Operations Management Exam Review Slides

NOTE: *These slides are to highlight key topics that may be on the exam. You need to review the complete course slides to do a proper exam preparation.*

Exam Guidelines

1. Only **handwritten notes** may be used
    a. All of the handwriting must be done by you
    b. No photocopies will be accepted
    c. There is no length limit
    d. You are encouraged to study in groups
    e. These will be collected after the exam
    f. You may contact the professor if you would like them returned
2. The exam will consist of **questions from the quizzes**
    a. These questions could be exact copies or slightly reworded problems.
    b. Others problems may be new wordings based on related concepts or terms
    c. Quantitative problems will have the numbers in the problem changed
3. The exam will have **one question about the activities**
    a. To prepare for these follow the below study plan
        i. Reread each case and write down what was being done
        ii. Read the questions and know the answers
4. There will be **20 to 30 questions**
    a. About two-thirds will be quantitative
        i. These will require calculations and a numerical answer
    b. About one -third will be qualitative
        i. These will be multiple choice or fill-in-the-blank type questions
5. All ExcelOM **templates from the previous quizzes will be available** for use

1

Operations and Productivity

2

Operations Strategy in a Global Environment

Operations Management

- Production
  - Creation of goods and services
- Operations management (OM)
  - Set of activities that create value in the form of goods and services by transforming inputs into outputs

Why Study OM?

- OM is one of three major functions of any organization
  - How people organize themselves for a productive enterprise
  - Understand how OM fits in with these functions
    - How it relates to your major
- Learn how goods and services are produced
- Understand what operations managers do
- OM is such a costly part of an organization

Ten Strategic Decisions

TABLE 1.2

DECISION	CHAPTER(S)
1. *Design of goods and services*	5, Supplement 5
2. *Managing quality*	6, Supplement 6
3. *Process and capacity strategy*	7, Supplement 7
4. *Location strategy*	8
5. *Layout strategy*	9
6. *Human resources and job design*	10
7. *Supply-chain management*	11, Supplement 11
8. *Inventory management*	12, 14, 16
9. *Scheduling*	13, 15
10. *Maintenance*	17

Very Brief History

- Division of labor
  - Adam Smith 1776; Charles Babbage 1852
- Standardized parts
  - Whitney 1800
- Scientific Management
  - Taylor 1881
- Coordinated assembly line
  - Ford/ Sorenson 1913
- Gantt charts
  - Gantt 1916
- Motion study
  - Frank and Lillian Gilbreth 1922
- Quality control
  - Shewhart 1924; Deming 1950

Goods vs. Services

TABLE 1.3

CHARACTERISTICS OF SERVICES	CHARACTERISTICS OF GOODS
Intangible: Ride in an airline seat	Tangible: The seat itself
Produced and consumed simultaneously: Beauty salon produces a haircut that is consumed as it is produced	Product can usually be kept in inventory (beauty care products)
Unique: Your investments and medical care are unique	Similar products produced (iPods)
High customer interaction: Often what the customer is paying for (consulting, education)	Limited customer involvement in production
Inconsistent product definition: Auto Insurance changes with age and type of car	Product standardized (iPhone)
Often knowledge based: Legal, education, and medical services are hard to automate	Standard tangible product tends to make automation feasible
Services dispersed: Service may occur at retail store, local office, house call, or via internet.	Product typically produced at a fixed facility
Quality may be hard to evaluate: Consulting, education, and medical services	Many aspects of quality for tangible products are easy to evaluate (strength of a bolt)
Reselling is unusual: Musical concert or medical care	Product often has some residual value

Productivity Challenge

Productivity is the ratio of outputs (goods and services) divided by the inputs (resources such as labor and capital)

The objective is to improve productivity!

Important Note!
Production is a measure of output only and not a measure of efficiency

Practice Problem - SOL

Chuck Sox makes wooden boxes in which to ship motorcycles. Chuck and his three employees invest a total of 30 hours per day making the 400 boxes.

1. Their productivity = **13.33 boxes/hour** (round your response to two decimal places).

Chuck and his employees have discussed redesigning the process to improve efficiency. Suppose they can increase the rate to **500 boxes per day**.

2. Their new productivity = **16.67 boxes/hour** (round your response to two decimal places).
3. The unit increase in productivity is **3.33 boxes/hour** (round your response to two decimal places).
4. The percentage LOADING... increase in productivity is **25%** (enter your response as a percentage rounded to nearest whole number).

