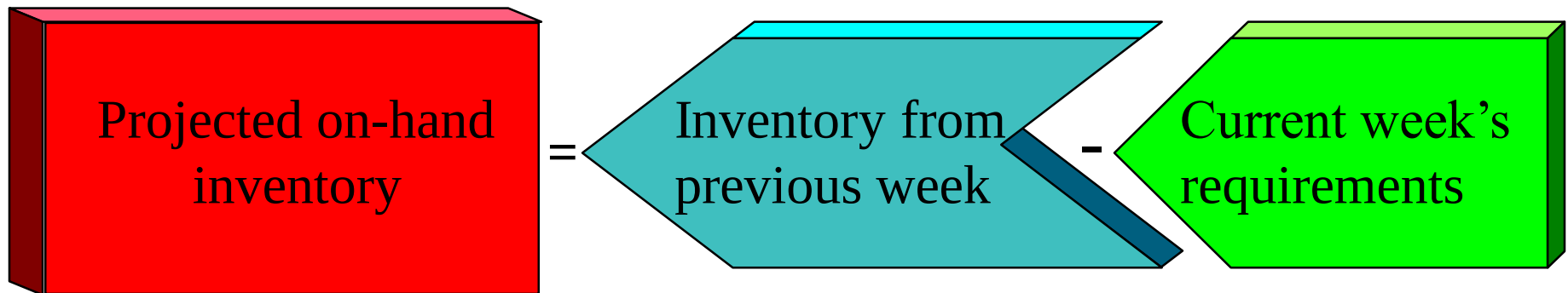




Operations Management



Introduction to Operations Management

Learning Objectives – con't

- Identify current trends in OM
- Describe the flow of information between OM and other business functions

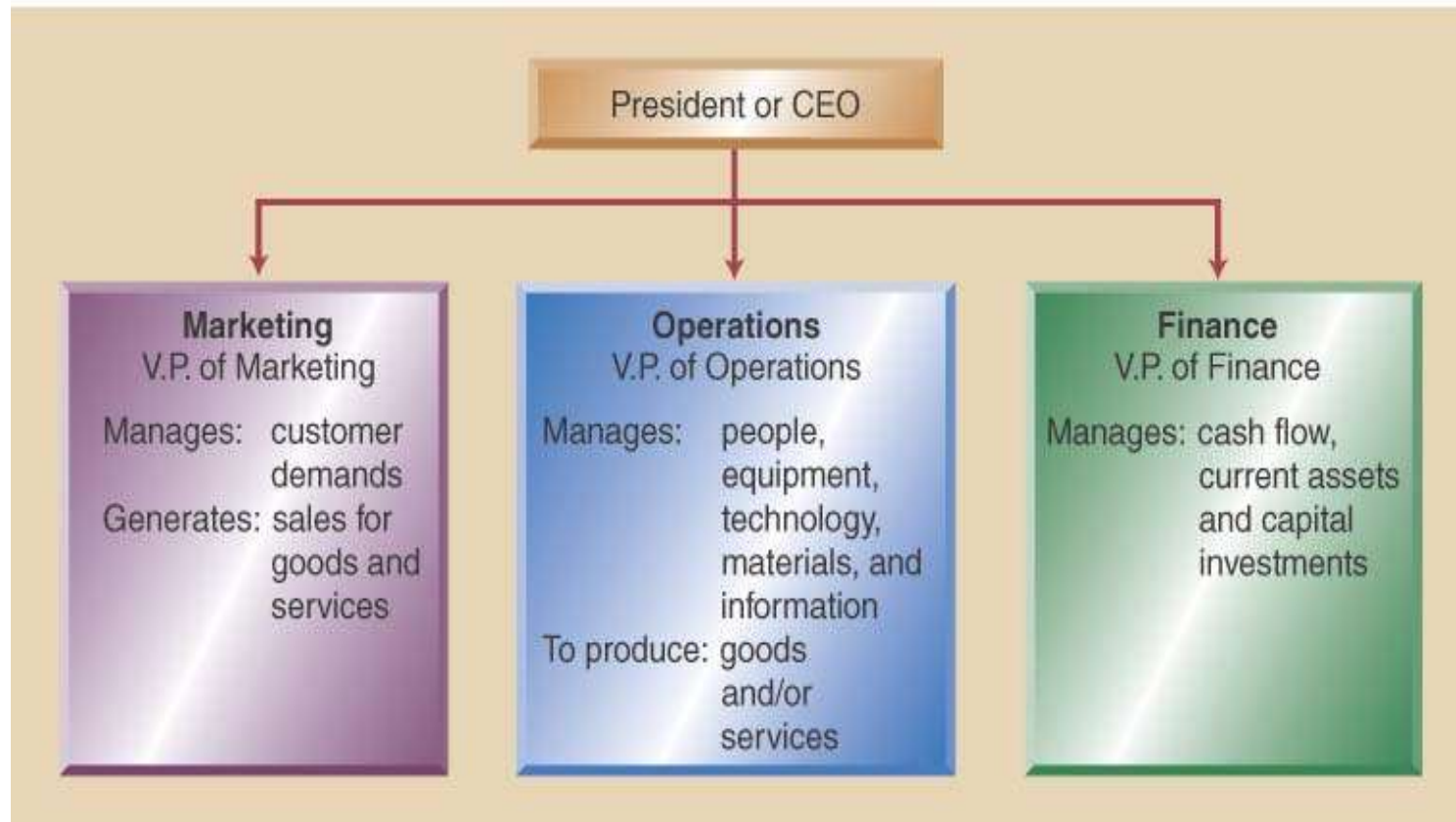
Operations Management is:

The ***business function*** responsible for **planning, coordinating, and controlling** the resources needed to produce products and services for a company

Operations Management is:

- A management function
- An organization's core function
- In *every* organization whether Service or Manufacturing, profit or Not for profit

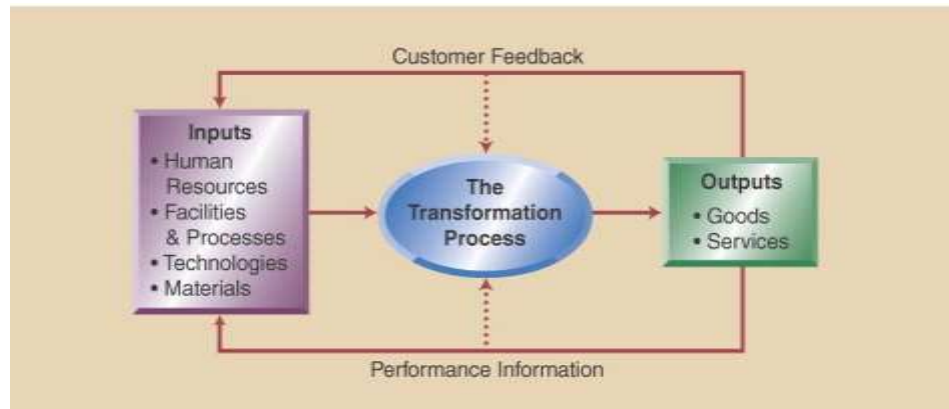
Typical Organization Chart



What is Role of OM?

- OM Transforms inputs to outputs
 - Inputs are resources such as
 - People, Material, and Money
 - Outputs are goods and services

OM's Transformation Process



OM's Transformation Role

- To add value
 - Increase product value at each stage
 - Value added is the net increase between output product value and input material value
- Provide an efficient transformation
 - Efficiency – means performing activities well for least possible cost

Manufacturers vs Service Organizations

- **Services:**

- Intangible product
- Product cannot be inventoried
- High customer contact
- Short response time
- Labor intensive

- **Manufacturers:**

- Tangible product
- Product is inventoried
- Low customer contact
- Longer response time
- Capital intensive

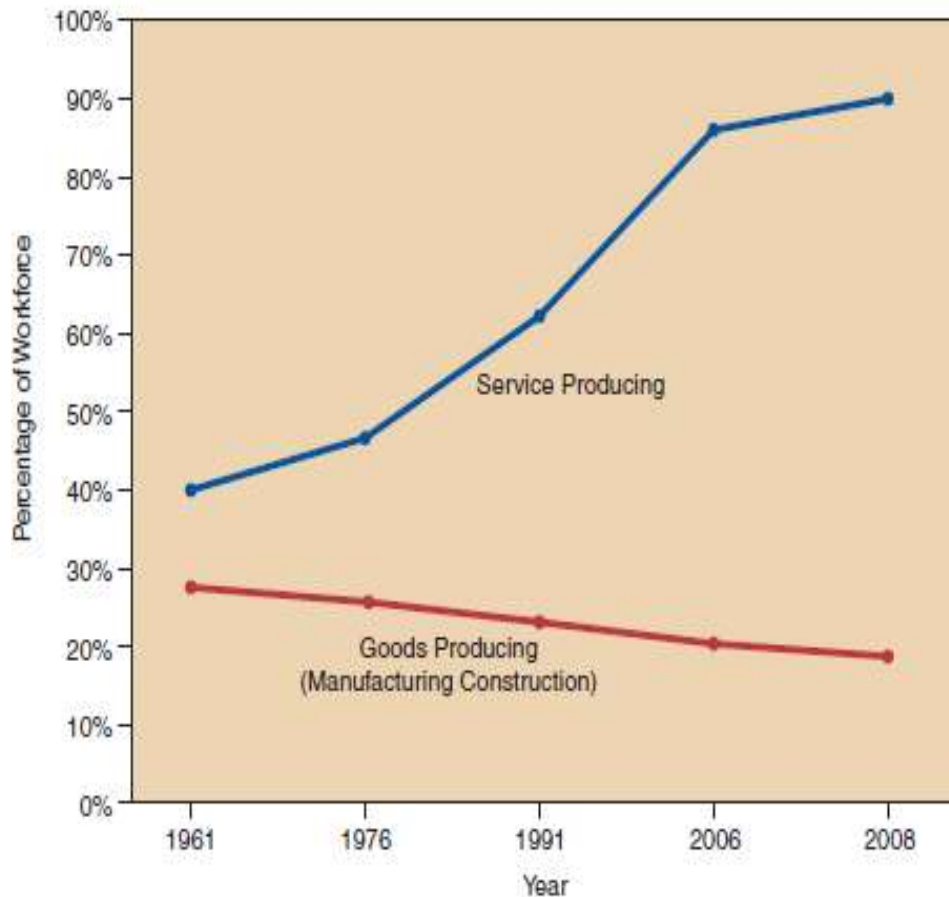
Similarities for Service/Manufacturers

- Both use technology
- Both have quality, productivity, & response issues
- Both must forecast demand
- Both can have capacity, layout, and location issues
- Both have customers, suppliers, scheduling and staffing issues

Service vs Manufacturing

- Manufacturing often provides services
- Services often provides tangible goods
- Some organizations are a blend of service/manufacturing/quasi-manufacturing
- Quasi-Manufacturing (QM) organizations
- QM characteristics include
 - Low customer contact & Capital Intensive

Growth of the Service Sector



- Service sector growing to 50-80% of non-farm jobs
- Global competitiveness
- Demands for higher quality
- Huge technology changes
- Time based competition
- Work force diversity

Source: U.S. Department of Commerce

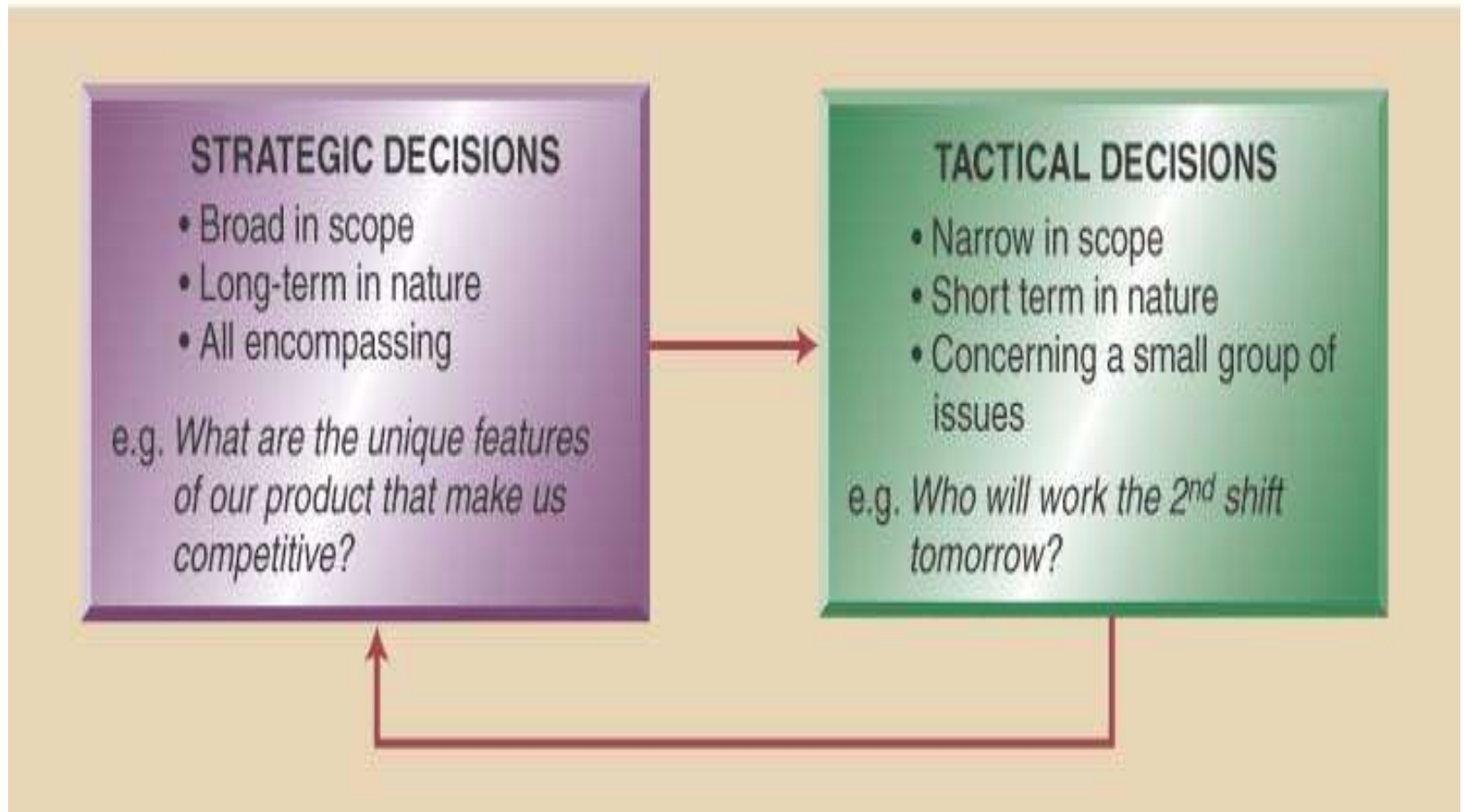
OM Decisions

- All organizations make decisions and follow a similar path
 - First decisions very broad – Strategic decisions
 - Strategic Decisions – set the direction for the entire company; they are broad in scope and long-term in nature

OM Decisions

- Following decisions focus on specifics - Tactical decision
 - Tactical decisions: focus on specific day-to-day issues like resource needs, schedules, & quantities to produce
 - are frequent
- Strategic decisions less frequent
- Tactical and Strategic decisions must align

OM Decisions



Plan of Book-Chapters link to Types of OM Decisions

Type of Decision	Operations Management Topic	Chapter
 Strategic	Operations Strategy	Ch. 2
	Product Design and Process Selection	Ch. 3
	Supply Chain Management	Ch. 4
	Total Quality Management	Ch. 5 and 6
	Just-in-Time and Lean Systems	Ch. 7
	Forecasting	Ch. 8
	Capacity Planning and Location Analysis	Ch. 9
	Facility Layout	Ch. 10
	Work System Design	Ch. 11
	Inventory and Resource Planning	Ch. 12, 13, 14, and 15
	Scheduling Issues	Ch. 16 and 17
Tactical		

Historical Development of OM

- | | |
|----------------------------|-------------|
| • Industrial revolution | Late 1700s |
| • Scientific management | Early 1900s |
| • Human relations movement | 1930s-60s |
| • Management science | 1940s-60s |
| • Computer age | 1960s |
| • Environmental Issues | 1970s |
| • JIT & TQM* | 1980s |

*JIT= Just in Time, TQM= Total Quality Management

Historical Development con't

- Reengineering 1990s
- Global competition 1980s
- Flexibility 1990s
- Time-Based Competition 1990s
- Supply chain Management 1990s
- Electronic Commerce 2000s
- Outsourcing & flattening of world 2000s

For long-run success, companies must place much importance on their operations

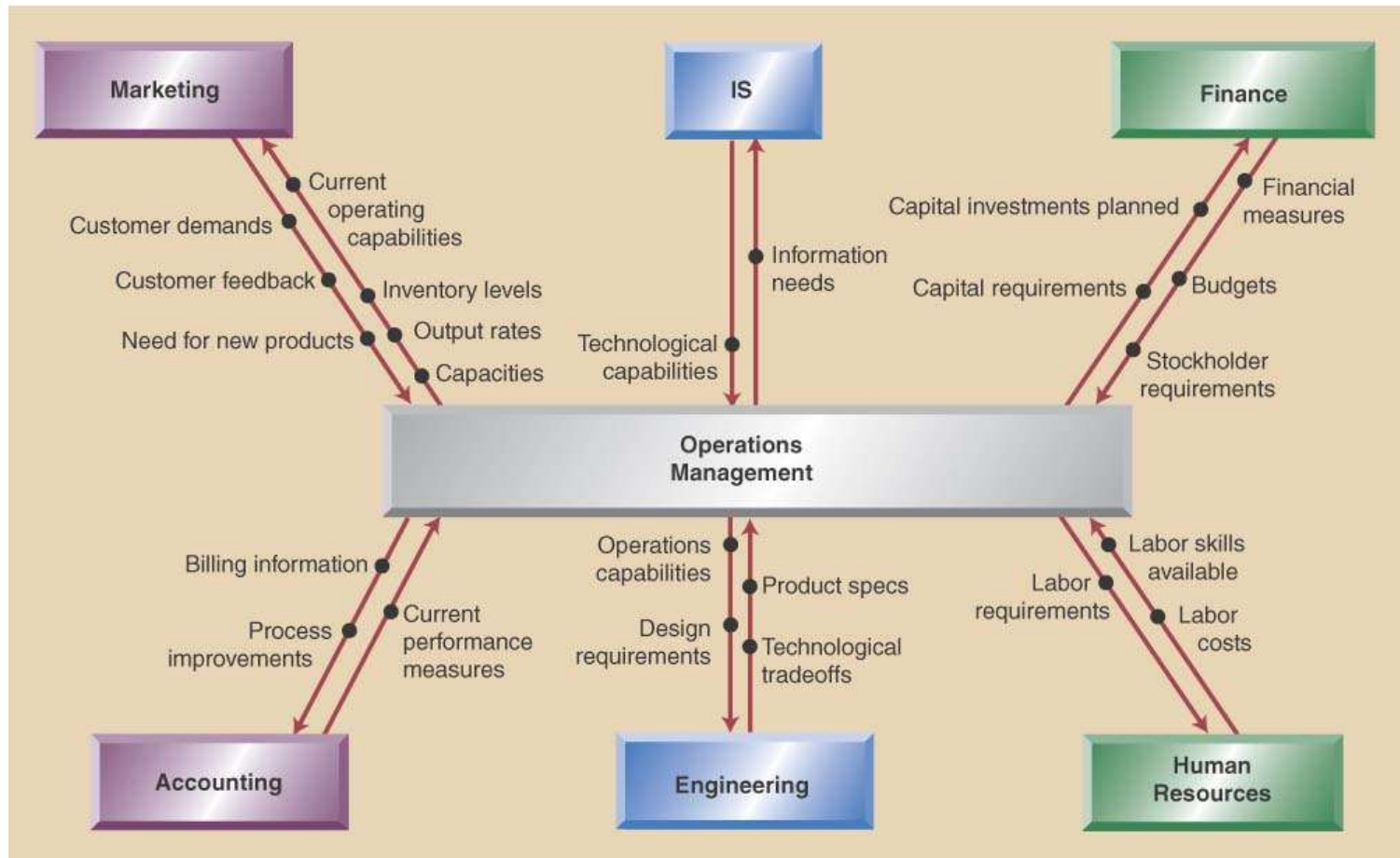
Today's OM Environment

- Customers demand better quality, greater speed, and lower costs
- Companies implementing lean system concepts – a total systems approach to efficient operations
- Recognized need to better manage information using ERP and CRM systems
- Increased cross-functional decision making

OM in Practice

- OM has the most diverse organizational function
- Manages the transformation process
- OM has many faces and names such as;
 - V. P. operations, Director of supply chains, Manufacturing manager
 - Plant manger, Quality specialists, etc.
- All business functions need information from OM in order to perform their tasks

Business Information Flow



OM Across the Organization

- Most businesses are supported by the functions of operations, marketing, and finance
- The major functional areas must interact to achieve the organization goals

OM Across the Organization – con't

- Marketing is not fully able to meet customer needs if they do not understand what operations can produce
- Finance cannot judge the need for capital investments if they do not understand operations concepts and needs
- Information systems enables the information flow throughout the organization
- Human resources must understand job requirements and worker skills
- Accounting needs to consider inventory management, capacity information, and labor standards

OM Highlights

- OM is the business function that is responsible for managing and coordinating the resources needed to produce a company's products and services.
- The role of OM is to transform organizational inputs into company's products or services outputs
- OM is responsible for a wide range of decisions, ranging from strategic to tactical.
- Organizations can be divided into manufacturing and service organizations, which differ in the tangibility of the product or service

OM Highlights – con't

- Many historical milestones have shaped OM. Some of these are the Industrial Revolution, scientific management, the human relations movement, management science, and the computer age
- OM is highly important function in today's dynamic business environment. Among the trends with significant impact are just-in-time, TQM, reengineering, flexibility, time-based competition, SCM, global marketplace, and environmental issues
- OM works closely with all other business functions

Decision Making

- Organizational Decision-making
 - Problem identification
 - Problem solution
 - Programmed decisions
 - Nonprogrammed decisions

Individual Decision Making

- Two Approaches
 - Rational Approach
 - When do we use it?