Developing Missions and Strategies

- **Mission** statements
  - Tell an organization where it is going
- **Strategy**
  - Tells the organization how to get there

Competing on Differentiation

- Uniqueness can go beyond both the physical characteristics and service attributes to encompass everything that impacts customer's perception of value
  - Safeskin gloves – leading edge products
  - Walt Disney Magic Kingdom – experience differentiation
  - Hard Rock Cafe – dining experience

Experience Differentiation

- Engaging a customer with a product through imaginative use of the five senses, so the customer "experiences" the product
  - Theme parks use sight, sound, smell, and participation
  - Movie theatres use sight, sound, moving seats, smells, and mists of rain
  - Restaurants use music, smell, and open kitchens

Competing on Cost

- Provide the maximum value as perceived by customer
- **<u>Does not imply low quality</u>**
  - Southwest Airlines – secondary airports, no frills service, efficient utilization of equipment
  - Walmart – small overhead, shrinkage, and distribution costs
  - Franz Colruyt – no bags, no bright lights, no music, and doors on freezers

Competing on Response

- Flexibility is matching market changes in design innovation and volumes
  – A way of life at Hewlett-Packard
- Reliability is meeting schedules
  – German machine industry
- Quickness in design, production, and delivery
  – Pizza Hut

Inventory Management

12

Inventory Management

- The objective of inventory management is to strike a balance between inventory investment and customer service

Importance of Inventory

- One of the most expensive assets of many companies representing as much as 50% of total invested capital
- Less inventory lowers costs but increases chances of running out
- More inventory raises costs but always keeps customers happy

Types of Inventory

- Raw material
  - Purchased but not processed
- Work-in-process (WIP)
  - Undergone some change but not completed
  - A function of cycle time for a product
- Maintenance/repair/operating (MRO)
  - Necessary to keep machinery and processes productive
- Finished goods
  - Completed product awaiting shipment

Inventory Models

- Holding costs
  - Costs of “carrying” inventory over time
- Ordering cost
  - Costs of placing an order and receiving goods
- Setup cost
  - Cost to prepare a machine or process for manufacturing an order
  - May be highly correlated with setup time

Independent Demand Models

- Economic order quantity (EOQ) model
  - Determines order quantity a company should **purchase** for its inventory given a set cost of production, demand rate and other variables
  - Minimizes variable inventory costs, and the formula takes into account storage, or holding, costs, ordering costs and shortage costs
- Production order quantity (POQ) model
  - Determines order quantity to minimize the total inventory costs by balancing the inventory holding cost and average fixed ordering cost
  - Determines how much to produce and when to order.
  - It is used when units are produced and sold the same time.
  - It suited for production environment. It also allows partial receipt of material.
- What is the difference between Production Order Quantity (POQ) and Economic Order Quantity (EOQ)?
  - POQ model assumes the company will produce its own quantity or the parts are going to be shipped to the company while they are being produced, therefore the orders are available or received in an incremental manner while the products are being produced.
- Safety stock
  - Quantity of an item to be held in inventory to reduce the risk that the item will be out of stock

Basic EOQ Model

- Important assumptions
  1. Demand is known, constant, and independent
  2. Lead time is known and constant
  3. Receipt of inventory is instantaneous and complete
  4. Quantity discounts are not possible
  5. Only variable costs are setup (or ordering) and holding
  6. Stockouts can be completely avoided

EOQ Example Solution

Given the data below

D = 17,000 units

S = \$13 per order

H = \$2 per unit per year

1. Determine optimal number of items to order
2. Expected number of orders
3. Optimal time between orders
4. Total annual cost

Order Quantity Data	
Annual Demand Rate, D	17000
Setup/Ordering Cost, S	13
Holding/Carrying Cost per Unit per Year, H	\$ 2.00
Unit price, P	
Results	
1 **Optimum Order Quantity, Q* (EOQ)**	470
Maximum Inventory, Q*	470
Average Inventory, Q*/2	235
2 Number of Orders, D/Q*	36
3 Annual Holding Cost, HQ*/2	470
Annual Order Cost, DS/Q*	470
Annual Unit Costs, PD	0
4 Total Annual Cost, T_c	940

250/36 = 6.9 ~ 7 days

POQ Example 2 - Solution

Given the data below

D = 17,000 units
S = \$13 per order
H = \$2 per unit per year
p = 500
Production days per year = 250

1. Determine optimal number of items to produce
2. Expected number of orders/setups
3. Optimal time between orders/setups
4. Total annual cost

Data	
Demand rate, D	17,000
Ordering/setup cost, S	$13
Holding/carrying cost, H	$2.00
Daily production rate, p	500
Days per year or ...	250
... Daily demand rate, d	
Unit price, P	
Results	
1 **Optimal production quantity, Q***	**506**
Maximum Inventory Level	**437**
Average Inventory	**218**
2 **Number of Setups**	**33.6**
Holding cost	**$437**
Setup cost	**$437**
Unit costs	**$0**
4 **Total cost, T_c**	**$874**

3 250/33.6 = 7.4 days

Reorder Points

- EOQ answers the "how much" question
- The reorder point (ROP) tells "when" to order
- Lead time (L) is the time between placing and receiving an order

$$\text{ROP} = \begin{pmatrix}\text{Demand} \\ \text{per day}\end{pmatrix}\begin{pmatrix}\text{Lead time for a new} \\ \text{order in days}\end{pmatrix}$$

$$\text{ROP} = d \times L$$

$$d = \frac{D}{\text{Number of working days in a year}}$$

This demonstrates the formulas behind the Excel sheet

Safety Stock

- Used when demand is not constant or certain
- Use safety stock to achieve a desired **service level** and avoid stockouts

$$\text{ROP} = d \times L + ss$$

Annual stockout costs = **The sum of the units short for each demand level** x **The probability of that demand level** x **The stockout cost/unit** x **The number of orders per year**

This demonstrates the formulas behind the Excel sheet

Safety Stock Example

Given the following data and table
ROP = 50 units
Stockout cost = $40 per frame
Orders per year = 6
Carrying cost = $5 per frame per year

NUMBER OF UNITS	PROBABILITY
30	0.2
40	0.2
ROP → 50	0.3
60	0.2
70	0.1
	1.0

1. What is the optimal safety stock to have?
2. How many frames should be ordered?

Data	
Reorder point	50
Annual carrying cost	5
Stockout cost	40
Orders per year	6

2 70 frames should be orderd given the ROP of 50 units

Profit Table

Probability	0.2	0.2	0.3	0.2	0.1
Safety stock\Demand	30	40	50	60	70
0	0	0	0	2400	4800
10	50	50	50	50	2450
1 20	100	100	100	100	100
30	150	150	150	150	150
40	200	200	200	200	200

Results

	EMV	Minimum	Maximum
	960	0	4800
	290	50	2450
	100	100	100
	150	150	150
	200	200	200
Minimum	100	0	100

Supply Chain Management

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Supply-Chain Management

- Objective
  - Structure the supply chain to maximize its competitive advantage and benefits to the ultimate consumer
- Involves
  - Coordination of all supply chain activities, starting with raw materials and ending with a satisfied customer
- Includes
  - Suppliers, manufacturers and/or service providers, distributors, wholesalers, retailers, and final customers

Supply Chain vs. Sales Strategy

Hau Lee Furniture

60% of sales $ in supply chain
Current gross profit = $10,000
Increase profits to $15,000 (50%)

	Current Strategy	% Sales	Supply Chain Strategy	% Sales	Sales Strategy	% Sales
Sales	$100,000	100%	$100,000	100%	$125,000	100%
Cost of materials	$60,000	60%	$55,000	55%	$75,000	60%
Production costs	$20,000	20%	$20,000	20%	$25,000	20%
Fixed costs	$10,000	10%	$10,000	10%	$10,000	8%
Profit	$10,000	10%	$15,000	15%	$15,000	12%

Table 11.2 - Low cost vs Response vs Differentiation

Sourcing Issues

- **Make-or-buy decisions**
  - Choosing between obtaining products and services externally as opposed to producing them internally
- **Outsourcing**
  - Transfer traditional internal activities and resources to outside vendors
  - Efficiency in specialization
  - Focus on core competencies

Six Sourcing Strategies

- Many suppliers
- Few suppliers
- Vertical integration
- Joint ventures
- *Keiretsu* networks
- Virtual companies

Supply Chain Risk

- More reliance on supply chains means more risk
  - More complicated = More risk
- Fewer suppliers increase dependence
- Compounded by globalization and logistical complexity
- Vendor reliability and quality risks
- Political and currency risks

➢ See Table 11.3

Measuring Performance

- Inventory turnover

$$\text{Inventory turnover} = \left(\frac{\text{Cost of goods sold}}{\text{Average inventory investment}} \right)$$

  - Inventory investment
    - Average of several periods
    - (beginning plus ending)/2
    - Ending inventory

Measuring Performance

- From PepsiCo, Inc. Annual Report
  - All values in billions

Net revenue		\$32.5
Cost of goods sold		\$14.2
Inventory:		
Raw material inventory	\$.74	
Work-in-process inventory	\$.11	
Finished goods inventory	\$.84	
Total inventory investment		\$1.69

$$\text{Inventory turnover} = \frac{14.2}{1.69} = 8.4$$

Measuring Performance

- Weeks of supply

$$\text{Weeks of supply} = \frac{\text{Average inventory investment}}{\left(\dfrac{\text{Annual cost of goods sold}}{\text{52 weeks}}\right)}$$