Individual Decision Making

- Bounded Rationality Perspective
 - When do we use it?
 - Intuitive Decision-making
- Nonprogrammed=
- Programmed=

Organizational Decision Making

- What is it?
- Four models
 - Management Science Approach
 - Carnegie Model
 - Incremental Decision Making Process
 - Garbage Can Model

Management Science Approach

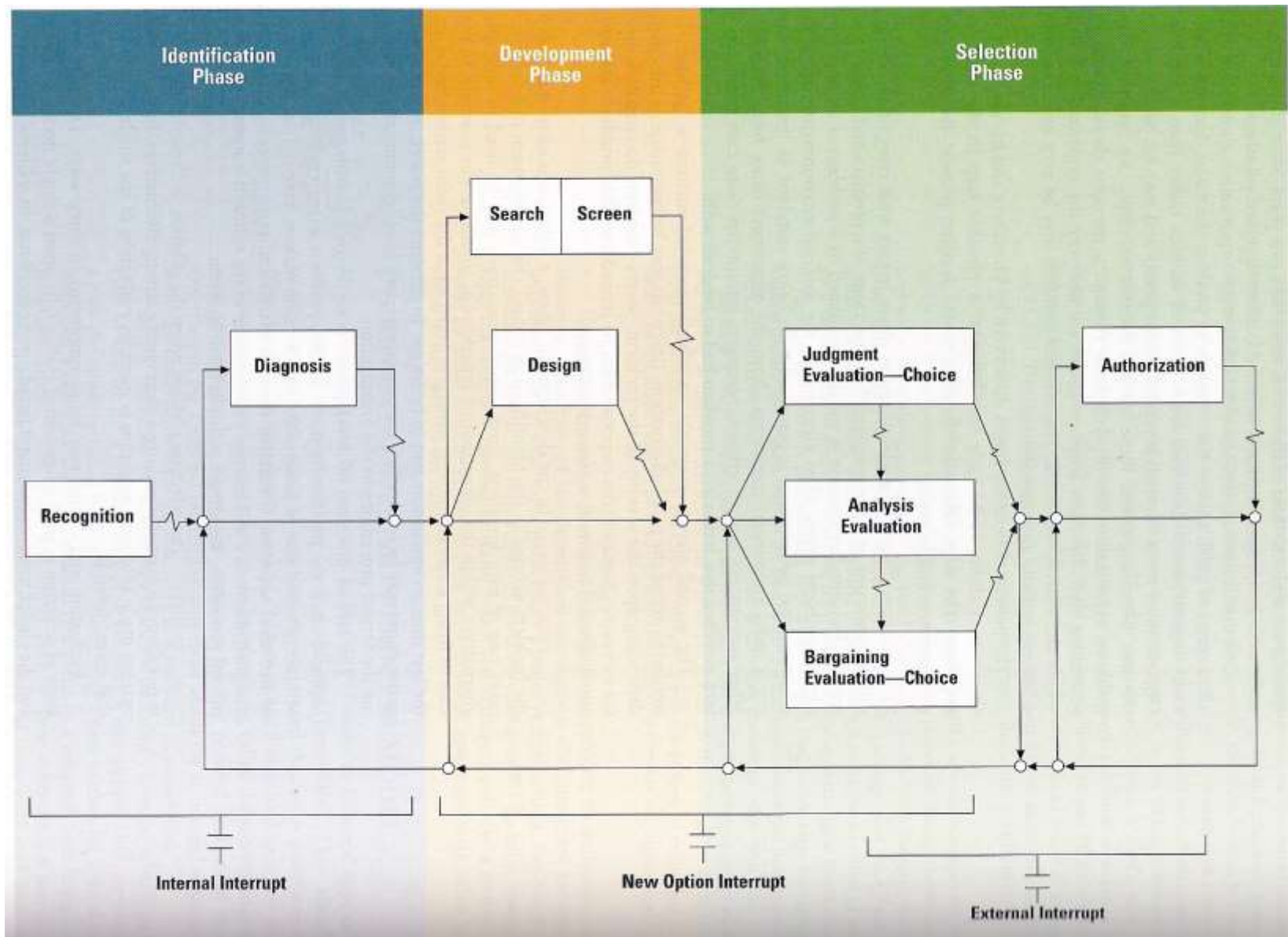
- Similar to rational individual approach
 - Structured
- Technology

Carnegie Model

- Coalitions
- Why use coalitions?
- Implications
 - Satisfaction
 - Short-term outlook
 - Discussion and bargaining
- Problem identification and implementation strategies

Incremental Decision Process Model

- Focuses on sequence of events from problem discovery to solution



Learning Organizations

- What are they?
 - How are they different from other organizations?
- Two Approaches to Decision Making
 - Combine Incremental Process & Carnegie Models
 - Garbage Can Model

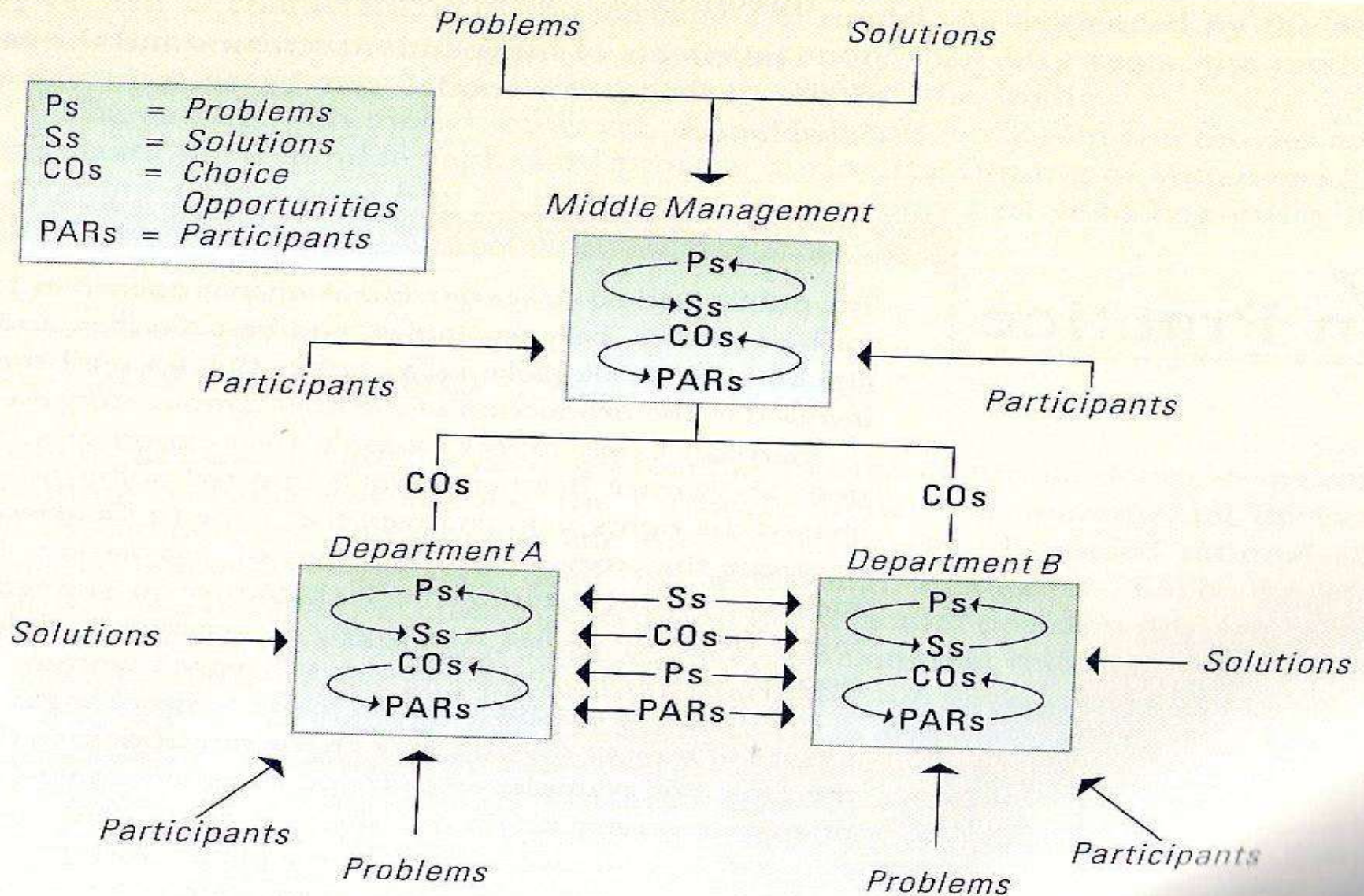
Garbage Can Model

- Extremely organic environments
- Three Causes
 - Problematic preferences
 - Unclear, poorly understood technology
 - Turnover

Garbage Can Model

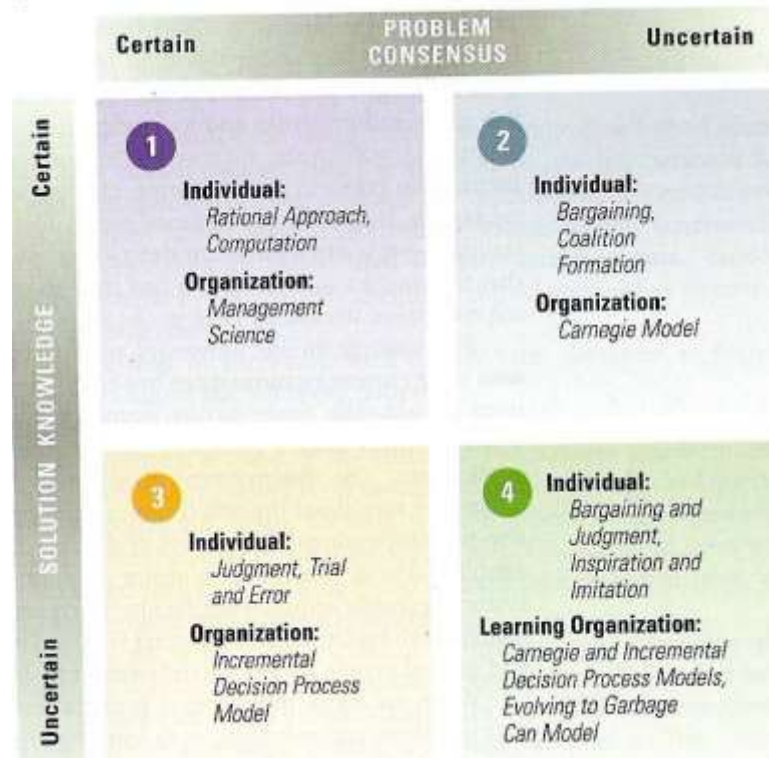
- Stream of Events
 - Problems
 - Potential solutions
 - Participants
 - Choice opportunities
- Consequences

Garbage Can Model



Contingency Decision-Making

- Two dimensions
 - Problem consensus
 - Technical knowledge about solutions



Special Decision Circumstances

- High Velocity Environments
 - Characteristics
 - How to overcome them
- Decision Making & Learning
- Escalating Commitment
 - Why does it happen?

Forecasting

Learning Objectives con't

- Generate forecasts for data with different patterns: level, trend, seasonality, and cyclical
- Describe causal modeling using linear regression
- Compute forecast accuracy
- Explain how forecasting models should be selected

Types of Forecasting Methods

- Decide what needs to be forecast
 - Level of detail, units of analysis & time horizon required
- Evaluate and analyze appropriate data
 - Identify needed data & whether it's available
- Select and test the forecasting model
 - Cost, ease of use & accuracy
- Generate the forecast
- Monitor forecast accuracy over time

Types of Forecasting Methods

- Forecasting methods are classified into two groups:

	Qualitative Methods	Quantitative Methods
1. Characteristics	Based on human judgment, opinions; subjective and nonmathematical.	Based on mathematics; quantitative in nature.
2. Strengths	Can incorporate latest changes in the environment and "inside information."	Consistent and objective; able to consider much information and data at one time.
3. Weaknesses	Can bias the forecast and reduce forecast accuracy.	Often quantifiable data are not available. Only as good as the data on which they are based.

Types of Forecasting Models

- Qualitative methods – judgmental methods
 - Forecasts generated subjectively by the forecaster
 - Educated guesses
- Quantitative methods – based on mathematical modeling:
 - Forecasts generated through mathematical modeling

Qualitative Methods

Type	Characteristics	Strengths	Weaknesses
Executive opinion	A group of managers meet & come up with a forecast	Good for strategic or new-product forecasting	One person's opinion can dominate the forecast
Market research	Uses surveys & interviews to identify customer preferences	Good determinant of customer preferences	It can be difficult to develop a good questionnaire
Delphi method	Seeks to develop a consensus among a group of experts	Excellent for forecasting long-term product demand, technological	Time consuming to develop

Quantitative Methods

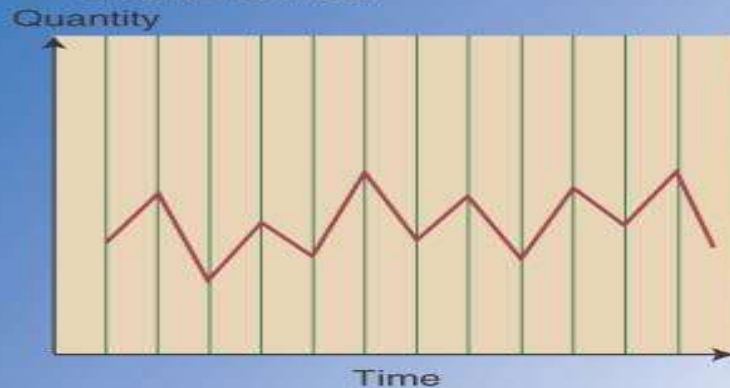
- **Time Series Models:**
 - Assumes information needed to generate a forecast is contained in a time series of data
 - Assumes the future will follow same patterns as the past
- **Causal Models or Associative Models**
 - Explores cause-and-effect relationships
 - Uses leading indicators to predict the future
 - Housing starts and appliance sales

Time Series Models

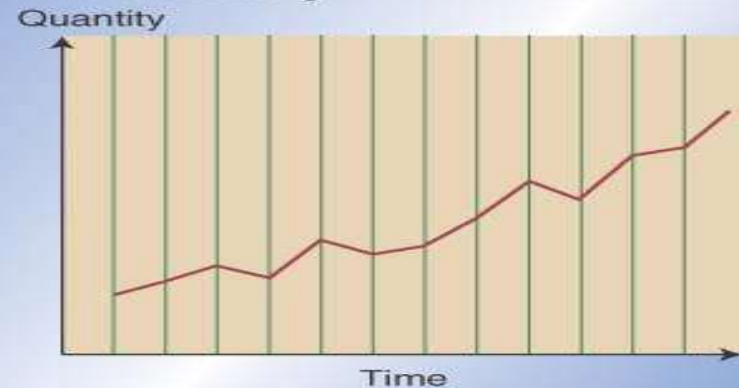
- Forecaster looks for data patterns as
 - Data = historic pattern + random variation
- Historic pattern to be forecasted:
 - Level (long-term average) – data fluctuates around a constant mean
 - Trend – data exhibits an increasing or decreasing pattern
 - Seasonality – any pattern that regularly repeats itself and is of a constant length
 - Cycle – patterns created by economic fluctuations
- Random Variation cannot be predicted

Time Series Patterns

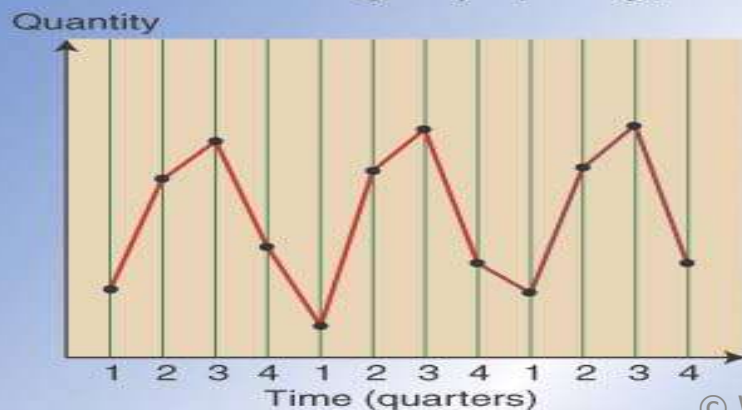
(a) Level or Horizontal Pattern:
Data follows a horizontal pattern around the mean



(b) Trend Pattern:
Data is progressively increasing (shown) or decreasing



(c) Seasonal Pattern:
Data exhibits a regularly repeating pattern



(d) Cycle:
Data increases or decreases over time



Time Series Models

- Naive: $F_{t+1} = A_t$
 - The forecast is equal to the actual value observed during the last period – good for level patterns
- Simple Mean: $F_{t+1} = \sum A_t / n$
 - The average of all available data - good for level patterns
- Moving Average: $F_{t+1} = \sum A_t / n$
 - The average value over a set time period (e.g.: the last four weeks)
 - Each new forecast drops the oldest data point & adds a new observation
 - More responsive to a trend but still lags behind actual data

Time Series Models con't

- Weighted Moving Average:

$$F_{t+1} = \sum C_t A_t$$

- All weights must add to 100% or 1.00
e.g. C_t .5, C_{t-1} .3, C_{t-2} .2 (weights add to 1.0)
- Allows emphasizing one period over others; above indicates more weight on recent data ($C_t=.5$)
- Differs from the simple moving average that weighs all periods equally - more responsive to trends

Time Series Models con't

- Exponential Smoothing: $F_{t+1} = \alpha A_t + (1 - \alpha)F_t$
Most frequently used time series method because of ease of use and minimal amount of data needed
- Need just three pieces of data to start:
 - Last period's forecast (F_t)
 - Last periods actual value (A_t)
 - Select value of smoothing coefficient, α between 0 and 1.0
- If no last period forecast is available, average the last few periods or use naive method
- Higher values (e.g. .7 or .8) may place too much weight on last period's random variation

Time Series Problem

- Determine forecast for periods 7 & 8
- **2-period** moving average
- **4-period** moving average
- **2-period** weighted moving average with t-1 weighted 0.6 and t-2 weighted 0.4
- **Exponential smoothing** with $\alpha=0.2$ and the period 6 forecast being 375

Period	Actual
1	300
2	315
3	290
4	345
5	320
6	360
7	375
8	

Time Series Problem Solution

Period	Actual	2-Period	4-Period	2-Per.Wgtd.	Expon. Smooth.
1	300				
2	315				
3	290				
4	345				
5	320				
6	360				
7	375	340.0	328.8	344.0	372.0
8		367.5	350.0	369.0	372.6

Forecasting trend problem: a company uses exponential smoothing with trend to forecast usage of its lawn care products. At the end of July the company wishes to forecast sales for August. July demand was 62. The trend through June has been 15 additional gallons of product sold per month. Average sales have been 57 gallons per month. The company uses $\alpha=0.2$ and $\beta=0.10$. Forecast for August.

- Smooth the level of the series:

$$S_{\text{July}} = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1}) = (0.2)(62) + (0.8)(57 + 15) = 70$$

- Smooth the trend:

$$T_{\text{July}} = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1} = (0.1)(70 - 57) + (0.9)(15) = 14.8$$

- Forecast including trend:

$$\text{FIT}_{\text{August}} = S_t + T_t = 70 + 14.8 = 84.8 \text{ gallons}$$

Linear Trend Line

A time series technique that computes a forecast with trend by drawing a straight line through a set of data using this formula:

$$Y = a + bx \text{ where}$$

Y = forecast for period X

X = the number of time periods from $X = 0$

A = value of y at $X = 0$ (Y intercept)

B = slope of the line

Forecasting Trend

- Basic forecasting models for trends compensate for the lagging that would otherwise occur
- One model, **trend-adjusted exponential smoothing** uses a three step process
 - **Step 1 - Smoothing the level of the series**

$$S_t = \alpha A_t + (1 - \alpha)(S_{t-1} + T_{t-1})$$

- **Step 2 – Smoothing the trend**

$$T_t = \beta(S_t - S_{t-1}) + (1 - \beta)T_{t-1}$$

- **Forecast including the trend**

$$FIT_{t+1} = S_t + T_t$$

Forecasting Seasonality

- Calculate the average demand per season
 - *E.g.*: average quarterly demand
- Calculate a seasonal index for each season of each year:
 - Divide the actual demand of each season by the average demand per season for that year
- Average the indexes by season
 - *E.g.*: take the average of all Spring indexes, then of all Summer indexes, ...

Seasonality con't

- Forecast demand for the next year & divide by the number of seasons
 - Use regular forecasting method & divide by four for average quarterly demand
- Multiply next year's average seasonal demand by each average seasonal index
 - Result is a forecast of demand for each season of next year

Seasonality problem: a university must develop forecasts for the next year's quarterly enrollments. It has collected quarterly enrollments for the past two years. It has also forecast total enrollment for next year to be 90,000 students. What is the forecast for each quarter of next year?

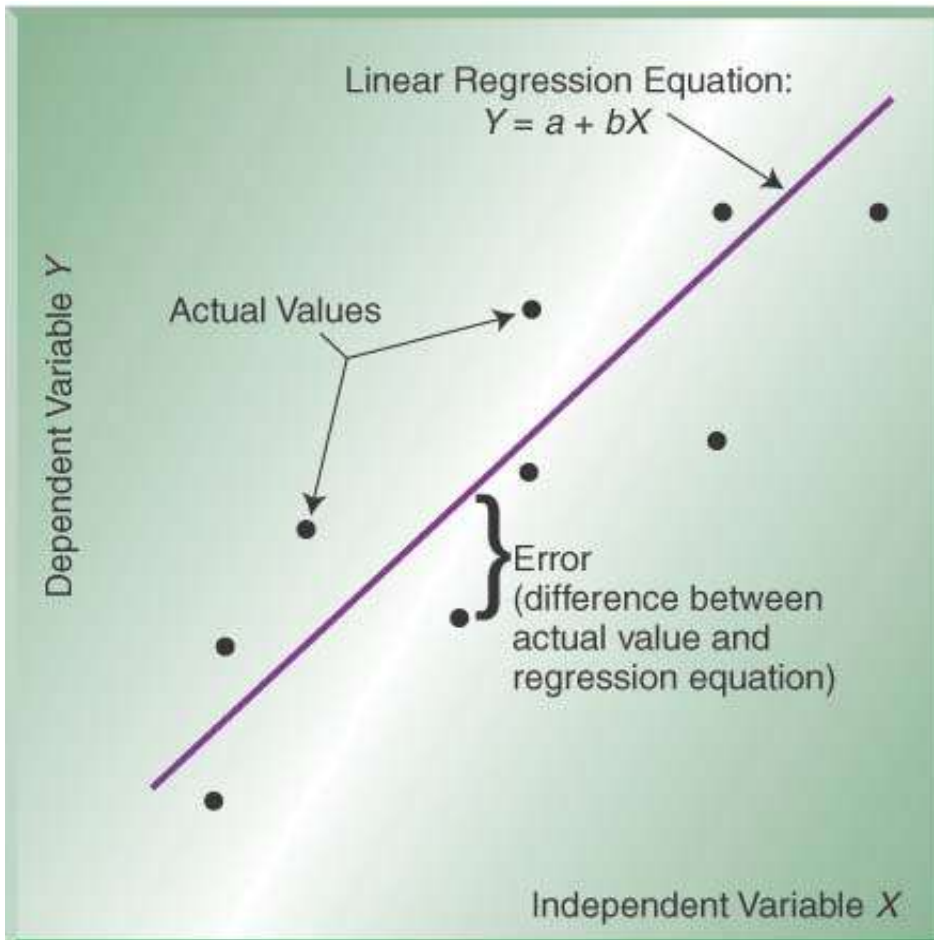
Quarter	Year 1	Seasonal Index	Year 2	Seasonal Index	Avg. Index	Year3
Fall	24000	1.2	26000	1.238	1.22	27450
Winter	23000		22000			
Spring	19000		19000			
Summer	14000		17000			
Total	80000		84000			90000
Average	20000		21000			22500

Causal Models

- Often, leading indicators can help to predict changes in future demand e.g. housing starts
- Causal models establish a cause-and-effect relationship between independent and dependent variables
- A common tool of causal modeling is linear regression:
- Additional related variables may require multiple regression modeling

$$\mathbf{Y} = \mathbf{a} + \mathbf{b}\mathbf{x}$$

Linear Regression



- Identify dependent (**y**) and independent (**x**) variables
- Solve for the slope of the line

$$b = \frac{\sum XY - n\bar{X}\bar{Y}}{\sum X^2 - n\bar{X}^2}$$

- Solve for the y intercept

- Develop your equation for the trend line

$$Y = a + bX$$

Linear Regression Problem: A maker of golf shirts has been tracking the relationship between sales and advertising dollars. Use linear regression to find out what sales might be if the company invested \$53,000 in advertising next year.

	Sales \$ (Y)	Adv.\$ (X)	XY	X ²	Y ²
1	130	32	4160	2304	16,900
2	151	52	7852	2704	22,801
3	150	50	7500	2500	22,500
4	158	55	8690	3025	24,964
5	153.85	53			
Tot	589	189	28202	9253	87165
Avg	147.25	47.25			

$$b = \frac{\sum XY - n\bar{X}\bar{Y}}{\sum X^2 - n\bar{X}^2}$$

$$b = \frac{28202 - 4(47.25)(147.25)}{9253 - 4(47.25)^2} = 1.15$$

$$a = \bar{Y} - b\bar{X} = 147.25 - 1.15(47.25)$$

$$a = 92.9$$

$$Y = a + bX = 92.9 + 1.15X$$

$$Y = 92.9 + 1.15(53) = 153.85$$

Correlation Coefficient

How Good is the Fit?

- Correlation coefficient (**r**) measures the direction and strength of the linear relationship between two variables. The closer the r value is to 1.0 the better the regression line fits the data points.

$$r = \frac{n(\sum XY) - (\sum X)(\sum Y)}{\sqrt{n(\sum X^2) - (\sum X)^2} * \sqrt{n(\sum Y^2) - (\sum Y)^2}}$$

$$r = \frac{4(28,202) - 189(589)}{\sqrt{4(9253) - (189)^2} * \sqrt{4(87,165) - (589)^2}} = .982$$

$$r^2 = (.982)^2 = .964$$

- Coefficient of determination (r^2) measures the amount of variation in the dependent variable about its mean that is explained by the regression line. Values of (r^2) close to 1.0 are desirable.

Multiple Regression

- An extension of linear regression but:
 - Multiple regression develops a relationship between a dependent variable and multiple independent variables. The general formula is:

$$Y = B_0 + B_1X_1 + B_2X_2 + \cdots + B_KX_K$$

Measuring Forecast Error

- Forecasts are never perfect
- Need to know how much we should rely on our chosen forecasting method
- Measuring **forecast error**:

$$\mathbf{E}_t = \mathbf{A}_t - \mathbf{F}_t$$

- Note that over-forecasts = negative errors
and under-forecasts = positive errors

Measuring Forecasting Accuracy

- Mean Absolute Deviation (MAD)
 - measures the total error in a forecast without regard to sign
- Cumulative Forecast Error (CFE)
 - Measures any bias in the forecast
- Mean Square Error (MSE)
 - Penalizes larger errors
- Tracking Signal
 - Measures if your model is working

$$\mathbf{MAD} = \frac{\sum |\mathbf{actual} - \mathbf{forecast}|}{\mathbf{n}}$$

$$\mathbf{CFE} = \sum (\mathbf{actual} - \mathbf{forecast})$$

$$\mathbf{MSE} = \frac{\sum (\mathbf{actual} - \mathbf{forecast})^2}{\mathbf{n}}$$

$$\mathbf{TS} = \frac{\mathbf{CFE}}{\mathbf{MAD}}$$

Accuracy & Tracking Signal Problem: A company is comparing the accuracy of two forecasting methods. Forecasts using both methods are shown below along with the actual values for January through May. The company also uses a tracking signal with ± 4 limits to decide when a forecast should be reviewed. Which forecasting method is best?

Month	Actual sales	Method A				Method B			
		F'cast	Error	Cum. Error	Tracking Signal	F'cast	Error	Cum. Error	Tracking Signal
Jan.	30	28	2	2	2	27	2	2	1
Feb.	26	25	1	3	3	25	1	3	1.5
March	32	32	0	3	3	29	3	6	3
April	29	30	-1	2	2	27	2	8	4
May	31	30	1	3	3	29	2	10	5
MAD			1				2		
MSE			1.4				4.4		

Selecting the Right Forecasting Model

1. The amount & type of available data

- Some methods require more data than others

2. Degree of accuracy required

- Increasing accuracy means more data

3. Length of forecast horizon

- Different models for 3 month vs. 10 years

4. Presence of data patterns

- Lagging will occur when a forecasting model meant for a level pattern is applied with a trend

Forecasting Software

- Spreadsheets
 - Microsoft Excel, Quattro Pro, Lotus 1-2-3
 - Limited statistical analysis of forecast data
- Statistical packages
 - SPSS, SAS, NCSS, Minitab
 - Forecasting plus statistical and graphics
- Specialty forecasting packages
 - Forecast Master, Forecast Pro, Autobox, SCA

Guidelines for Selecting Software

- Does the package have the features you want?
- What platform is the package available for?
- How easy is the package to learn and use?
- Is it possible to implement new methods?
- Do you require interactive or repetitive forecasting?
- Do you have any large data sets?
- Is there local support and training available?
- Does the package give the right answers?

Other Forecasting Methods

- **Focus Forecasting**

- Developed by Bernie Smith
- Relies on the use of simple rules
- Test rules on past data and evaluate how they perform

- **Combining Forecasts**

- Combining two or more forecasting methods can improve accuracy

Collaborative Planning Fore-casting & Replenishment (CPFR)

- Establish collaborative relationships between buyers and sellers
- Create a joint business plan
- Create a sales forecast
- Identify exceptions for sales forecast
- Resolve/collaborate on exception items
- Create order forecast
- Identify exceptions for order forecast
- Resolve/collaborate on exception items
- Generate order

Forecasting within OM: How it all fits together

Forecasts impact not only other business functions but all other operations decisions. Operations managers make many forecasts, such as the expected demand for a company's products. These forecasts are then used to determine:

- product designs that are expected to sell (Ch 2),
- the quantity of product to produce (Chs 5 and 6),
- the amount of needed supplies and materials (Ch 12).

Forecasting within OM con't

Also, a company uses forecasts to

- determine future space requirements (Ch 10),
- capacity and
- location needs (Ch 9), and
- the amount of labor needed (Ch 11).

Forecasting within OM con't

Forecasts drive strategic operations decisions, such as:

- choice of competitive priorities, changes in processes, and large technology purchases (Ch 3).
- Forecast decisions serve as the basis for tactical planning; developing worker schedules (Ch 11).

Virtually all operations management decisions are based on a forecast of the future.

Forecasting Across the Organization

- Forecasting is critical to management of all organizational functional areas
 - Marketing relies on forecasting to predict demand and future sales
 - Finance forecasts stock prices, financial performance, capital investment needs..
 - Information systems provides ability to share databases and information
 - Human resources forecasts future hiring requirements

Forecasting Highlights

- Three basic principles of forecasting are: forecasts are rarely perfect, are more accurate for groups than individual items, and are more accurate in the shorter term than longer time horizons.
- The forecasting process involves five steps: decide what to forecast, evaluate and analyze appropriate data, select and test model, generate forecast, and monitor accuracy.
- Forecasting methods can be classified into two groups: qualitative and quantitative. Qualitative methods are based on the subjective opinion of the forecaster and quantitative methods are based on mathematical modeling.

Forecasting Highlights con't

- Time series models are based on the assumption that all information needed is contained in the time series of data. Causal models assume that the variable being forecast is related to other variables in the environment.
- There are four basic patterns of data: level or horizontal, trend, seasonality, and cycles. In addition, data usually contain random variation. Some forecast models used to forecast the level of a time series are: naïve, simple mean, simple moving average, weighted moving average, and exponential smoothing. Separate models are used to forecast trends and seasonality.
- A simple causal model is linear regression in which a straight-line relationship is modeled between the variable we are forecasting and another variable in the environment. The correlation is used to measure the strength of the linear relationship between these two variables.

Forecasting Highlights con't

- Three useful measures of forecast error are mean absolute deviation (MAD), mean square error (MSE) and tracking signal.
- There are four factors to consider when selecting a model: amount and type of data available, degree of accuracy required, length of forecast horizon, and patterns present in the data.

Capacity Planning

Capacity Planning

- Capacity is the **upper limit** or ceiling on the load that an operating unit can handle.
- The basic questions in capacity handling are:
 - What **kind** of capacity is needed?
 - How **much** is needed?
 - **When** is it needed?

Importance of Capacity Decisions

- Impacts ability to meet future demands
- Affects operating costs
- Major determinant of initial costs
- Involves long-term commitment
- Affects competitiveness
- Affects ease of management

Various Capacities

- Design capacity
 - Maximum obtainable output
- Effective capacity, expected variations
 - Maximum capacity subject to planned and expected variations such as maintenance, coffee breaks, scheduling conflicts.
- Actual output, unexpected variations and demand
 - Rate of output actually achieved--cannot exceed effective capacity. It is subject to random disruptions: machine break down, absenteeism, material shortages and most importantly the **demand**.

Efficiency and Utilization

$$\text{Efficiency} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

$$\text{Utilization} = \frac{\text{Actual output}}{\text{Design capacity}}$$

This definition of efficiency is not used very much.
Utilization is more important.

Efficiency/Utilization Example for a Trucking Company

Design capacity = 50 trucks/day available

Effective capacity = 40 trucks/day, because 20% of truck capacity goes through planned maintenance

Actual output = 36 trucks/day, 3 trucks delayed at maintenance, 1 had a flat tire

$$\text{Efficiency} = \frac{\text{Actual Output}}{\text{Effective Capacity}} = \frac{36 \text{ units / day}}{40 \text{ units / day}} = 90\%$$

$$\text{Utilization} = \frac{\text{Actual Output}}{\text{Design Capacity}} = \frac{36 \text{ units / day}}{50 \text{ units / day}} = 72\%$$

Determinants of Effective Capacity/Output

- Facilities, *layout*
- Products or services, *product mixes/setups*
- Processes, *quality*
- Human considerations, *motivation*
- Operations, *scheduling and synchronization problems*
- Supply Chain factors, *material shortages*
- External forces, *regulations*

Caution: While discussing these the book considers effective capacity almost synonymous to output.

Some Possible Growth/Decline Patterns

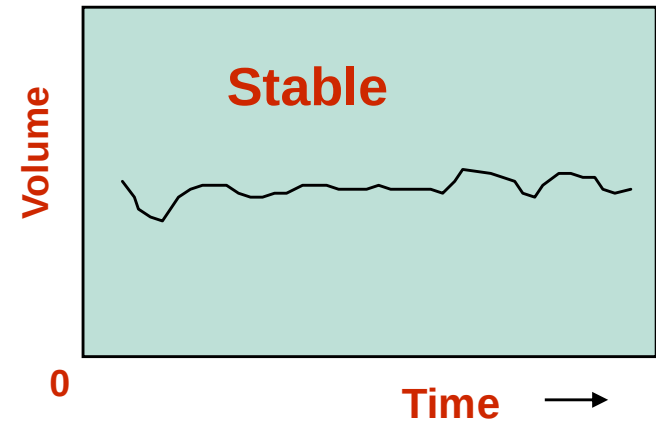
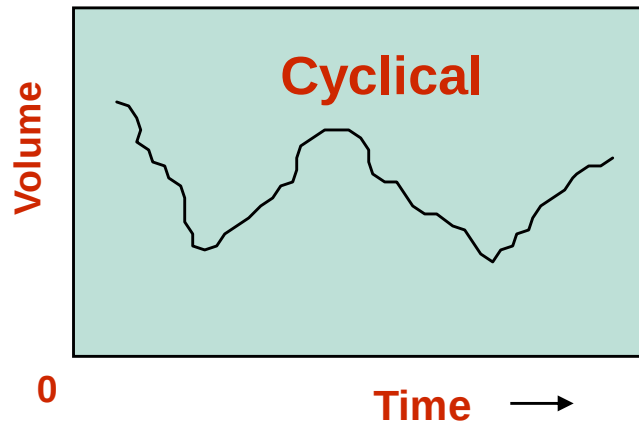
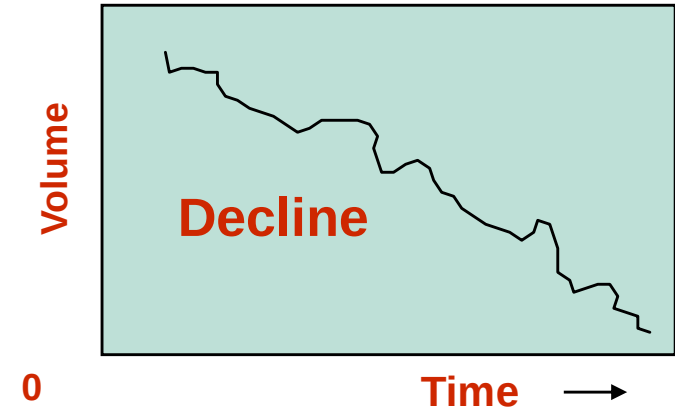
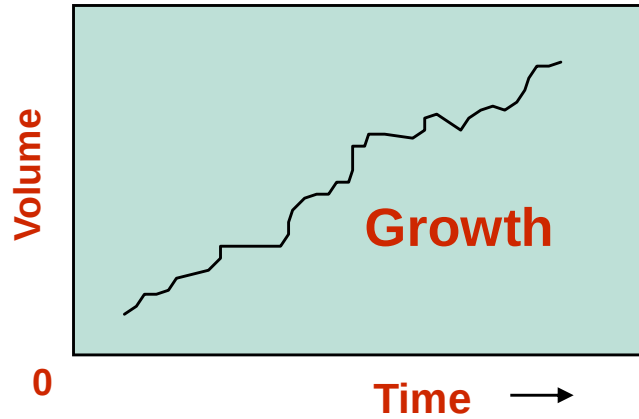


Figure 5-1

Developing Capacity Alternatives

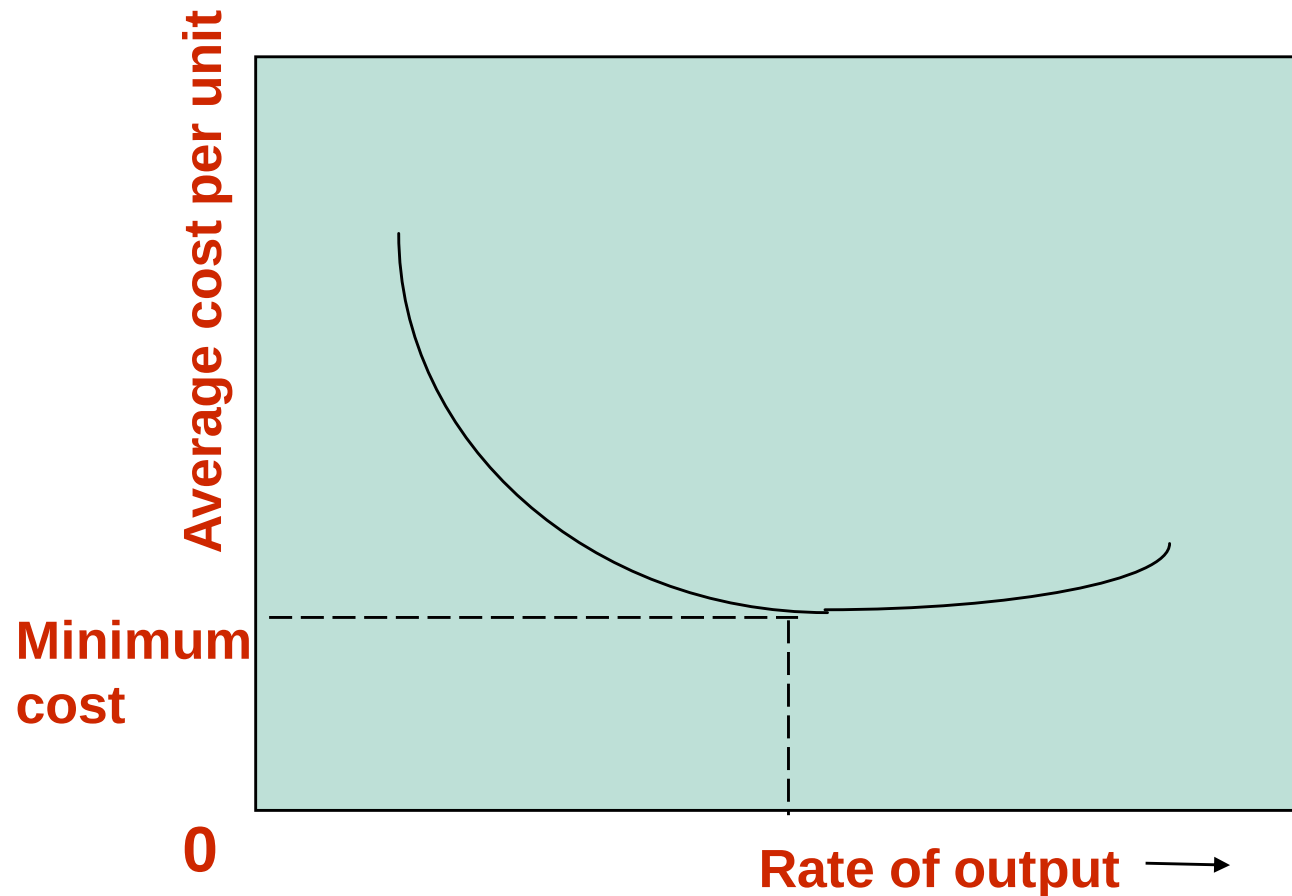
- Design flexibility into systems,
 - modular expansion
- Take a “big picture” approach to capacity changes,
 - hotel rooms, car parks, restaurant seats
- Differentiate new and mature products,
 - pay attention to the life cycle, demand variability vs. discontinuation
- Prepare to deal with capacity “chunks”,
 - no machine comes in continuous capacities
- Attempt to smooth out capacity requirements,
 - complementary products, subcontracting
- Identify the optimal operating level,
 - facility size

Outsourcing: Make or Buy

- Outsourcing: Obtaining a good or service from an external provider
- Decide on outsourcing by considering
 - Available capacity
 - Expertise
 - Quality considerations
 - The nature of demand: Stability
 - Cost
 - Risk: Loss of control over operations with outsourcing; loss of know-how. Loss of revenue.

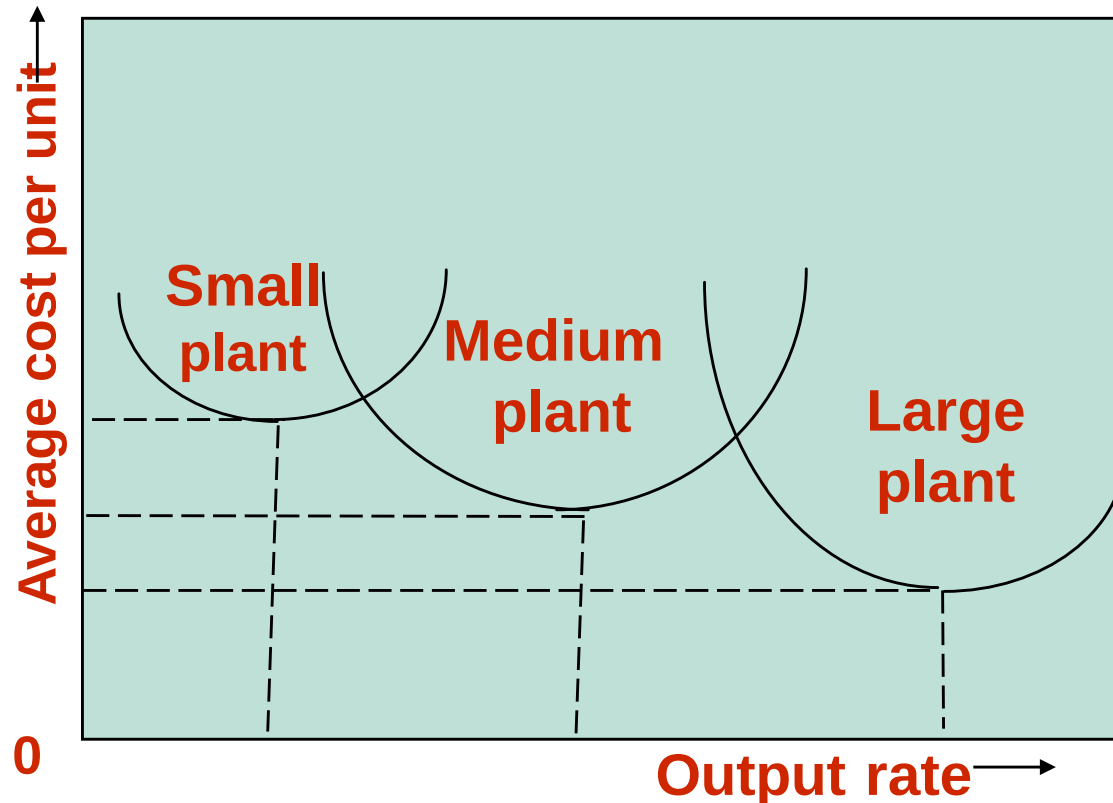
Evaluating Alternatives: Facility Size

Production units have an optimal rate of output for minimal cost.



Evaluating Alternatives: Facility Size

Minimum cost & optimal operating rate are functions of size of production unit.