<u>For PepsiCo</u>

Inventory investment = \$1.69 billion

Avg weekly cost of goods sold = \$14.2 billion / 52 = \$0.27 billion

Weeks of supply = 1.69 / .27 = 6.2 weeks

Benchmarking the Supply Chain

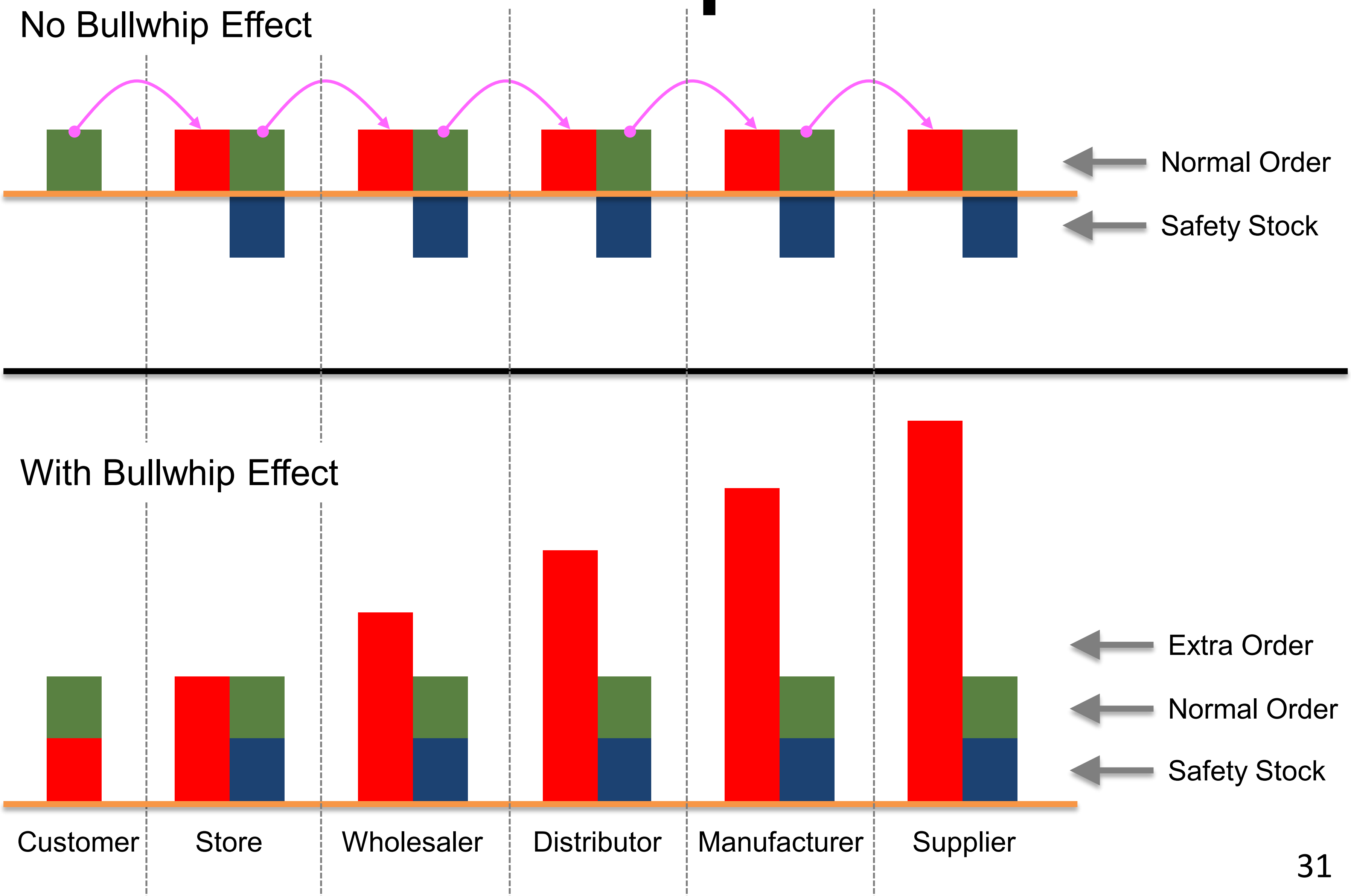
- Comparison with benchmark firms

TABLE 11.7	Supply Chain Metrics in the Consumer Packaged Goods Industry	
	TYPICAL FIRMS	**BENCHMARK FIRMS**
Order fill rate	71%	98%
Order fulfillment lead time (days)	7	3
Cash-to-cash cycle time (days)	100	30
Inventory days of supply	50	20

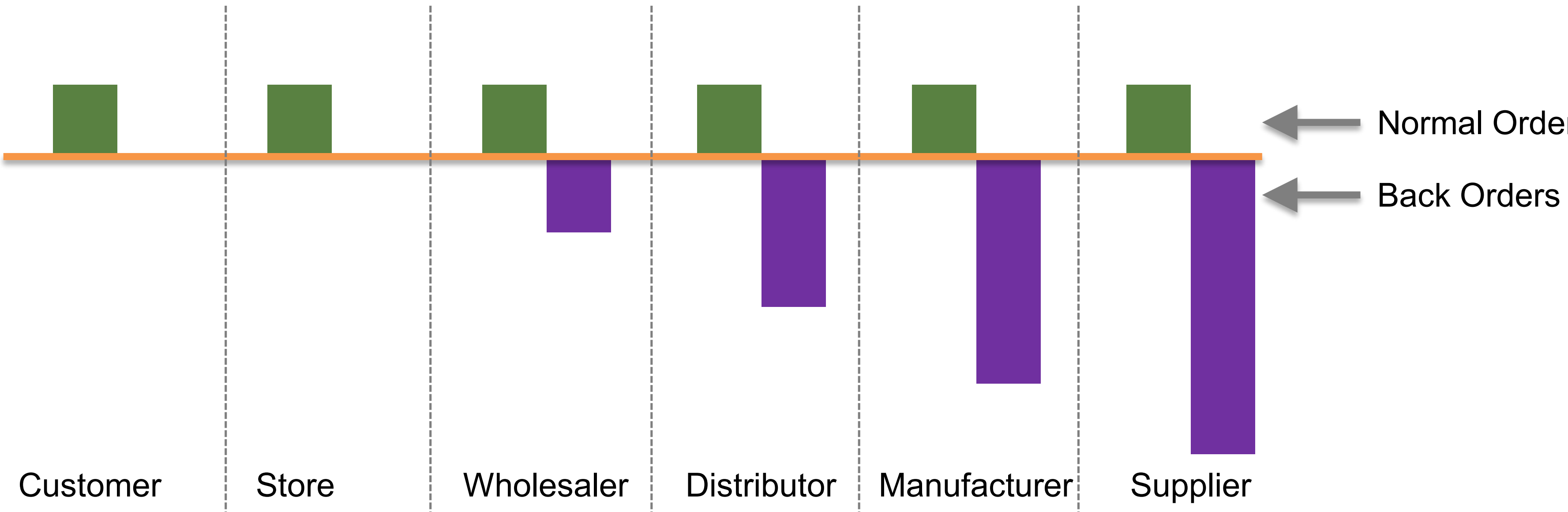
The Bullwhip Effect

- The tendency for larger order size fluctuations as orders are relayed through the supply chain
- Creates unstable production schedules, expensive capacity change costs, longer lead times, obsolescence
- Damage can be minimized with supplier coordination and planning
- *Need to understand idea of safety stock*

Bullwhip Effect



Bullwhip Effect



The Bullwhip Effect Measure

$$\text{Bullwhip} = \frac{\text{Variance of orders}}{\text{Variance of demand}} = \frac{\sigma^2_{\text{orders}}}{\sigma^2_{\text{demand}}}$$

If measure is:

> 1 ➔ Variance *amplification* is present
= 1 ➔ No amplification is present
< 1 ➔ *Smoothing* or *dampening* is occurring

Bullwhip Calculation

- The supplier order variances are 34 and is experiencing a demand variance of 23.
  - Would you expect there to be a bullwhip effect; if so, how bad is it?
  - 34/23 = 1.5
  - >1 = Bullwhip effect present
  - Recommended action
    - Immediate
      - Decrease order
    - Long-term
      - Increase communication through supply chain

Process Strategy

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Process Strategy

- The objective is to create a process to produce offerings that meet customer requirements within cost and other managerial constraints

Process Planning

- Make-or-buy decisions
- Process selection
- Specific equipment selection
- Process plans
- Process analysis

Make vs Buy

- See spreadsheet
- A firm's must decide whether to make or buy 18,000 items used in their production line.
  - The costs for making the item are $98,000 annual cost and a $40 cost per item.
  - The costs for buying the item are $45 per item.
  - Should the company make or buy this item?