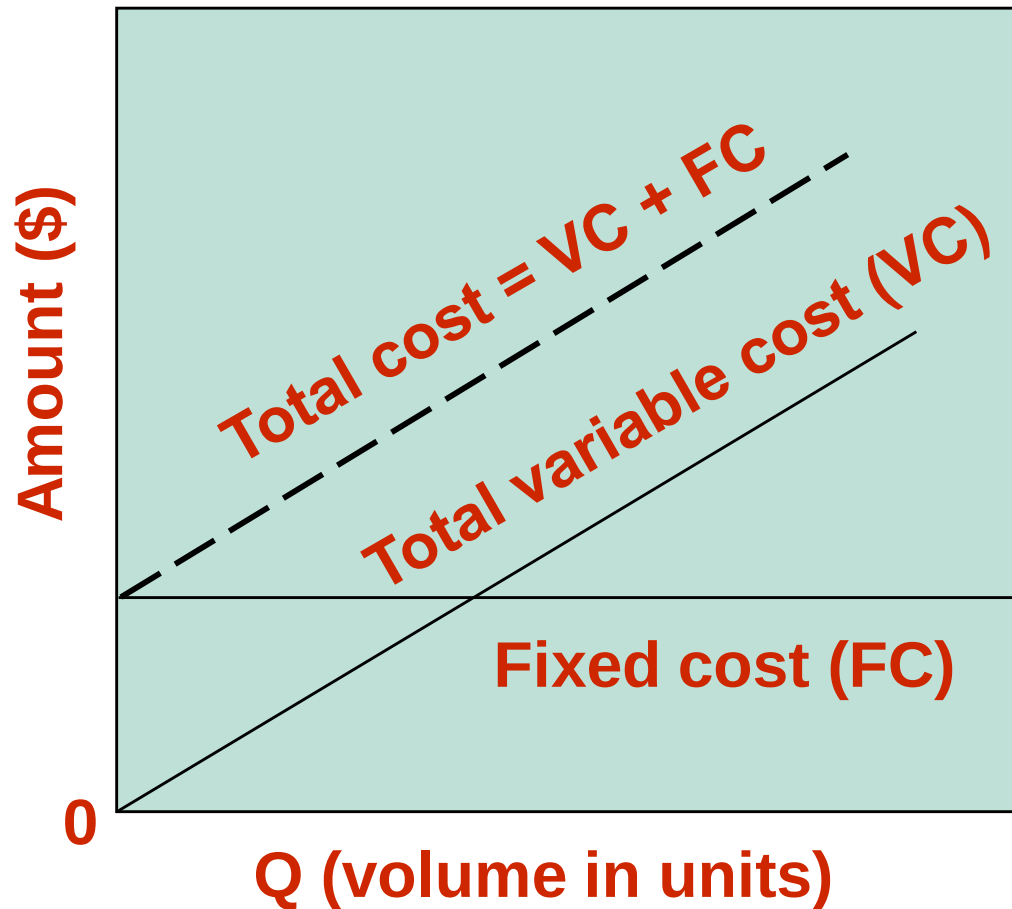
Planning Service Capacity

- Need to be near customers
 - Capacity and location are closely tied
- Inability to store services
 - Capacity must be matched with timing of demand
- Degree of volatility of demand
 - Peak demand periods

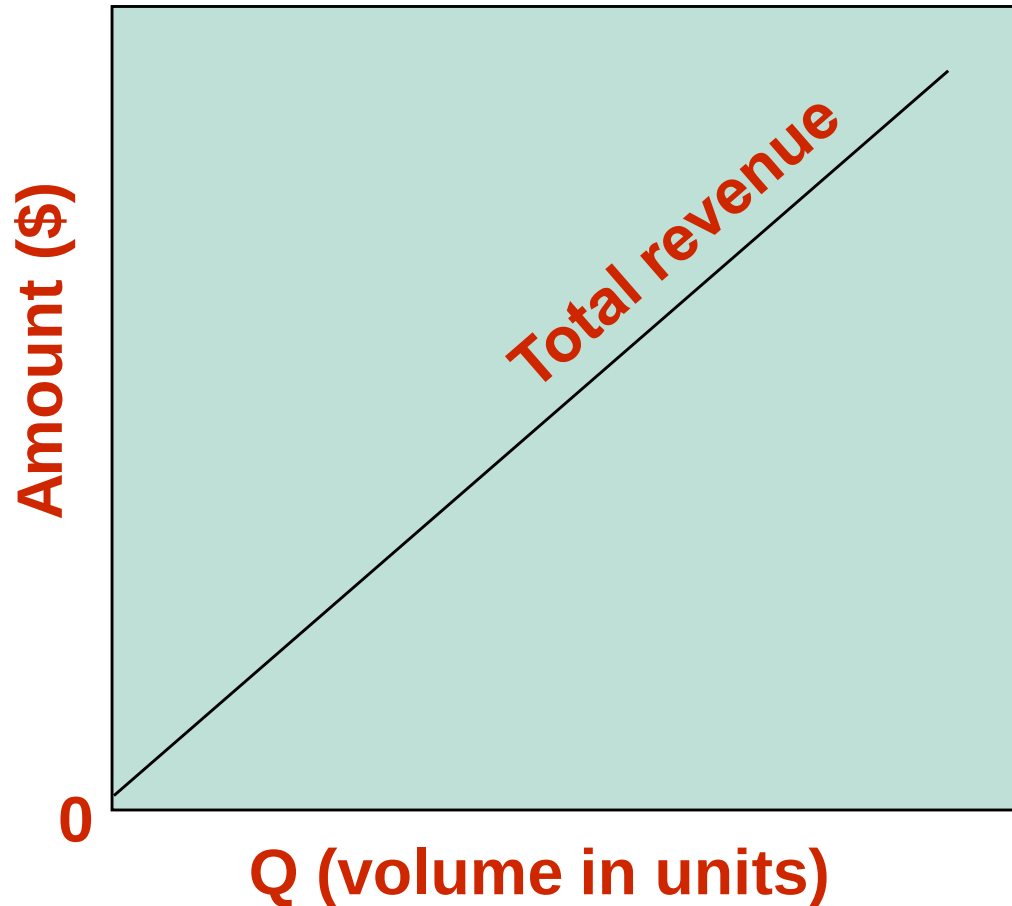
Example: Calculating Processing Requirements

Product	Annual Demand	Standard processing time per unit (hr.)	Processing time needed (hr.)
#1	400	5.0	2,000
#2	300	8.0	2,400
#3	700	2.0	<u>1,400</u> 5,800

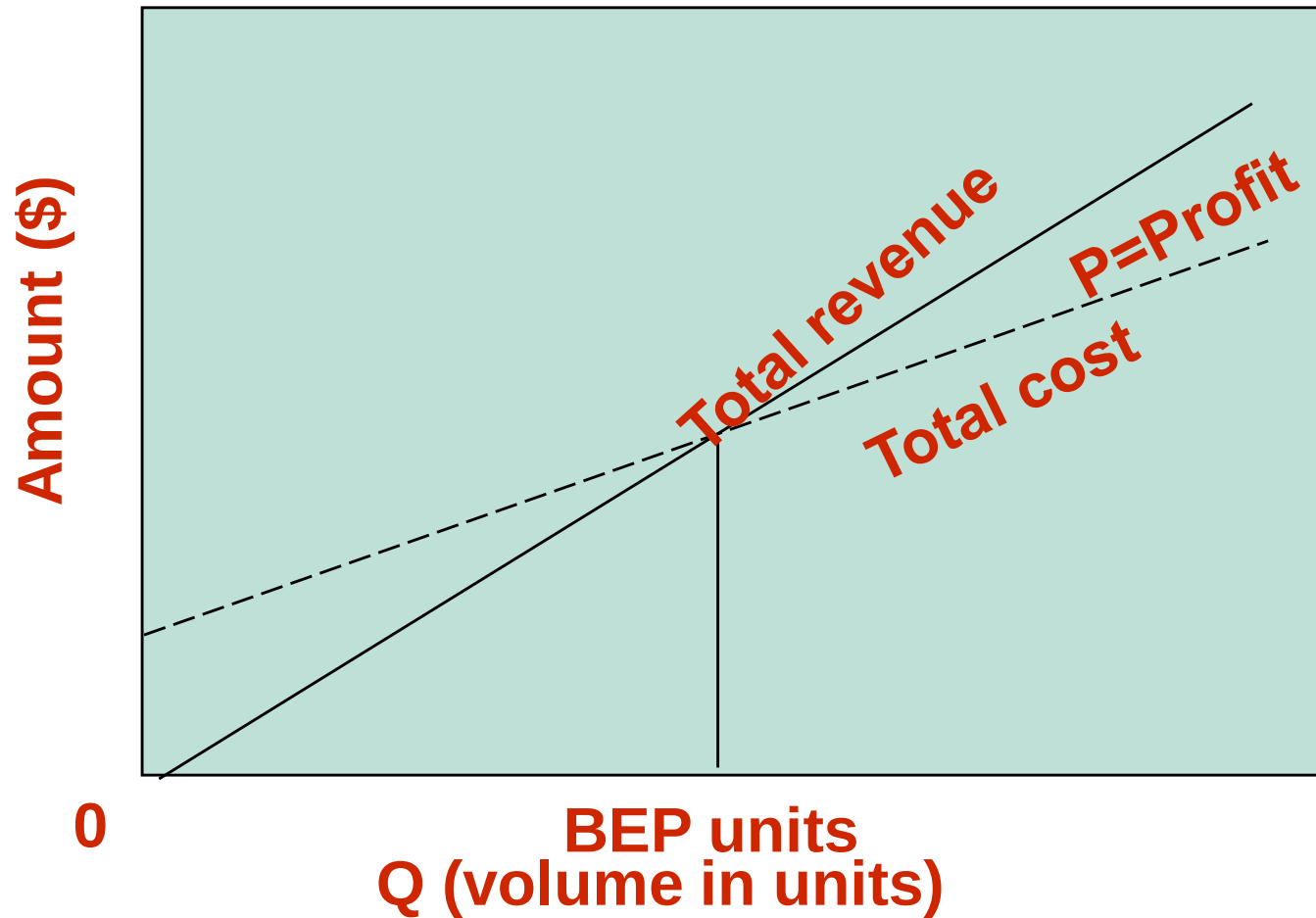
Cost-Volume Relationships



Cost-Volume Relationships

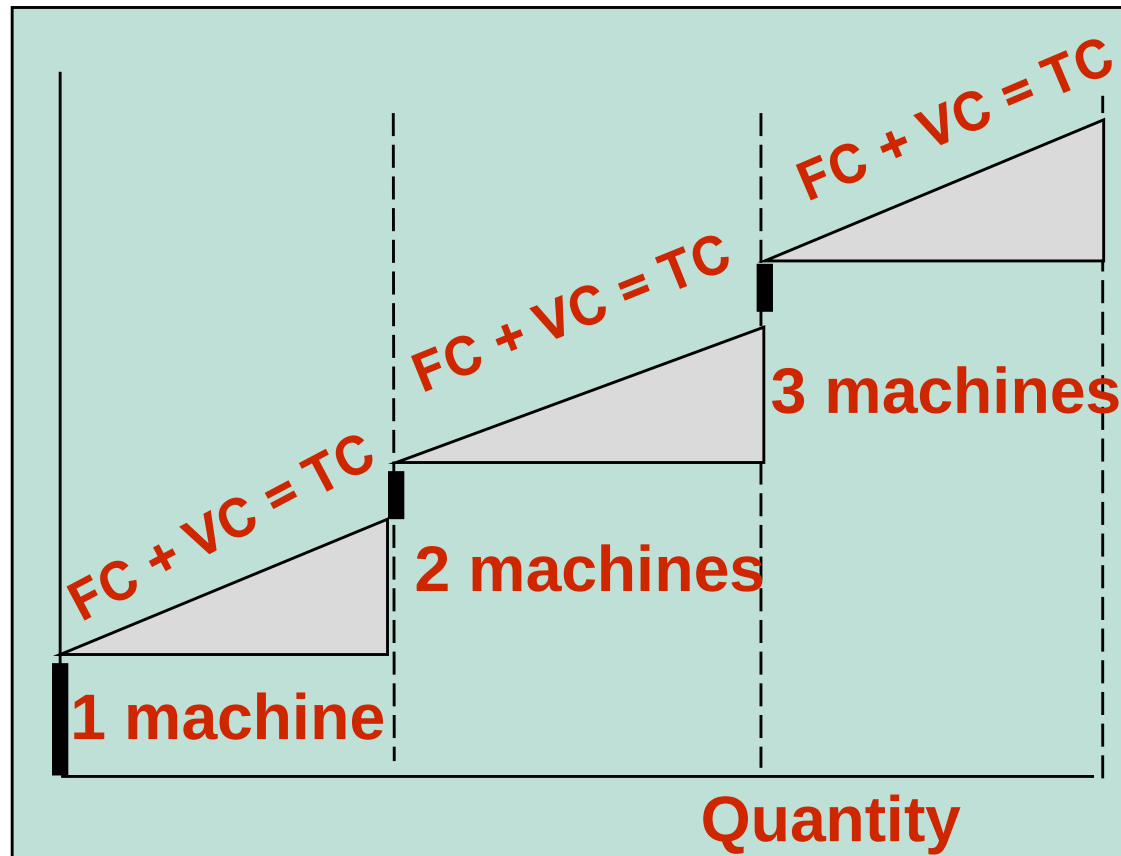


Cost-Volume Relationships: Break-even analysis



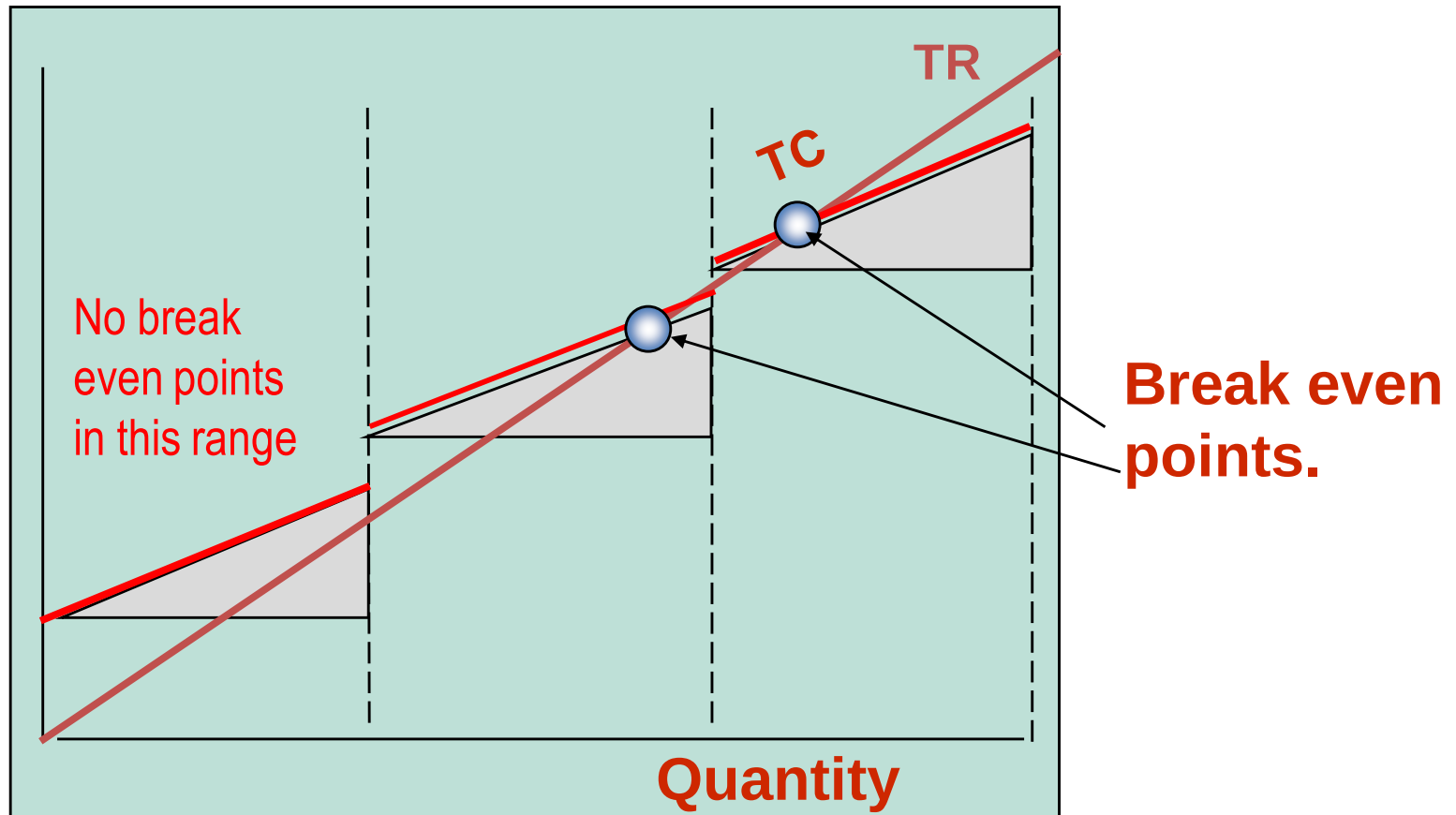
$$P = (\text{Quantity})(\text{Contribution To Margin}) - (\text{Fixed cost}) = Q(R - v) - FC$$

Break-Even Problem with Multiple Fixed Costs



Fixed costs and variable costs.
Thick lines are fixed costs.

Break-Even Problem with Step Fixed Costs



Step fixed costs and variable costs.

Cost-Volume(Break-even) Analysis

- Break-even quantity: Level of production that equates total costs to total revenues

Assumptions:

- One product is involved
- Everything produced can be sold
- Variable cost per unit is the same with volume
- Fixed costs do not change with volume
- Revenue per unit constant with volume
- Revenue per unit exceeds variable cost per unit

Summary

- Capacity types
- Efficiency, utilization
- Break-even analysis

Decision Theory

Decision Theory represents a general approach to decision making which is suitable for a wide range of operations management decisions, including:

capacity
planning

product and
service design

location
planning

equipment
selection

Decision Theory Elements

- A set of possible future conditions (call them **scenarios**) exists that will have a bearing on the results of the decision
 - Uncertain scenarios
- A list of **alternatives** for the manager to choose from
- A known **payoff** for each alternative under each possible future condition

Payoff Table

~~Input or implied by the problem set up~~

Alternatives	Possible future demand		
	Low	Moderate	High
Small facility	\$10	\$10	\$10
Medium facility	\$7	\$12	\$12
Large facility	\$-4	\$2	\$16

Present value in \$ millions.

This payoff table is given as an input.

Decision Making under Uncertainty

When maximizing an objective:

MaxiMin - Choose the alternative which has the maximum of minimum possible payoffs for each alternative. Conservative strategy because tries to make the best of the worst possible outcome (for each decision). Which facility?

MaxiMax - Choose the alternative with the largest possible payoff. Radical strategy. Which facility?

Average(Laplace) - Choose the alternative with the best average payoff of any of the alternatives. Which facility?

Decision Making under Uncertainty

When minimizing an objective: Say cost.

MiniMax - Choose the alternative which has the minimum of the maximum possible costs for each alternative. Conservative strategy.

MiniMin - Choose the alternative with the least possible cost. Radical strategy.

Average(Laplace) - Choose the alternative with the minimum average cost of any of the alternatives.

Average cost may not be a good indicator. Some alternatives may have more risk than others. In that case, it is ok to choose a slightly costly alternative with low risk.

Example: Hyatt at the Airport “some time ago”

Construct the payoff matrix

	Airport location Las Colinas	Airport Location Richardson
Purchase Price	\$18	\$12
PV of hotel if airport is built here	\$31	\$23
PV of hotel if airport is built at the other location	\$6	\$4

Payoff Matrix for MaxiMax, MaxiMin

	Airport location Las Colinas	Airport location Richardson
Buy Las Colinas	\$13	<u>-\$12</u>
Buy Richardson	<u>-\$8</u>	\$11
Buy Both	\$5	<u>-\$1</u>
<u>Buy None</u>	<u>\$0</u>	<u>\$0</u>

Regret: What I have done against what I could have done. MiniMax

Regret.

	Airport location Las Colinas	Airport location Richardson
Buy Las Colinas	\$0=no regret	<u>\$23</u>
Buy Richardson	<u>\$21</u>	\$0=no regret
Buy Both	\$8	<u>\$12</u>
Buy None	<u>\$13</u>	\$11

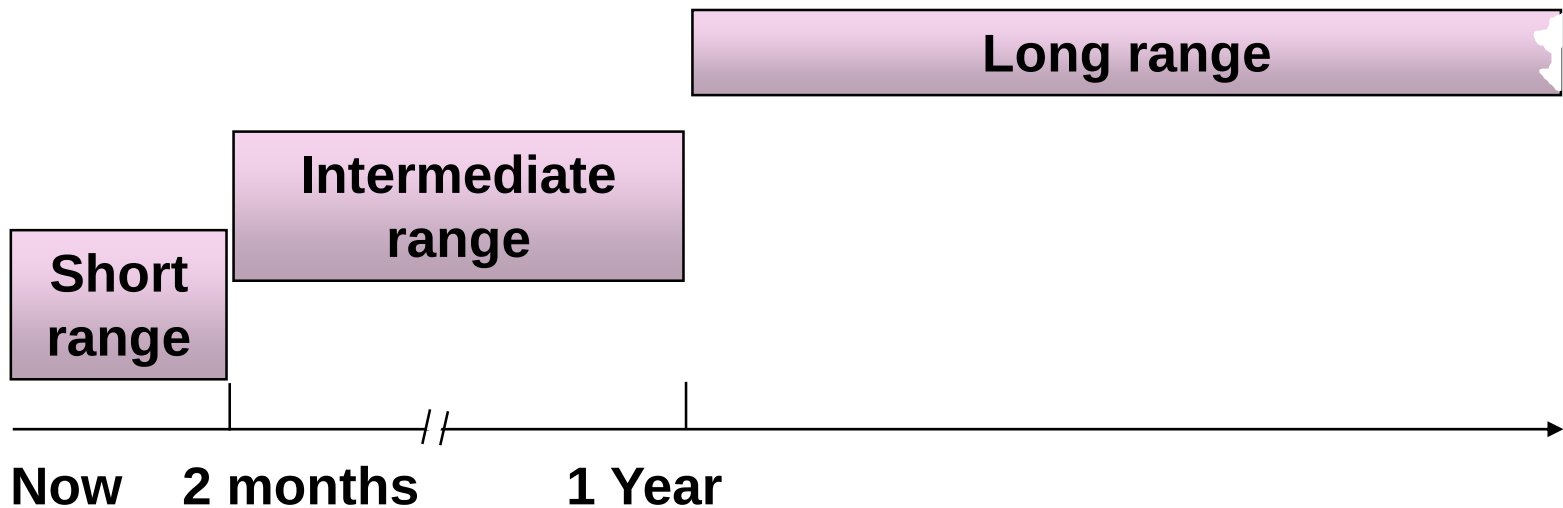
Summary

- Capacity types
- Efficiency, utilization
- Break-even analysis
- Decision Theory (decision making under uncertainty)

Aggregate Planning

Planning Horizon

Aggregate planning: Intermediate-range capacity planning, usually covering 2 to 12 months.