Crossover/Cost-Volume Analysis

- Borges Machine Shop, Inc., has a 1-year contract for the production of 200,000 gear housings for a new off-road vehicle. Owner Luis Borges hopes the contract will be extended and the volume increased next year. Borges has developed costs for three alternatives. They are general-purpose equipment (GPE), flexible manufacturing system (FMS), and expensive, but efficient, dedicated machine (DM).
- The cost data are given in the table below

	General-Purpose Equipment (GPE)	Flexible Manufacturing System (FMS)	Dedicated Machine (DM)
Annual contracted units	200,000	200,000	200,000
Annual fixed cost	$150,000	$225,000	$525,000
Per unit variable cost	$16.00	$14.00	$13.00

  - The option GPE is best when the contracted volume is below 37,500 units *(enter your response as a whole number).*
  - The option FMS is best when the contracted volume is between 37,500 and 300,000 units *(enter your responses as whole numbers).*
  - The option DM is best when the contracted volume is over 300,000 units *(enter your response as a whole number).*

Process Strategies

- Four basic strategies
  1. Process focus
  2. Repetitive focus
  3. Product focus
  4. Mass customization

- Within these basic strategies there are many ways they may be implemented

Process, Volume, and Variety

Figure 7.1

Volume

Variety (flexibility)	**Low Volume**	**Repetitive Process**	**High Volume**
High Variety one or few units per run, (allows customization)	**Process Focus** projects, job shops (machine, print, hospitals, restaurants) *Arnold Palmer Hospital*		**Mass Customization** (difficult to achieve, but huge rewards) *Dell Computer*
Changes in Modules modest runs, standardized modules		**Repetitive** (autos, motorcycles, home appliances) *Harley-Davidson*	
Changes in Attributes (such as grade, quality, size, thickness, etc.) high throughput and/or long runs only	**Poor Strategy** (Both *fixed* and *variable* costs are high)		**Product Focus** (commercial baked goods, steel, glass, beer) *Frito-Lay*

Make-or Buy Solution

- Set up an equation so the “make” is equal to the “buy”
- In this example, use the following equation. Let d be the number of days to use the item.

  $$\$150d = \$1{,}000 + \$50d$$

- Solve for d as follows:
  - Subtract $50d from the right side of the equation to get

    $$\$100d = \$1{,}000$$

  - Divide both sides of the equation by $100

    $$d = 10 \text{ days}$$

- The lease cost is the same as the purchase cost at 10 days
- If you need the item for 12 days, it would be more economical to purchase it

- **USE EXCEL TEMPLATE**

"Baseline" Time-Function Map

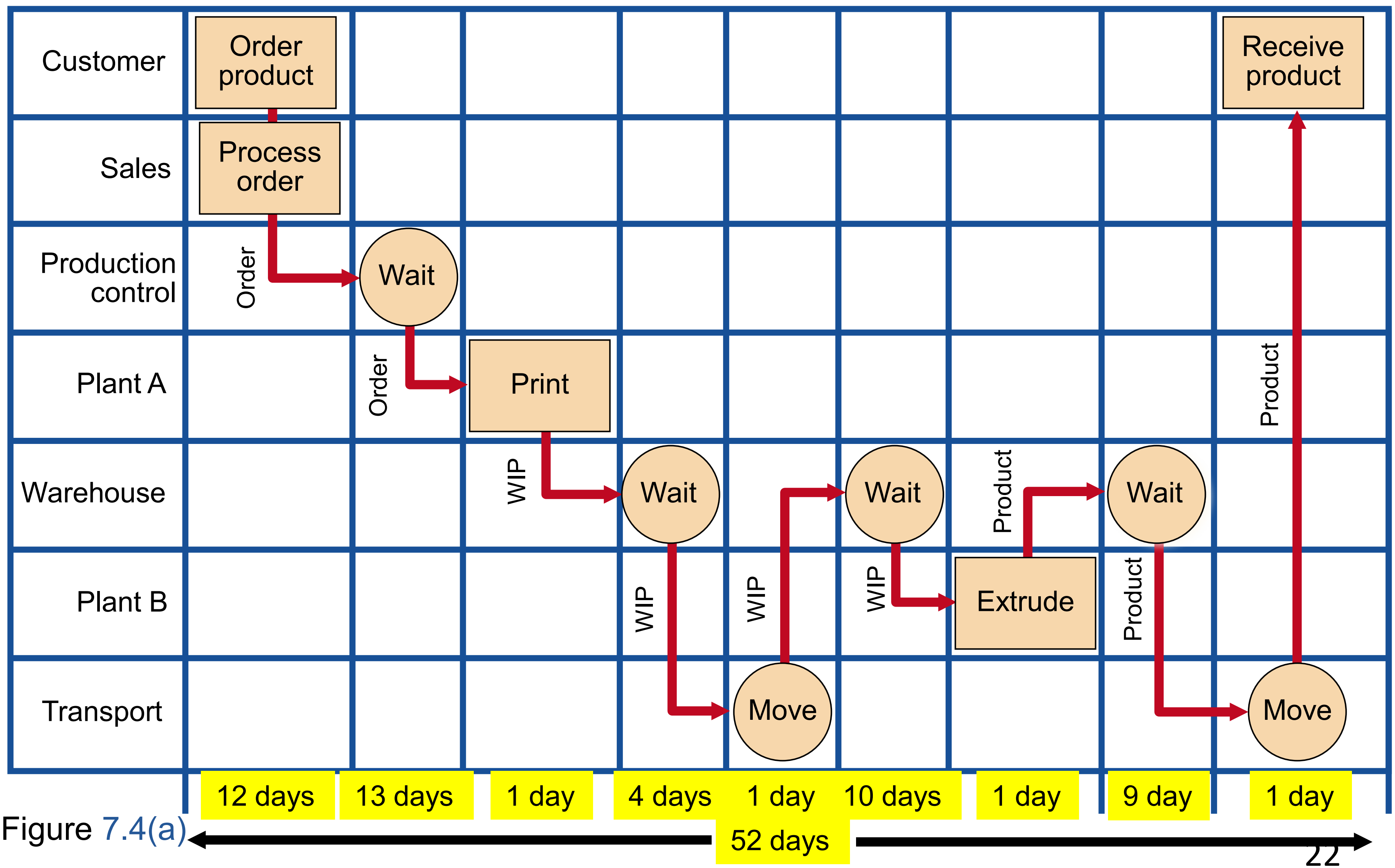


Figure 7.4(a)

"Target" Time-Function Map

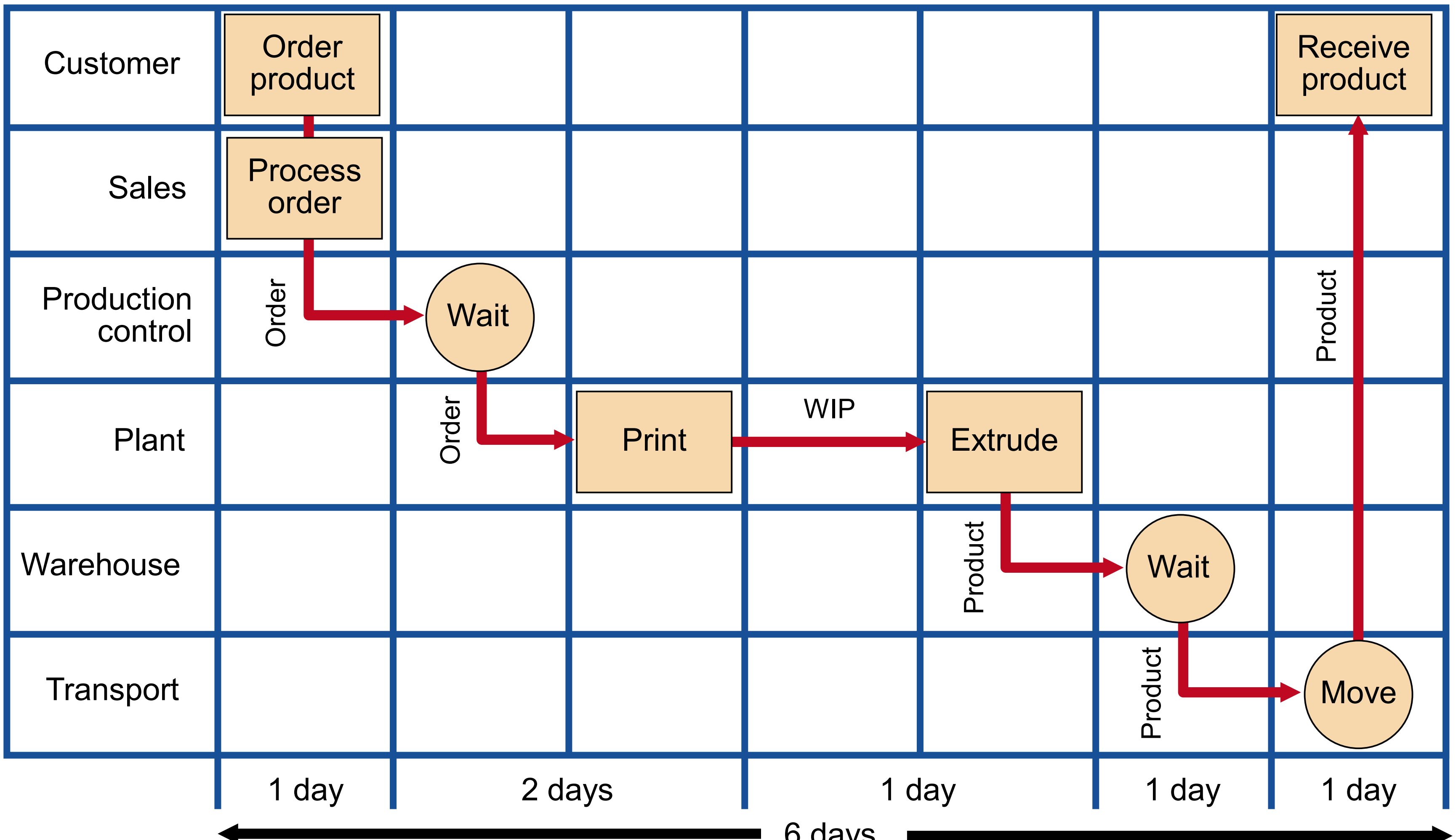


Figure 7.4(b)