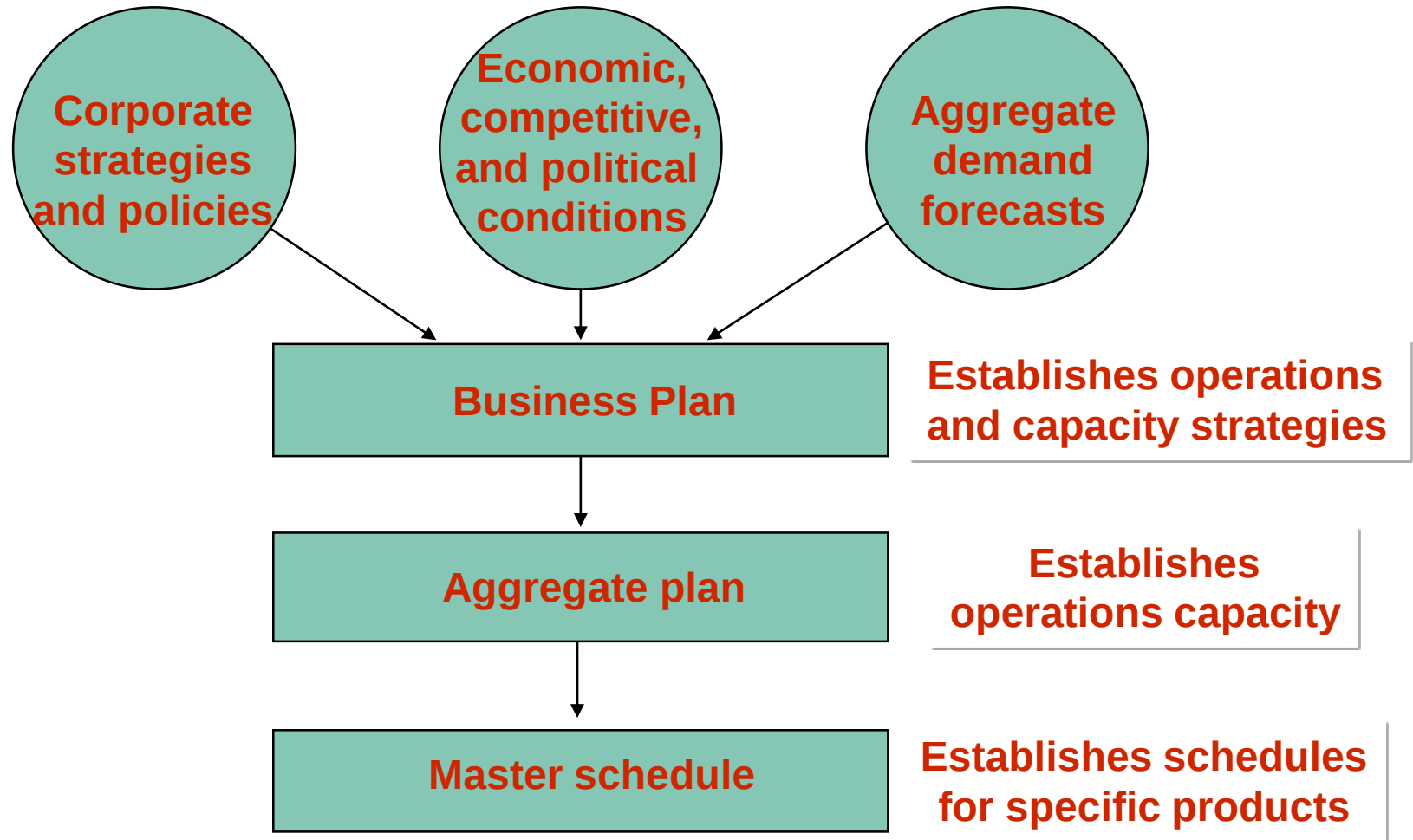


Overview of Planning Levels

- Short-range plans (Detailed plans)
 - Machine loading
 - Job assignments
- Intermediate plans (General levels)
 - Employment
 - Output
- Long-range plans
 - Long term capacity
 - Location / layout

Planning Sequence

Figure 12.1



Aggregate Planning Inputs

- Resources
 - Workforce
 - Facilities
- Demand forecast
- Policies
 - Subcontracting
 - Overtime
 - Inventory levels
 - Back orders
- Costs
 - Inventory carrying
 - Back orders
 - Hiring/firing
 - Overtime
 - Inventory changes
 - subcontracting

Aggregate Planning Outputs

- Total cost of a plan
- Projected levels of inventory
 - Inventory
 - Output
 - Employment
 - Subcontracting
 - Backordering

Aggregate Planning Strategies

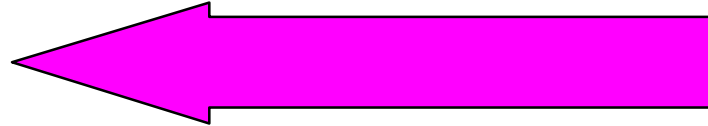
- Proactive
 - Alter demand to match capacity
- Reactive
 - Alter capacity to match demand
- Mixed
 - Some of each

Demand Options

- Pricing



- Promotion



- Back orders



- New demand



Capacity Options

- Hire and layoff workers
- Overtime/slack time
- Part-time workers
- Inventories
- Subcontracting

Aggregate Planning Strategies

- Maintain a level workforce
- Maintain a steady output rate
- Match demand period by period
- Use a combination of decision variables

Basic Strategies

- Level capacity strategy:
 - Maintaining a steady rate of regular-time output while meeting variations in demand by a combination of options.
- Chase demand strategy:
 - Matching capacity to demand; the planned output for a period is set at the expected demand for that period.

Chase Approach

- Advantages
 - Investment in inventory is low
 - Labor utilization is high
- Disadvantages
 - The cost of adjusting output rates and/or workforce levels

Level Approach

- Advantages
 - Stable output rates and workforce
- Disadvantages
 - Greater inventory costs
 - Increased overtime and idle time
 - Resource utilizations vary over time

Techniques for Aggregate Planning

1. Determine demand for each period
2. Determine capacities for each period
3. Identify policies that are pertinent
4. Determine units costs
5. Develop alternative plans and costs
6. Select the best plan that satisfies objectives.
Otherwise return to step 5.

Average Inventory

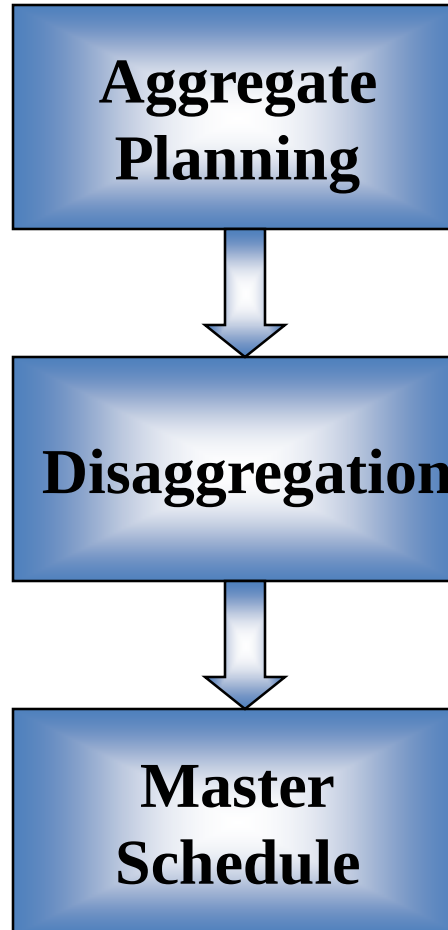
$$\text{Average inventory} = \frac{\text{Beginning Inventory} + \text{Ending Inventory}}{2}$$

Aggregate Planning in Services

- Services occur when they are rendered
- Demand for service can be difficult to predict
- Capacity availability can be difficult to predict
- Labor flexibility can be an advantage in services

Aggregate Plan to Master Schedule

Figure 12.4



Disaggregating the Aggregate Plan

- Master schedule: The result of disaggregating an aggregate plan; shows quantity and timing of specific end items for a scheduled horizon.
- Rough-cut capacity planning: Approximate balancing of capacity and demand to test the feasibility of a master schedule.

Master Scheduling

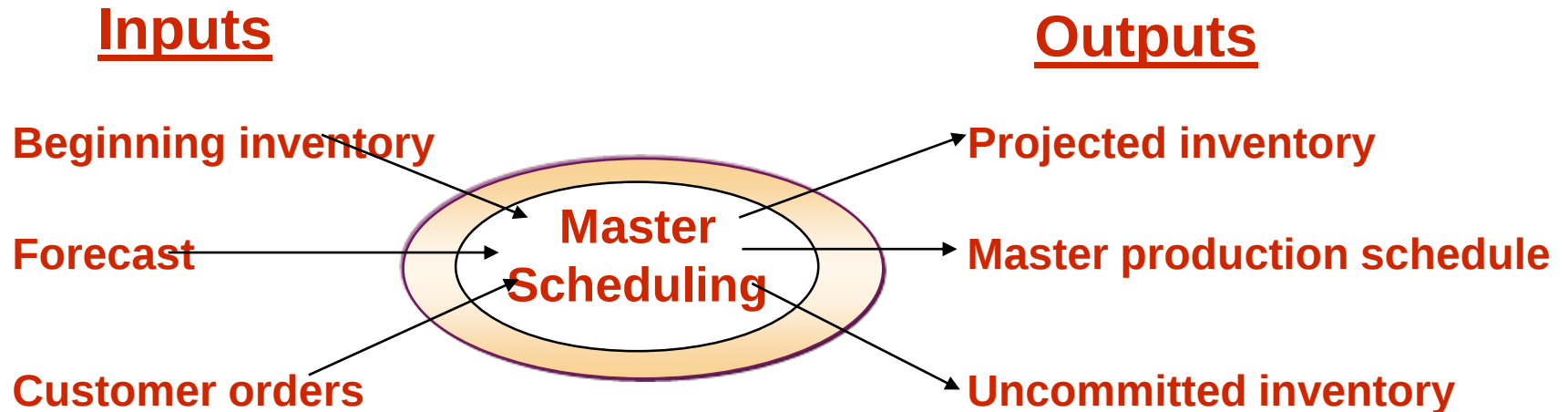
- Master schedule
 - Determines quantities needed to meet demand
 - Interfaces with
 - Marketing
 - Capacity planning
 - Production planning
 - Distribution planning

Master Scheduler

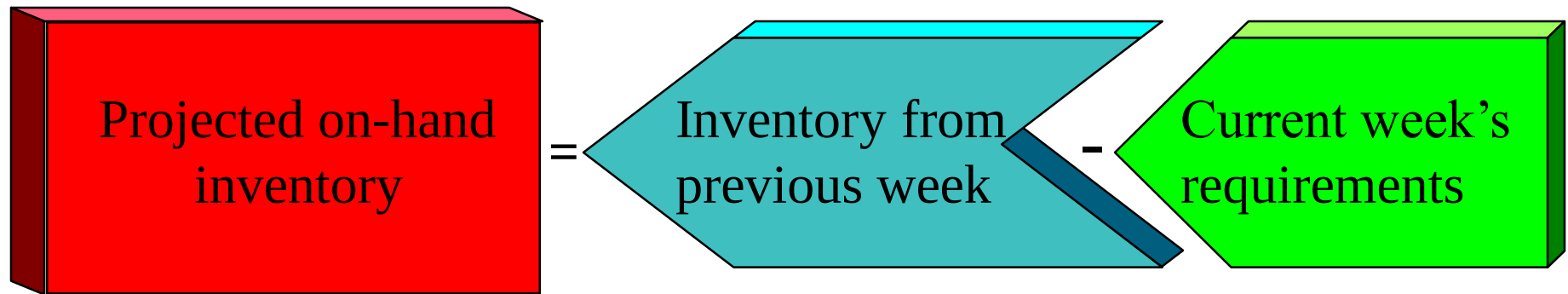
- Evaluates impact of new orders
- Provides delivery dates for orders
- Deals with problems
 - Production delays
 - Revising master schedule
 - Insufficient capacity

Master Scheduling Process

Figure 12.6

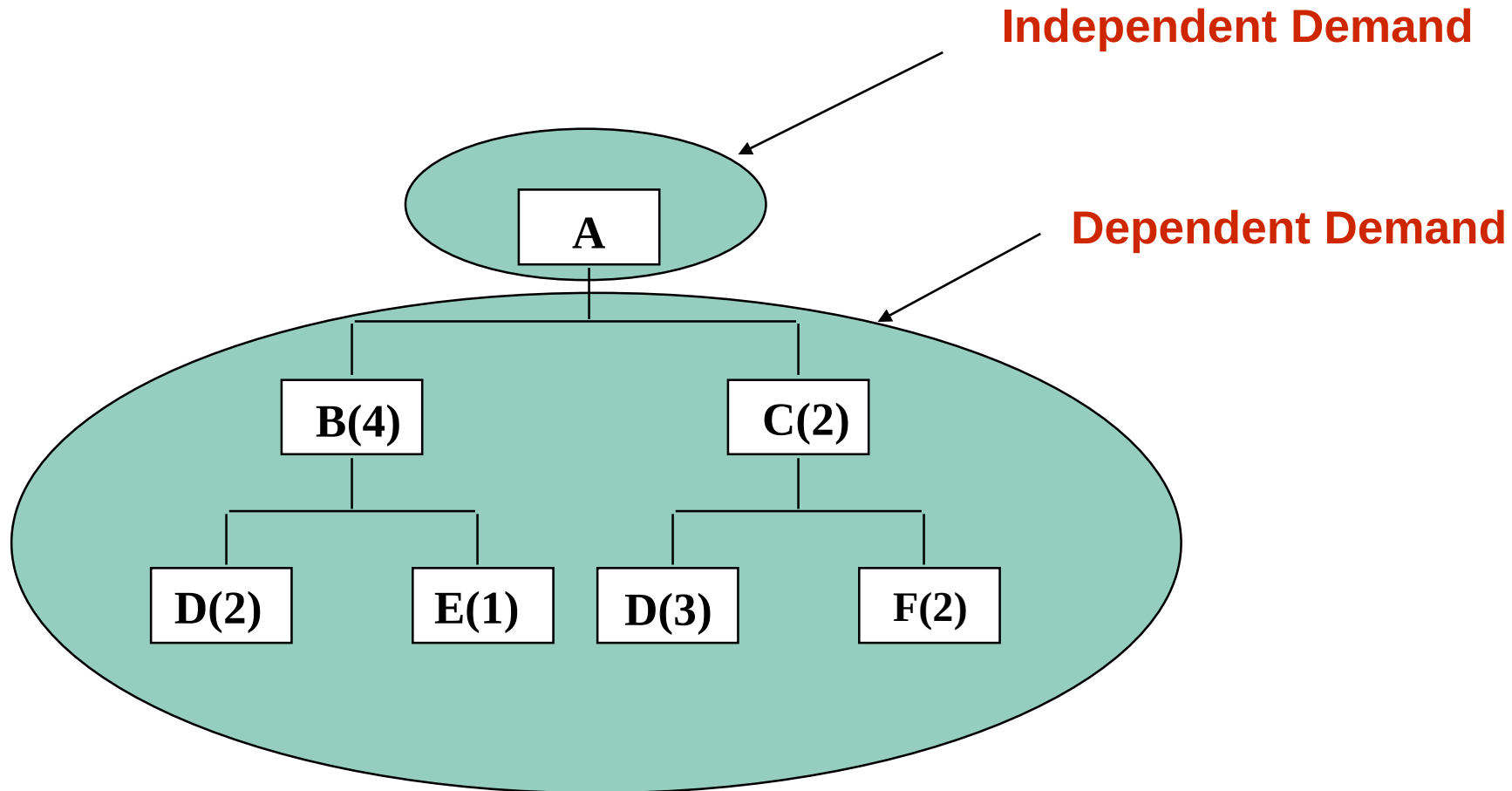


Projected On-hand Inventory



Inventory Management

Inventory: a stock or store of goods



**Independent demand is uncertain.
Dependent demand is certain.**

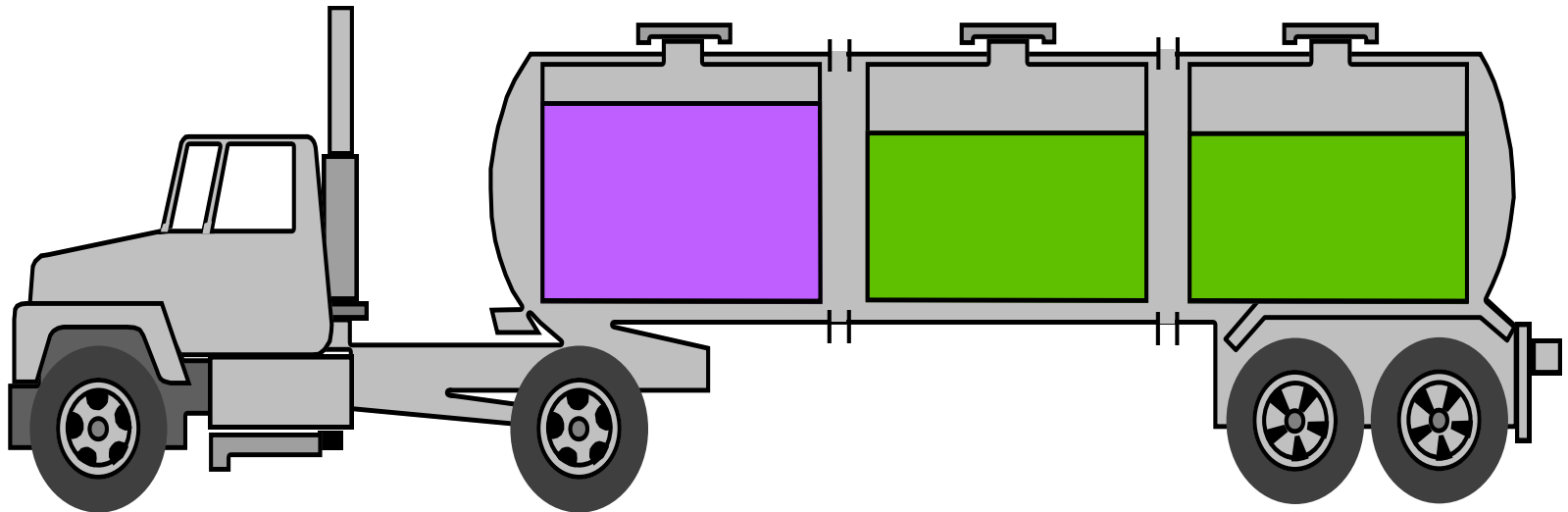
Types of Inventories

- Raw materials & purchased parts
- Partially completed goods called *work in progress*
- Finished-goods inventories
 - (*manufacturing firms*)
or merchandise
(*retail stores*)



Types of Inventories (Cont'd)

- Replacement parts, tools, & supplies
- Goods-in-transit to warehouses or customers



Functions of Inventory

- To meet anticipated demand
- To smooth production requirements
- To decouple operations
- To protect against stock-outs

Functions of Inventory (Cont'd)

- To take advantage of order cycles
- To help hedge against price increases
- To permit operations
- To take advantage of quantity discounts

Objective of Inventory Control

- To achieve satisfactory levels of customer service while keeping inventory costs within reasonable bounds
 - Level of customer service
 - Costs of ordering and carrying inventory

Effective Inventory Management

- A system to keep track of inventory
- A reliable forecast of demand
- Knowledge of lead times
- Reasonable estimates of
 - Holding costs
 - Ordering costs
 - Shortage costs
- A classification system

Inventory Counting Systems

- Periodic System

Physical count of items made at periodic intervals

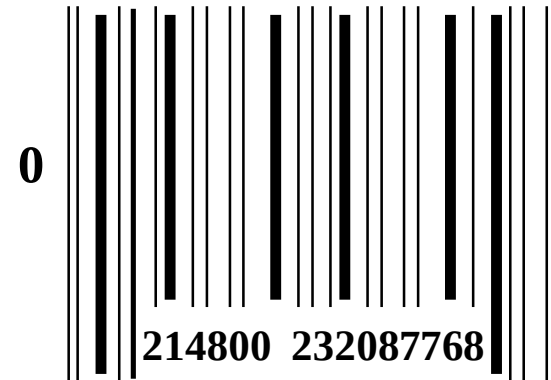
- Perpetual Inventory System

System that keeps track of removals from inventory continuously, thus monitoring current levels of each item



Inventory Counting Systems (Cont'd)

- *Two-Bin System* - Two containers of inventory; reorder when the first is empty
- *Universal Bar Code* - Bar code printed on a label that has information about the item to which it is attached



Key Inventory Terms

- Lead time: time interval between ordering and receiving the order
- Holding (carrying) costs: cost to carry an item in inventory for a length of time, usually a year
- Ordering costs: costs of ordering and receiving inventory
- Shortage costs: costs when demand exceeds supply

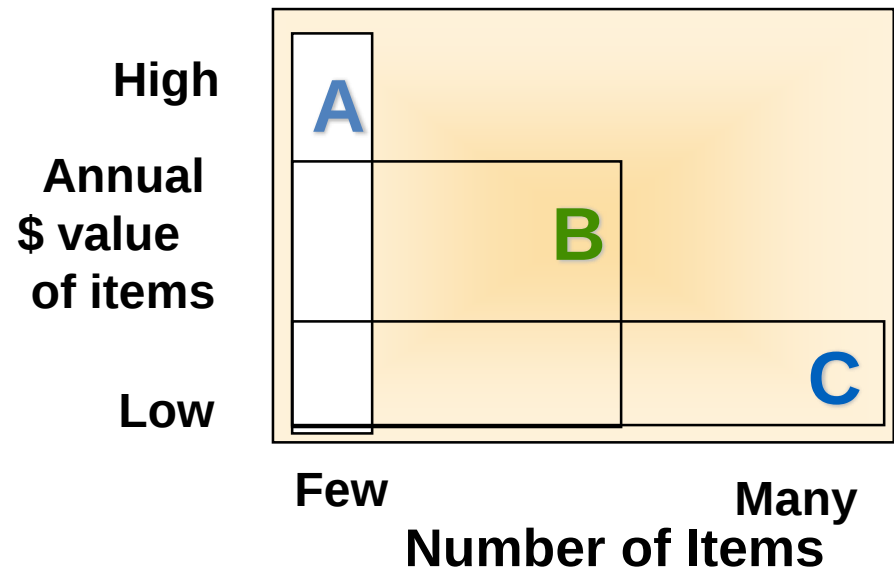
ABC Classification System

Classifying inventory according to some measure of importance and allocating control efforts accordingly.

A - very important

B - mod. important

C - least important



Cycle Counting

- A physical count of items in inventory
- Cycle counting management
 - How much accuracy is needed?
 - When should cycle counting be performed?
 - Who should do it?

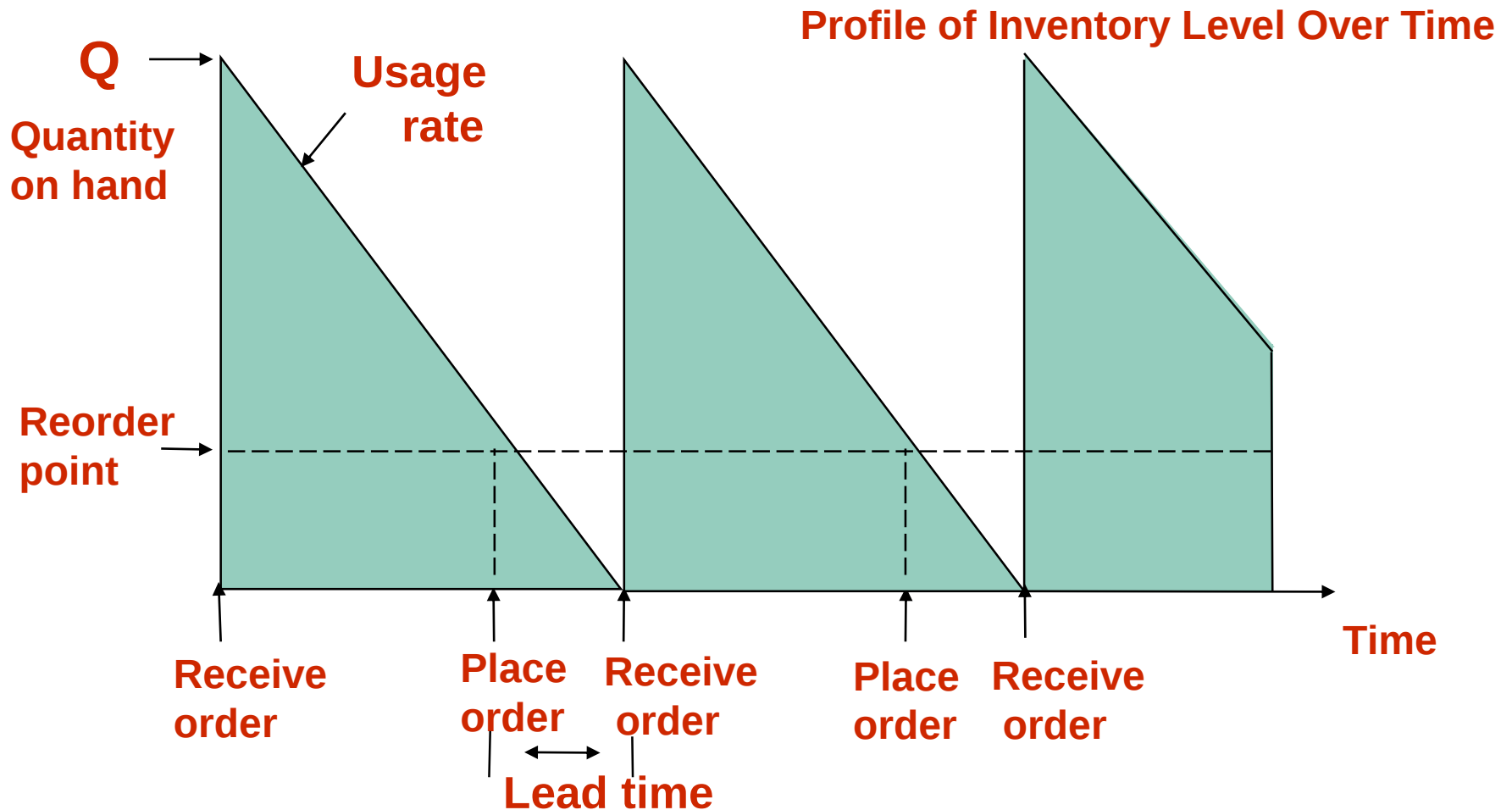
Economic Order Quantity Models

- Economic order quantity model
- Economic production model
- Quantity discount model

Assumptions of EOQ Model

- Only one product is involved
- Annual demand requirements known
- Demand is even throughout the year
- Lead time does not vary
- Each order is received in a single delivery
- There are no quantity discounts

The Inventory Cycle



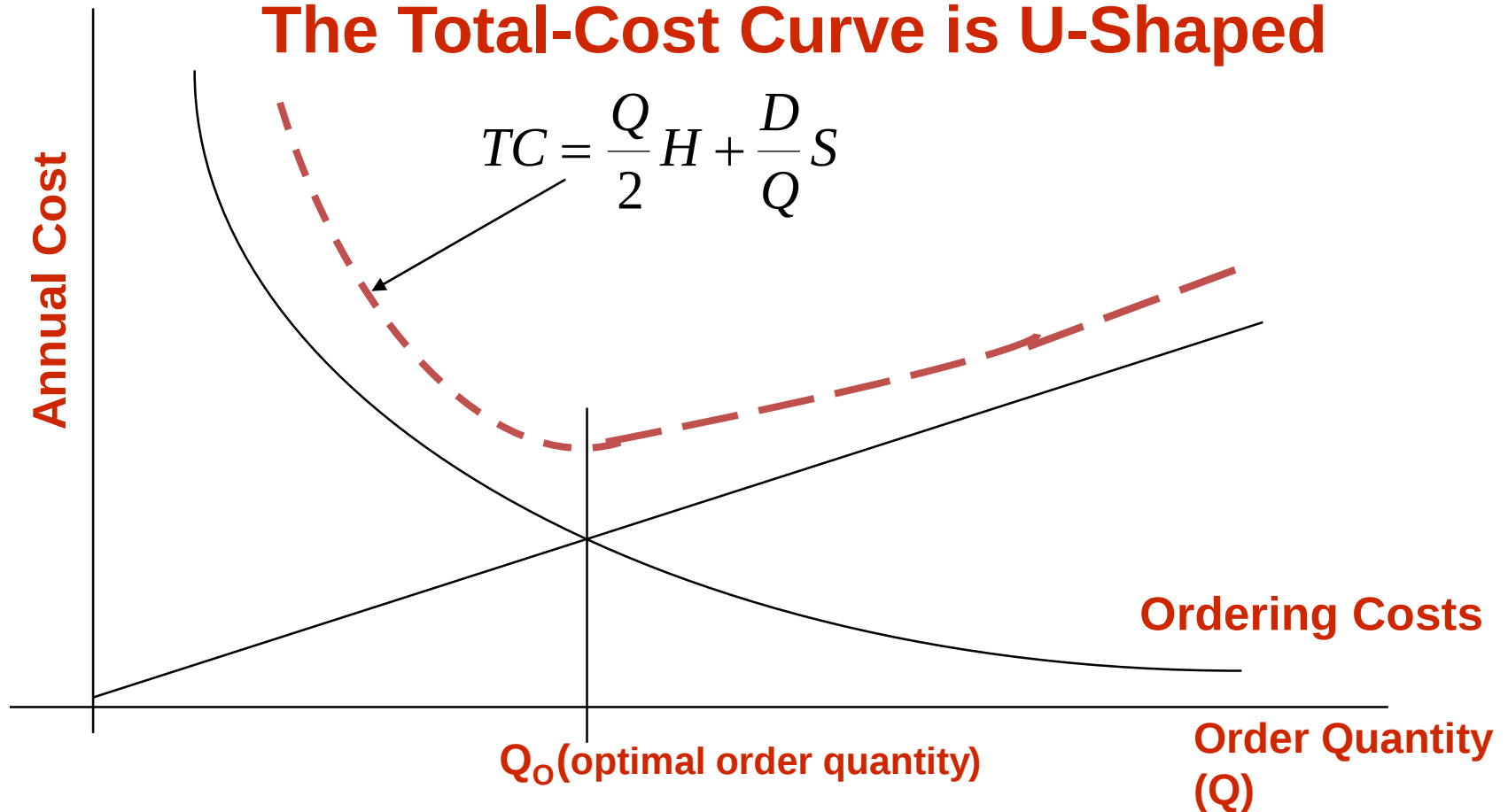
Total Cost

$$\text{Total cost} = \text{Annual carrying cost} + \text{Annual ordering cost}$$

$$TC = \frac{Q}{2} H + \frac{D}{Q} S$$

Cost Minimization Goal

The Total-Cost Curve is U-Shaped



Deriving the EOQ

Using calculus, we take the derivative of the total cost function and set the derivative (slope) equal to zero and solve for Q.

$$Q_{\text{OPT}} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(\text{Annual Demand})(\text{Order or Setup Cost})}{\text{Annual Holding Cost}}}$$

Minimum Total Cost

The total cost curve reaches its minimum where the carrying and ordering costs are equal.

$$Q_{\text{OPT}} = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(\text{Annual Demand})(\text{Order or Setup Cost})}{\text{Annual Holding Cost}}}$$

Economic Production Quantity (EPQ)

- Production done in batches or lots
- Capacity to produce a part exceeds the part's usage or demand rate
- Assumptions of EPQ are similar to EOQ except orders are received incrementally during production

Economic Production Quantity Assumptions

- Only one item is involved
- Annual demand is known
- Usage rate is constant
- Usage occurs continually
- Production rate is constant
- Lead time does not vary
- No quantity discounts

Economic Run Size

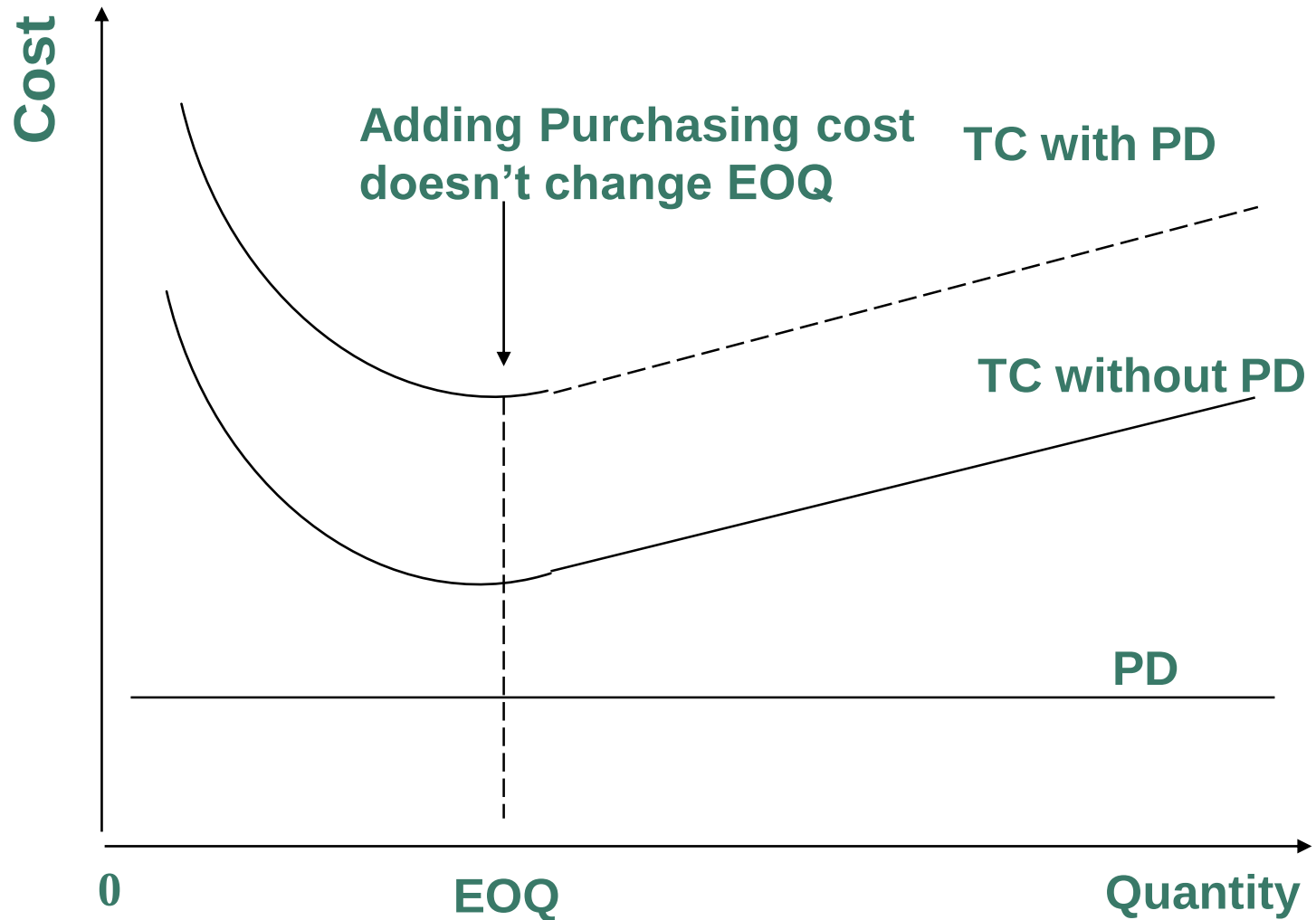
$$Q_0 = \sqrt{\frac{2DS}{H}} \sqrt{\frac{p}{p-u}}$$

Total Costs with Purchasing Cost

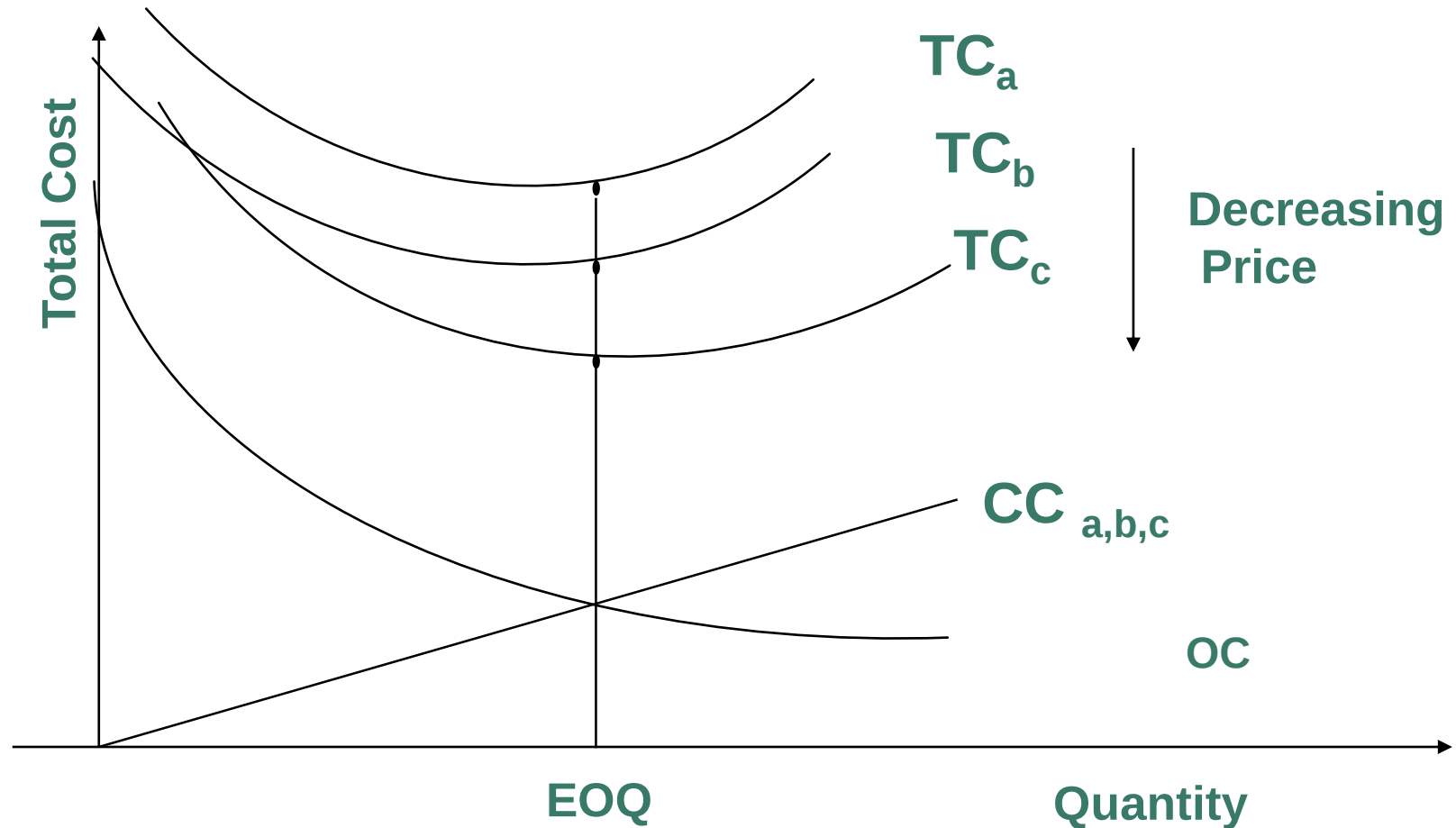
$$TC = \text{Annual carrying cost} + \text{Annual ordering cost} + \text{Purchasing cost}$$

$$TC = \frac{Q}{2}H + \frac{D}{Q}S + PD$$

Total Costs with PD



Total Cost with Constant Carrying Costs



When to Reorder with EOQ Ordering

- Reorder Point - When the quantity on hand of an item drops to this amount, the item is reordered
- Safety Stock - Stock that is held in excess of expected demand due to variable demand rate and/or lead time.
- Service Level - Probability that demand will not exceed supply during lead time.

Determinants of the Reorder Point

- The rate of demand
- The lead time
- Demand and/or lead time variability
- Stockout risk (safety stock)

Fixed-Order-Interval Model

- Orders are placed at fixed time intervals
- Order quantity for next interval?
- Suppliers might encourage fixed intervals
- May require only periodic checks of inventory levels
- Risk of stockout

Fixed-Interval Benefits

- Tight control of inventory items
- Items from same supplier may yield savings in:
 - Ordering
 - Packing
 - Shipping costs
- May be practical when inventories cannot be closely monitored

Fixed-Interval Disadvantages

- Requires a larger safety stock
- Increases carrying cost
- Costs of periodic reviews

Single Period Model

- Single period model: model for ordering of perishables and other items with limited useful lives
- Shortage cost: generally the unrealized profits per unit
- Excess cost: difference between purchase cost and salvage value of items left over at the end of a period

Operations Strategy

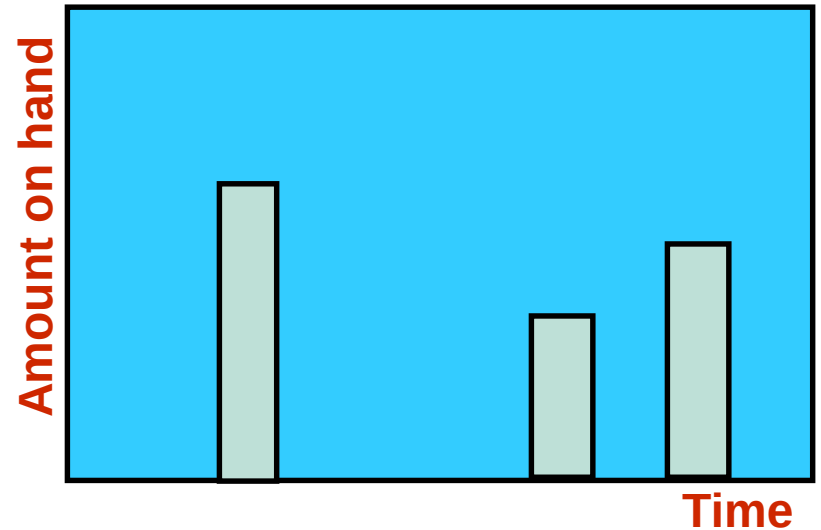
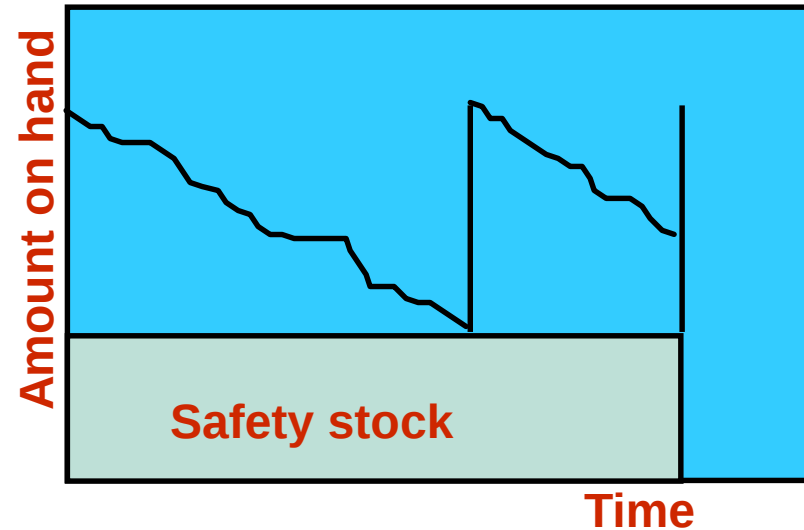
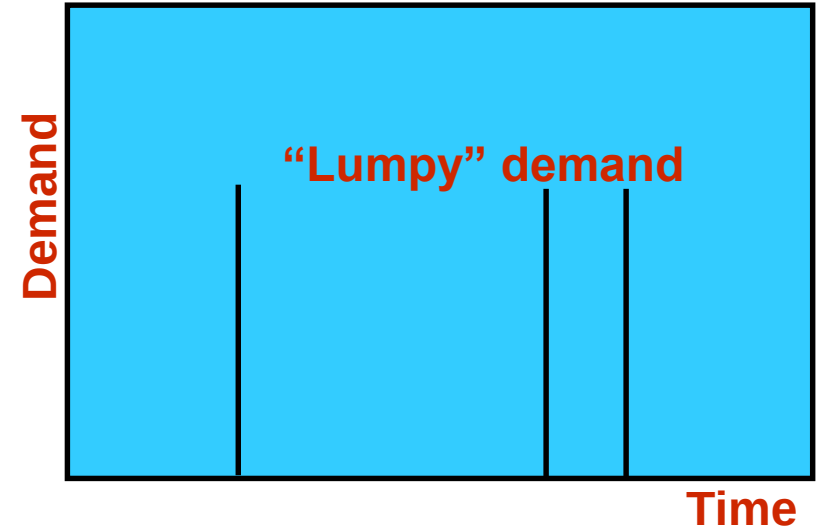
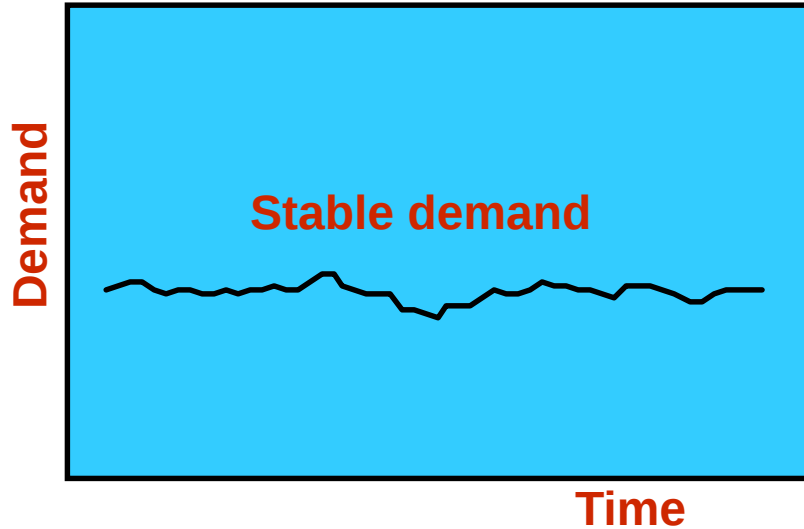
- Too much inventory
 - Tends to hide problems
 - Easier to live with problems than to eliminate them
 - Costly to maintain
- Wise strategy
 - Reduce lot sizes
 - Reduce safety stock

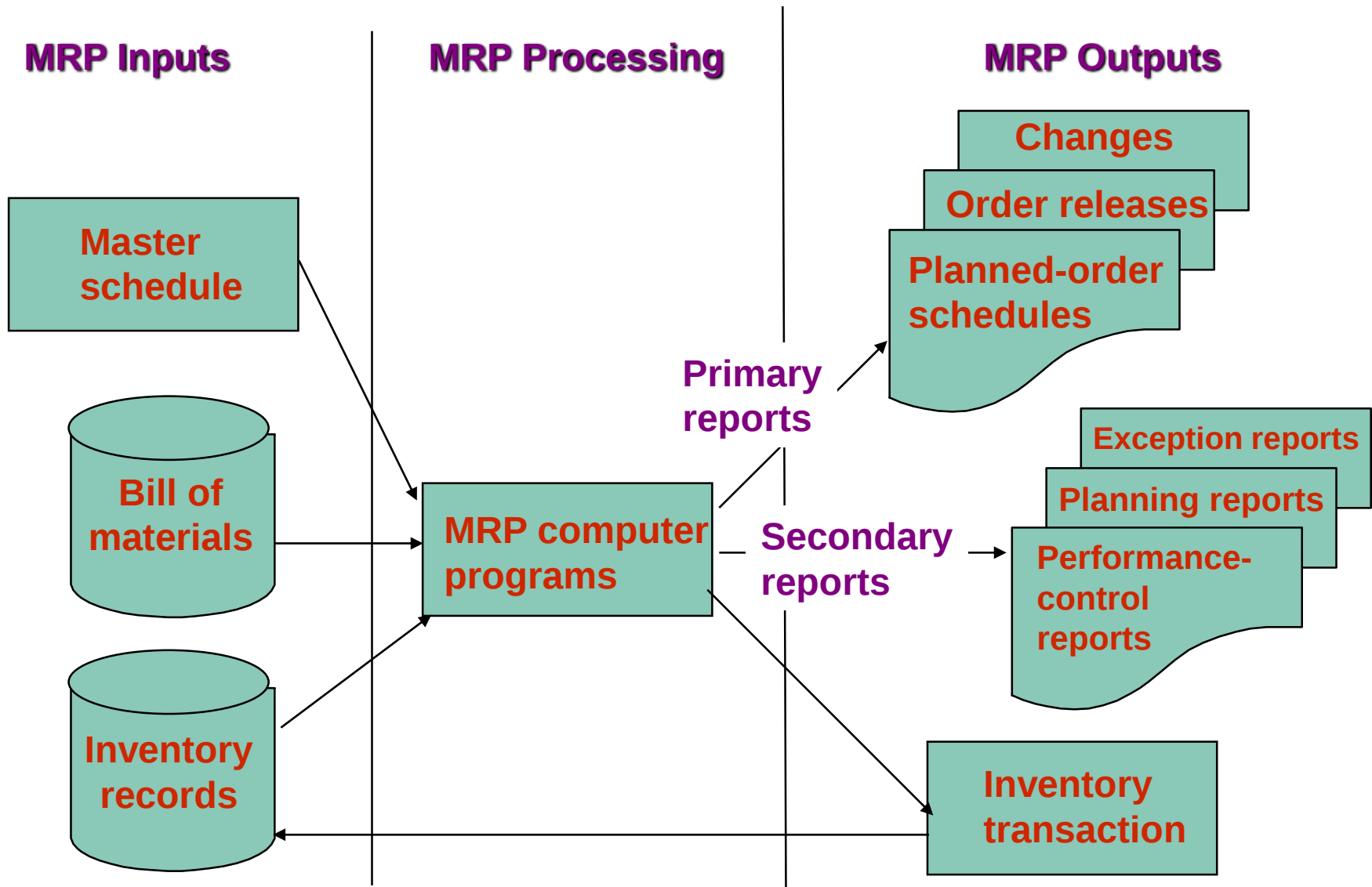
Unit 7: Material Requirements Planning (MRP)

Computer-based information system for ordering and scheduling of dependent-demand inventories, i.e. *what* is needed, *how much* is needed, and *when* is it needed

- Dependent demand – Demand for items that are sub-assemblies, parts or raw materials to be used in the production of finished goods.
- Independent demand – finished products

Independent vs Dependent Demand





MRP Inputs

- Master Production Schedule (MPS) – States which end items are to be produced, when they are needed, and in what quantities
- Bill of Materials (BOM) – a listing of all of the raw materials, parts, and sub-assemblies needed to produce one unit of a product
- Inventory Records – includes information on the status of an item during the planning horizon, eg. quantity, supplier, order lead time, lot size

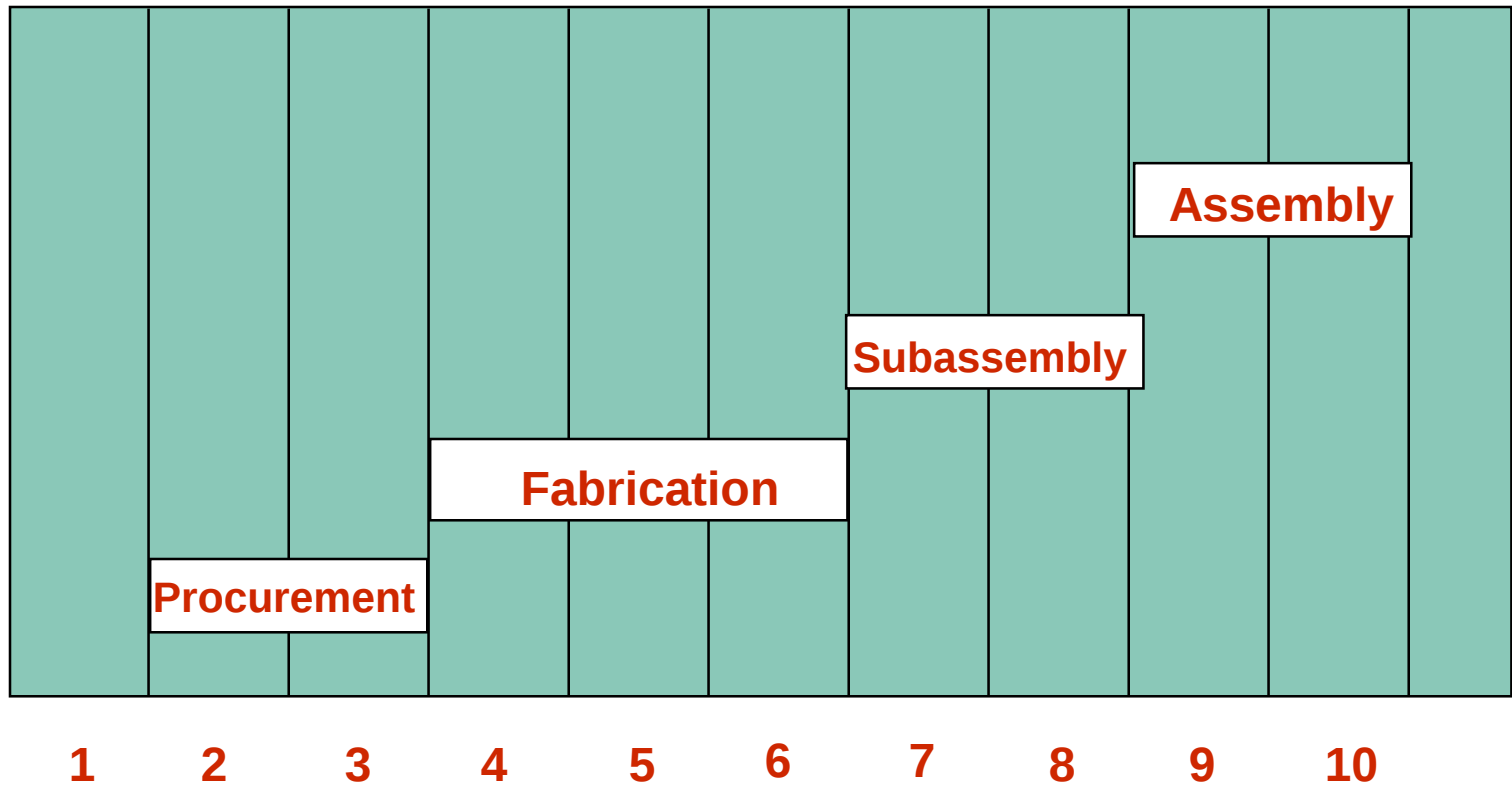
Master Schedule

Master schedule: One of three primary inputs in MRP; states which end items are to be produced, when these are needed, and in what quantities.

Cumulative lead time: The sum of the lead times that sequential phases of a process require, from ordering of parts or raw materials to completion of final assembly.

Planning Horizon

Figure 15-4



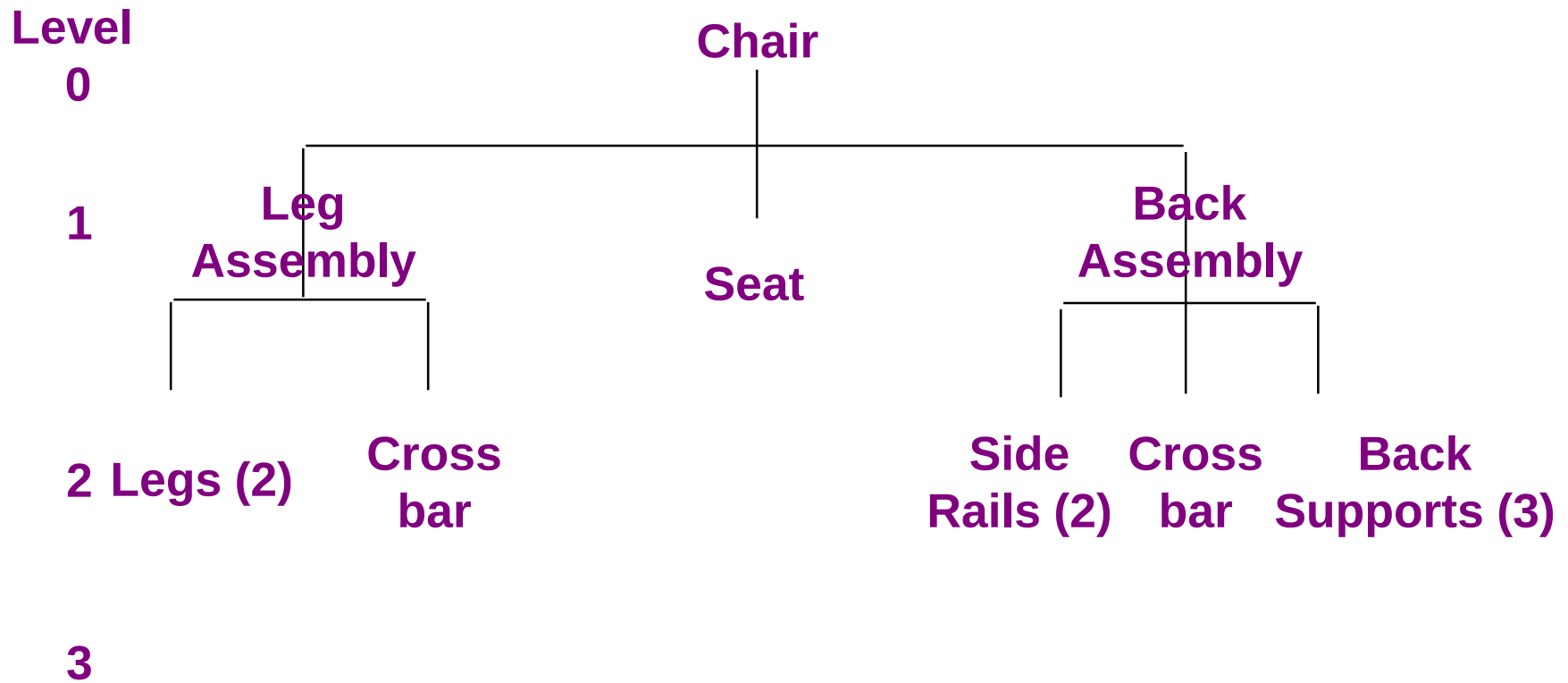
Bill-of-Materials

Bill of materials: One of the three primary inputs of MRP; a listing of all of the raw materials, parts, subassemblies, and assemblies needed to produce one unit of a product.

Product structure tree: Visual depiction of the requirements in a bill of materials, where all components are listed by levels.

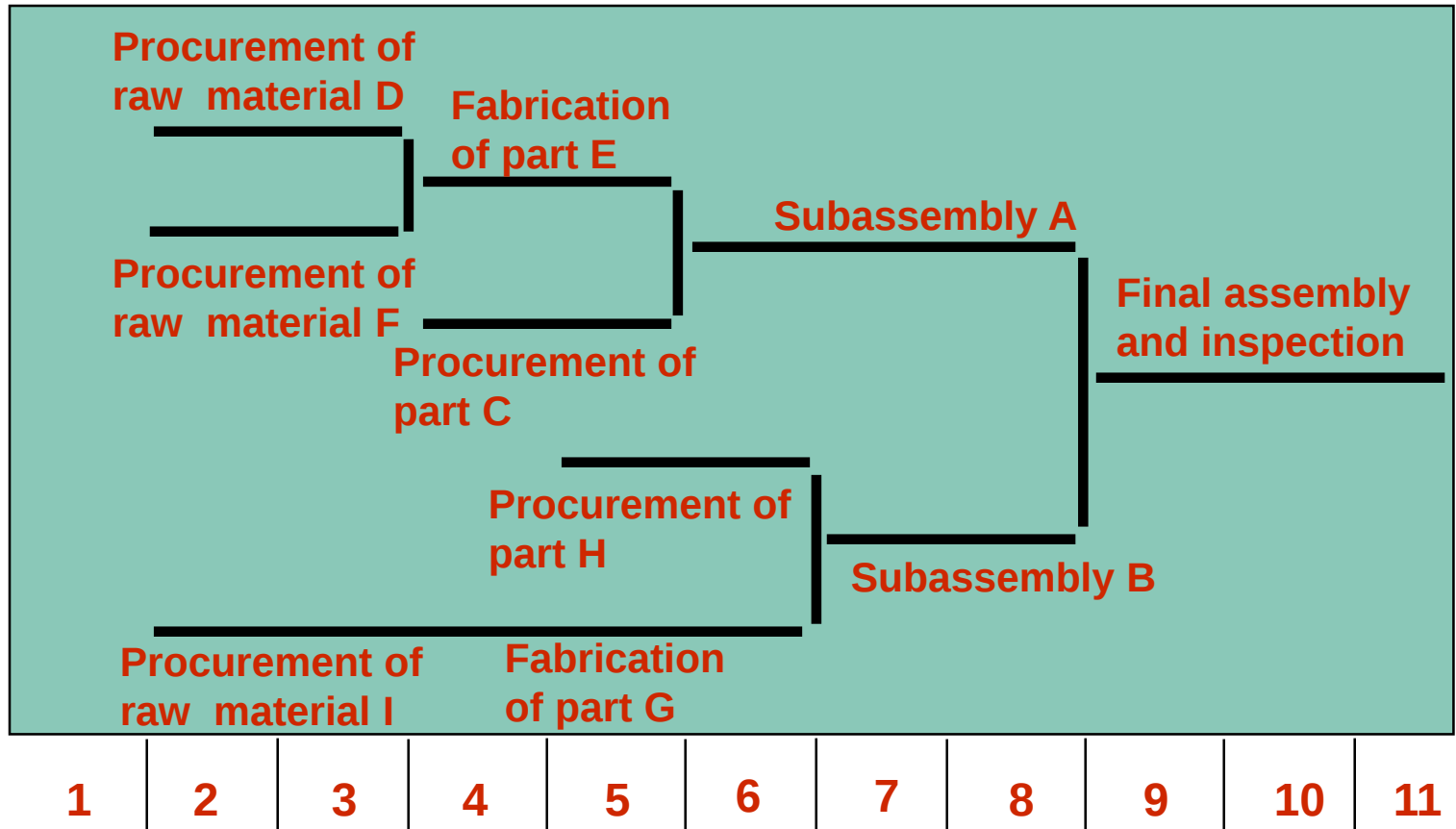
Product Structure Tree

Figure 15-5



Assembly Time Chart

Figure 15-7



MRP Processing

Processes the following for each time period:

- Gross requirements
- Schedule receipts
- Projected on hand
- Net requirements
- Planned-order receipts
- Planned-order releases

MRP Outputs

Primary Reports

- Planned Orders – schedule indicating the amount and timing of future orders
- Order Releases – Authorization for the execution of planned orders
- Changes – revisions of due dates or order quantities, or cancellation of orders

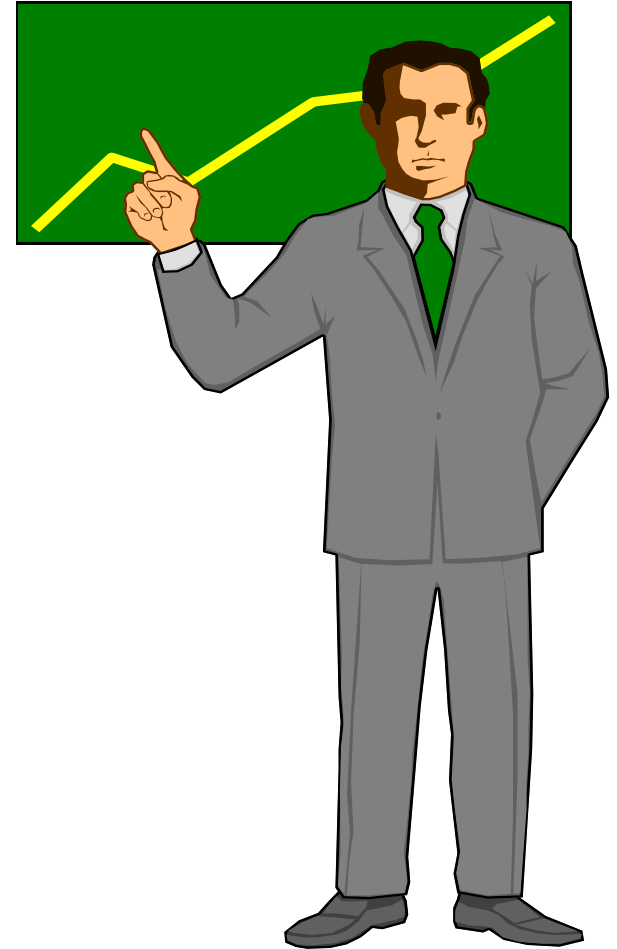
MRP Outputs

Secondary Reports

- Performance-control reports – Evaluation of system operation, including deviations from plans and cost information
- Planning reports – Data useful for assessing future material requirements
- Exception Reports – Data on major discrepancies encountered

Other Considerations

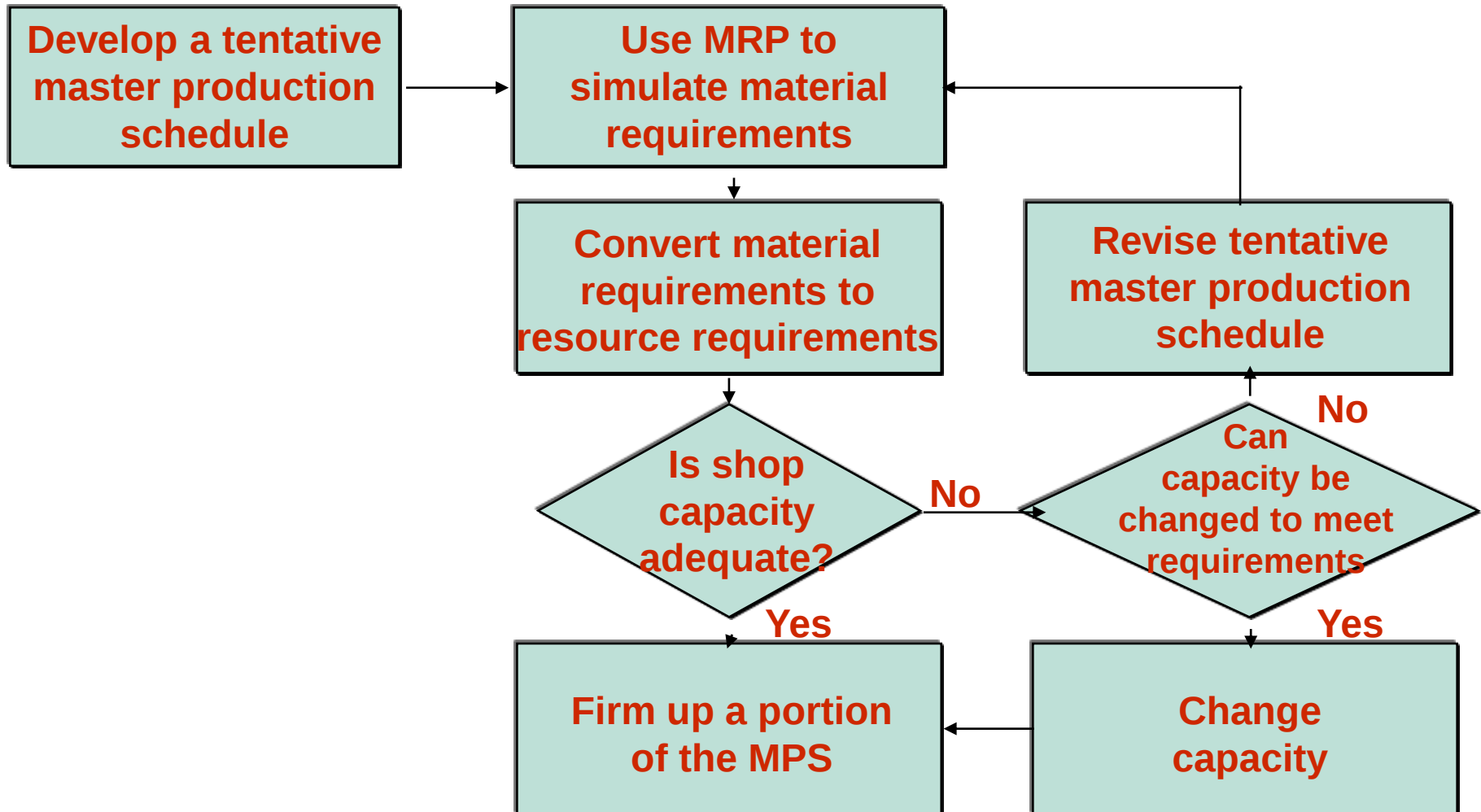
- Safety Stock
- Lot sizing
 - Lot-for-lot ordering
 - Economic order quantity
 - Fixed-period ordering
 - Part-period model



Capacity Planning

- Capacity requirements planning – the process of determining short-range capacity requirements
- Load reports – Department or work centre reports that compare known or expected future capacity requirements with projected capacity availability
- Time fences – series of time intervals during which order changes are allowed or restricted

MRP Planning



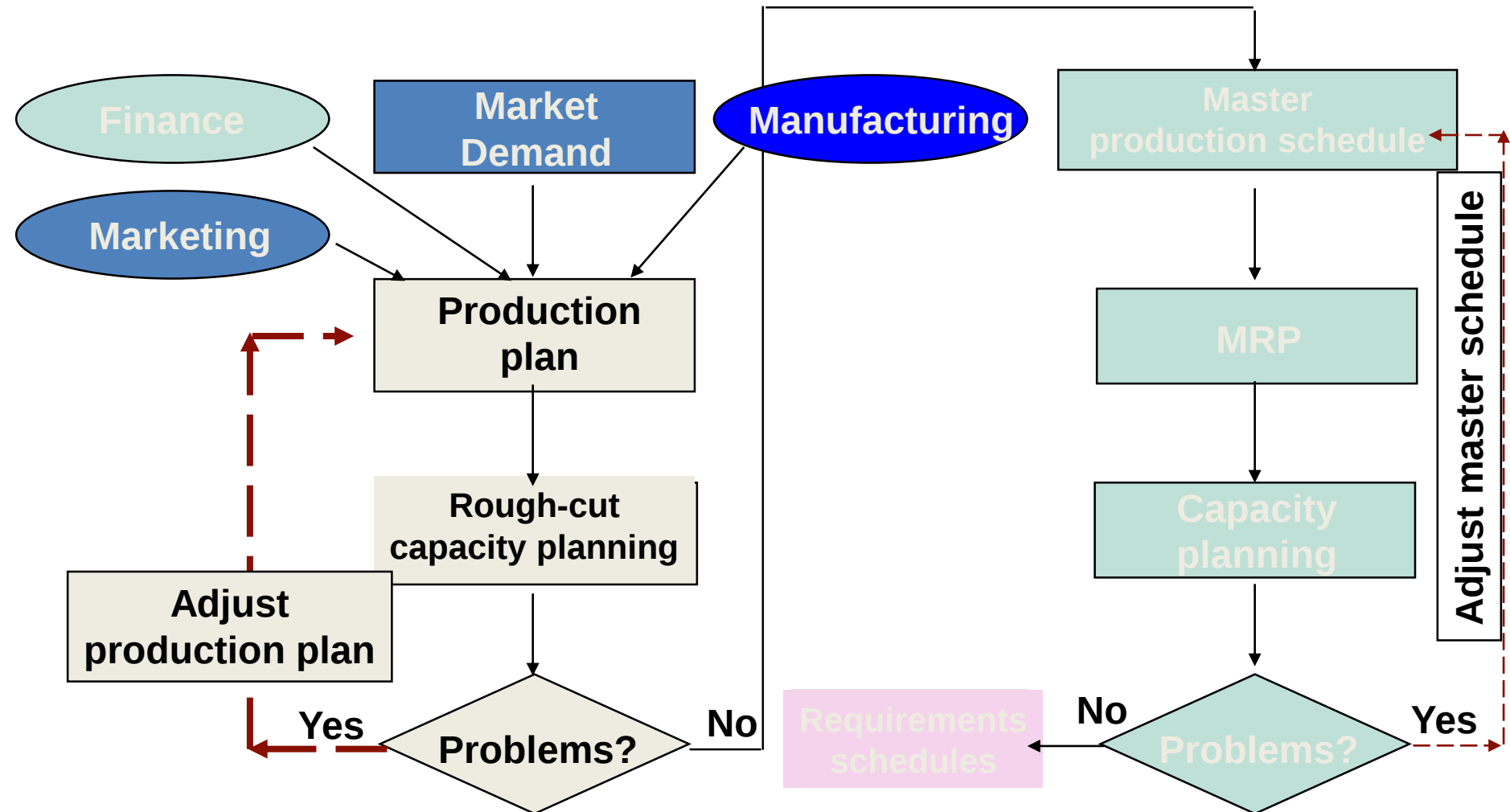
Benefits of MRP

- Low levels of inventories and reduction in manufacturing lead time
- Ability to track material requirements hence reducing shortages
- Ability to evaluate capacity requirements
- Means of allocating production time

Manufacturing Resources Planning (MRP II)

- Involves the whole production process, starting with aggregate planning, then MPS and finally MRP.
- Emphasizes integration with:
 - Financial planning
 - Marketing
 - Engineering
 - Purchasing
 - Manufacturing
 - Personnel

MRP II



Enterprise Resource Planning (ERP)

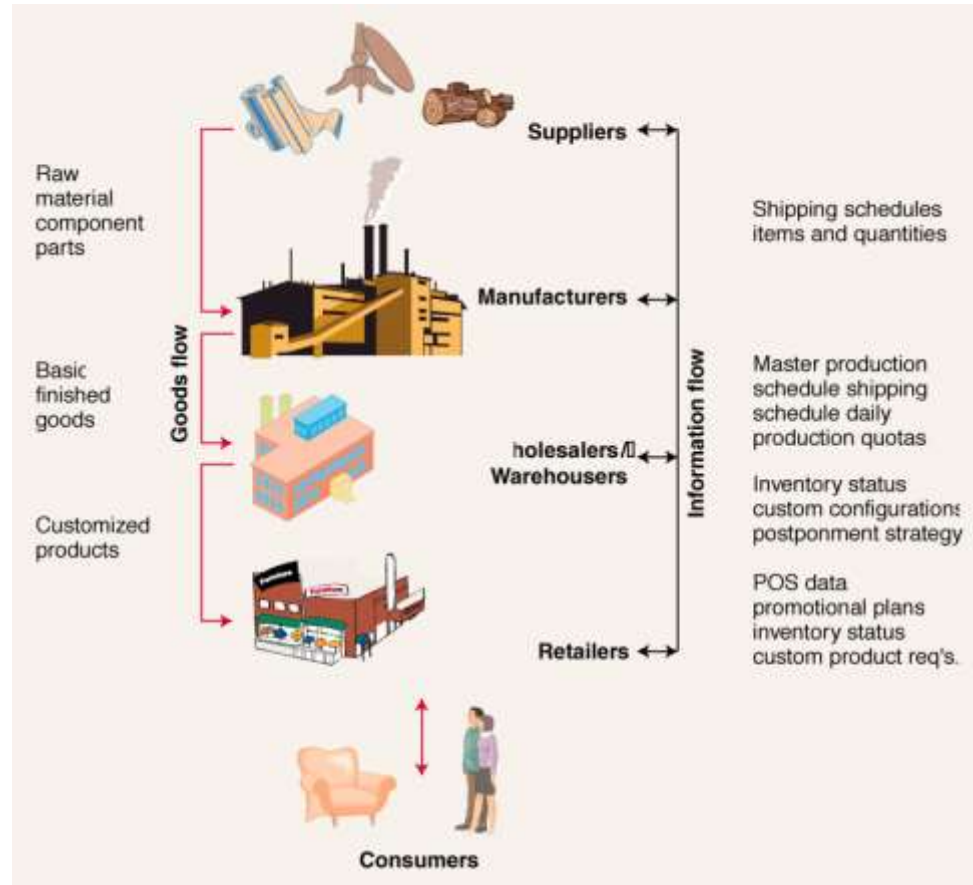
- Integration of financial, manufacturing and human resources on a single computer system.
- Represents expanded effort to integrate standardized record keeping using one database that will permit information sharing among different areas of an organization to manage the system more effectively.

Supply Chain Management

What is a Supply Chain?

The network of external suppliers, internal processes, and external distributors, and the links connecting them, that deliver a finished product or service to the customer.

A Basic Supply Chain



Supply Chain Management

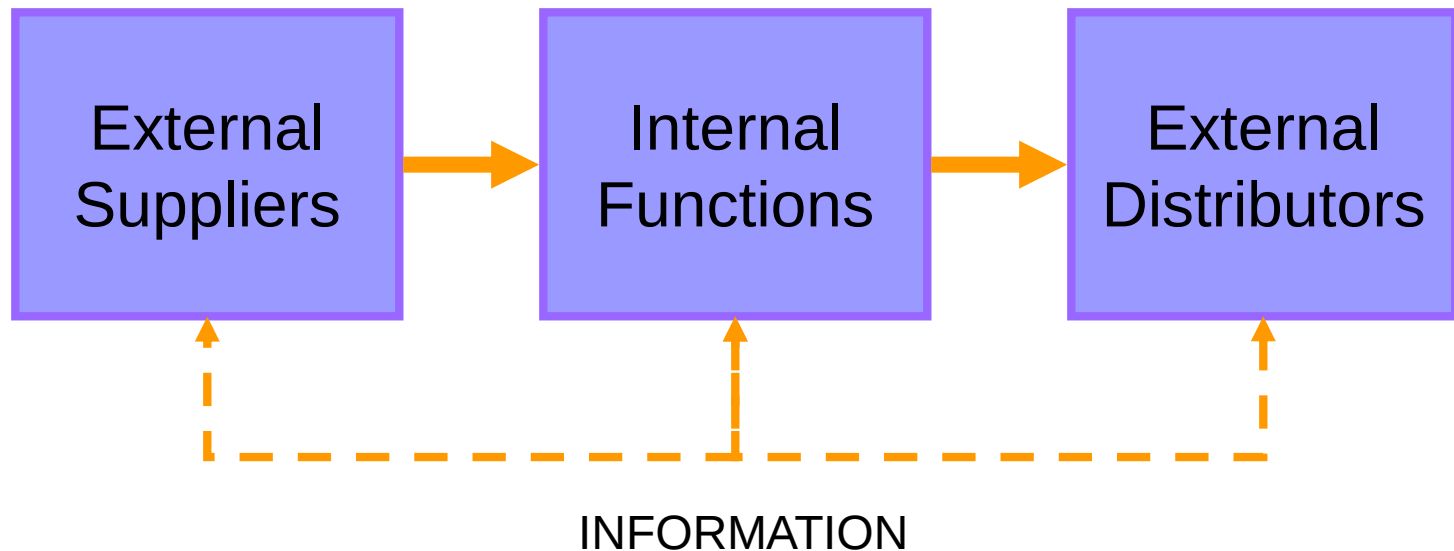
Supply Chain Management entails:

- Making decisions regarding the structure of the supply chain
- Coordinating the movement of goods and delivery of services
- Sharing information between members of the supply chain.

SCM Factors

- **SCM** must consider the following trends, improved capabilities, & realities:
 - **Consumer Expectations and Competition** – power has shifted to the consumer
 - **Globalization** – capitalize on emerging markets
 - **Information Technology** – e-commerce, Internet, EDI, scanning data, intranets
 - **Government Regulations** - like trade barriers
 - **Environment Issues** – e.g. waste minimization

Components of a Typical Supply Chain



External Suppliers

- External suppliers provide the necessary raw materials, services, and component parts.
- Purchased materials & services frequently represent 50% (or more) of the costs of goods sold.
- Suppliers are frequently members of several supply chains – often in different roles.

External Suppliers

- Tier one suppliers:
 - Directly supplies materials or services to the firm that does business with the final customer
- Tier two suppliers:
 - Provides materials or services to tier one suppliers
- Tier three suppliers:
 - Provides materials or services to tier two suppliers

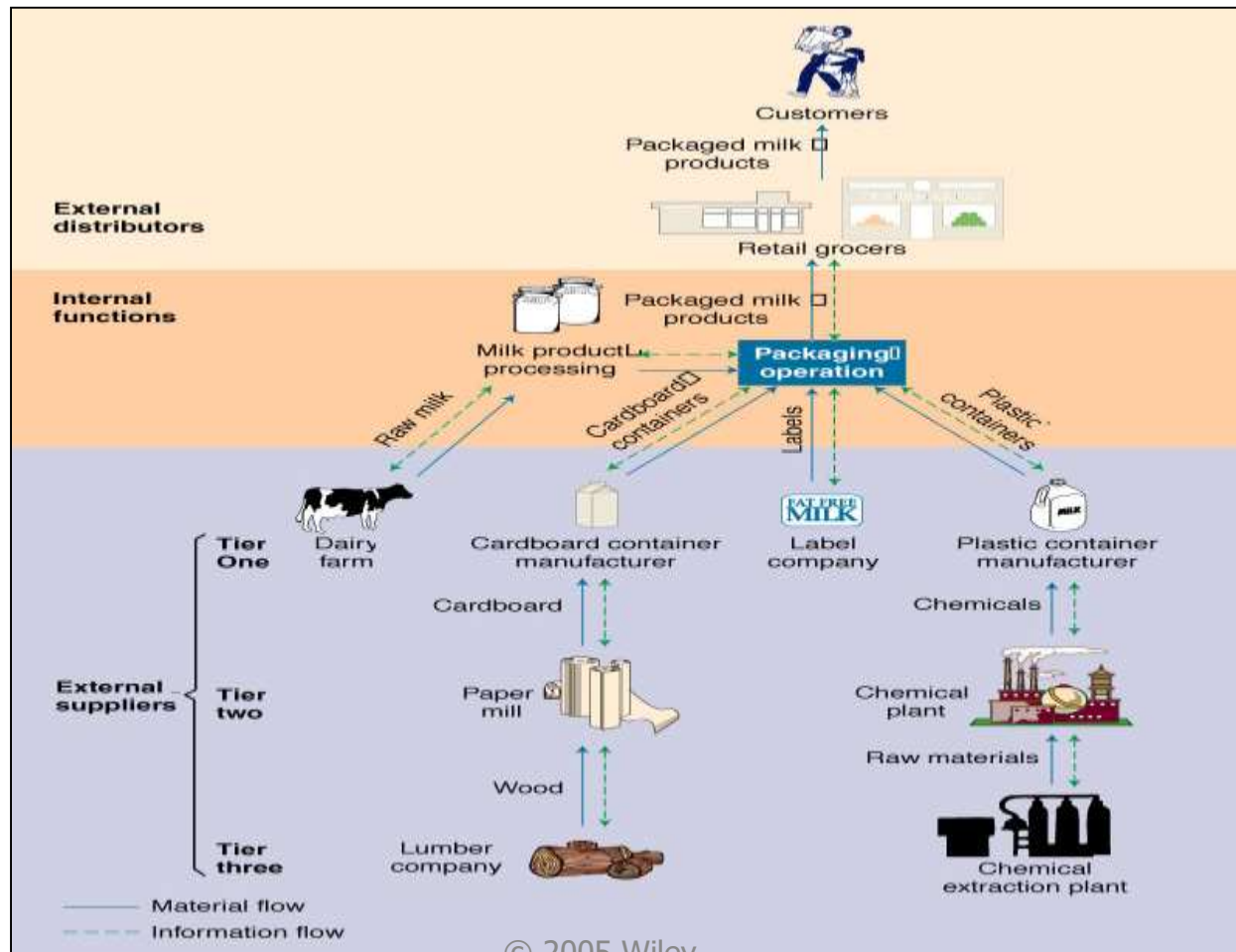
Internal Functions

- Vary by industry & firm, but might include:
 - Processing
 - Purchasing
 - Production Planning & Control
 - Quality Assurance
 - Shipping

Logistics & Distribution

- Logistics: getting the right material to the right place at the right time in the right quantity:
 - Traffic Management:
 - The selection, scheduling & control of carriers (e.g.: trucks & rail) for both incoming & outgoing materials & products
 - Distribution Management:
 - The packaging, storing & handling of products in transit to the end-user.

Dairy Products Supply Chain



Vertical Integration

- A measure of how much of the supply chain is controlled by the manufacturer.
 - Backward integration:
 - Acquiring control of raw material suppliers.
 - Forward integration:
 - Acquiring control of distribution channels.

Outsourcing

- Entails paying third-party suppliers to provide raw materials and services, rather than making them in-house.
- Outsourcing is increasing as many firms try to focus their internal operations on what they do best.

Insourcing vs. Outsourcing

- **What questions need to be asked before sourcing decisions are made?**
 - Is product/service technology critical to firm's success?
 - Is operation a core competency?
 - Do you have the capital to provide capacity & keep the process current?
 - Will outsourcing extend lead times and limit flexibility?
 - Can others do it for less cost and better quality?

Purchasing's Role in SCM

- **Purchasing role has attained increased importance since material costs represent 50-60% of cost of goods sold**
 - Ethics considerations
 - Developing supplier relationships
 - Determining how many suppliers
 - Developing partnerships
- **Industry trend is to a much smaller supplier base. Why?**

Partnering with Suppliers

- Involves developing a long-term, mutually-beneficial relationship:
 - Requires trust to share information, risk, opportunities, & investing in compatible technology
 - Work together to reduce waste and inefficiency & develop new products
 - Agree to share the gains

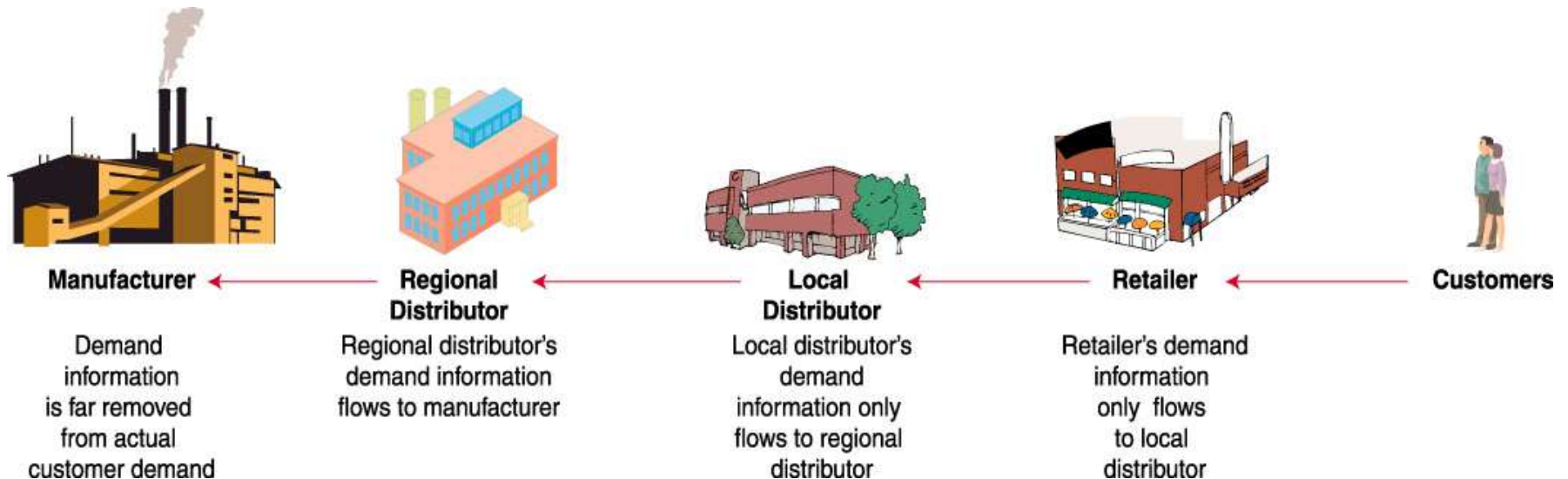
Supplier Relationships and JIT

- Use single-source suppliers when possible
- Build long-term relationships
- Work together to certify processes
- Co-locate facilities to reduce transport if possible
- Stabilize delivery schedules
- Share cost & other information
- Early involvement during new product designs

The Role of Warehouses

- General Warehouses:
 - Used for long-term storage of goods
- Distribution Warehouses:
 - Transportation consolidation:
 - Consolidate LTL into TL deliveries
 - Product mixing & blending:
 - Group multiple items from various suppliers
 - Improve service:
 - Reduced response time
 - Allow for last-minute customization

Information Flow in Supply Chains



Information Sharing

- Supply chain partners can benefit by sharing information on sales, demand forecasts, inventory levels & marketing campaigns
- Inaccurate or distorted information leads to the Bullwhip Effect

The Bullwhip Effect

- If information isn't shared, everyone has to guess what is going on downstream.
- Guessing wrong leads to too much or too little inventory:
 - If too much, firms hold off buying more until inventories fall (leading suppliers to think demand has fallen).
 - If too little, firms demand a rush order & order more than usual to avoid being caught short in the future (leading suppliers to think demand has risen).

Short-Circuit the Bullwhip

- Make information transparent:
 - Use Electronic Data Interchange (EDI) to support Just-In-Time supplier replenishment
 - Use bar codes & electronic scanning to capture & share point-of-sale data
- Eliminate wholesale price promotions & quantity discounts

Electronic Data Interchange

- The most common method of using computer-to-computer links to exchange data between supply chain partners in a standardized format.
- Benefits include:
 - Quick transfer of information
 - Reduced paperwork & administration
 - Improved data accuracy & tracking capability

Integrated SCM

- **Implementing integrated SCM requires:**
 - Analyzing the whole supply chain
 - Starting by integrating internal functions first
 - Integrating external suppliers through partnerships
- **Possible Supply Chain Objectives**
 - Reduce costs, improve quality
 - Reduce lead time and inventory
 - Reduce time to market
 - Increase sales
 - Improve demand data/forecasting