Burger Process for Chef

Present Method ☒ PROCESS CHART Proposed Method ☐

SUBJECT CHARTED *Hamburger Assembly Process* DATE *12 / 1 / 15*

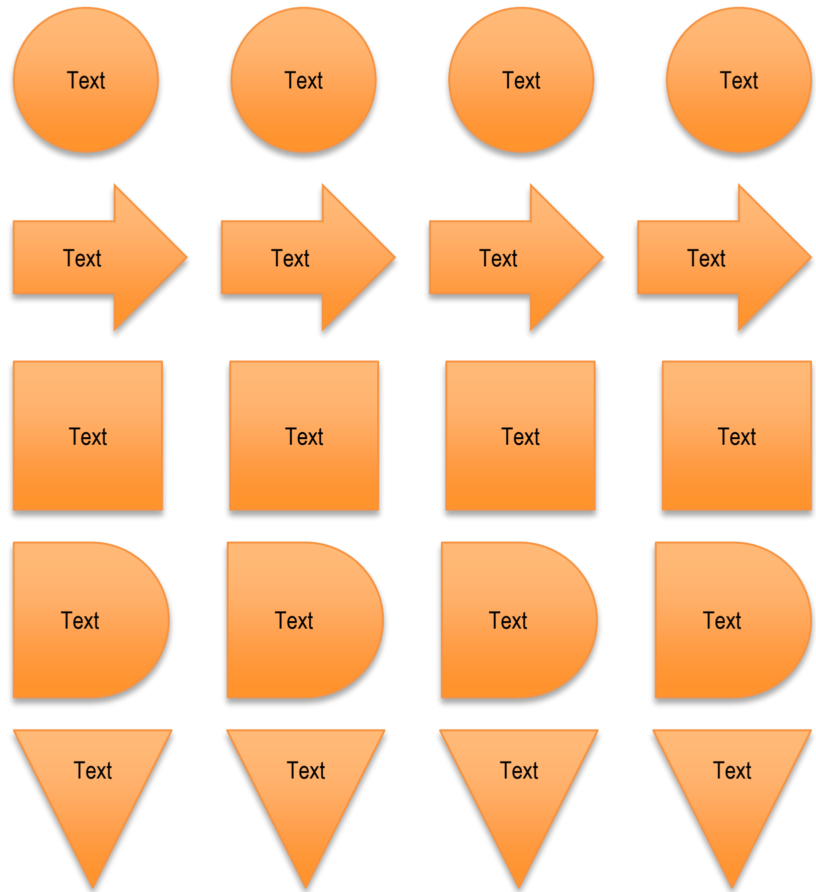
DEPARTMENT ________ CHART BY *KH* SHEET NO. *1* OF *1*

DIST. IN FEET	TIME IN MINS.	CHART SYMBOLS	PROCESS DESCRIPTION
	—	○ ⇨ □ D ▽	*Meat Patty in Storage*
1.5	*.05*	○ ⇨ □ D ▽	*Transfer to Broiler*
	2.50	○ ⇨ □ D ▽	*Broiler*
	.05	○ ⇨ □ D ▽	*Visual Inspection*
1.0	*.05*	○ ⇨ □ D ▽	*Transfer to Rack*
	.15	○ ⇨ □ D ▽	*Temporary Storage*
.5	*.10*	○ ⇨ □ D ▽	*Obtain Buns, Lettuce, etc.*
	.20	○ ⇨ □ D ▽	*Assemble Order*
.5	*.05*	○ ⇨ □ D ▽	*Place in Finish Rack*
		○ ⇨ □ D ▽	
3.5	*3.15*	*2 4 1 – 2*	TOTALS

Value-added time = Operation time/Total time = (2.50+.20)/3.15 = 85.7%

○ = operation; ⇨ = transport; □ = inspect; D = delay; ▽ = storage.

Figure 7.5



__Assemble your process flow chart below.__

Burger Process – SOLUTION

Present Method ☒ PROCESS CHART Proposed Method ☐

SUBJECT CHARTED *Hamburger Assembly Process* DATE *12 / 1 / 15*

DEPARTMENT ______ CHART BY *KH* SHEET NO. *1* OF *1*

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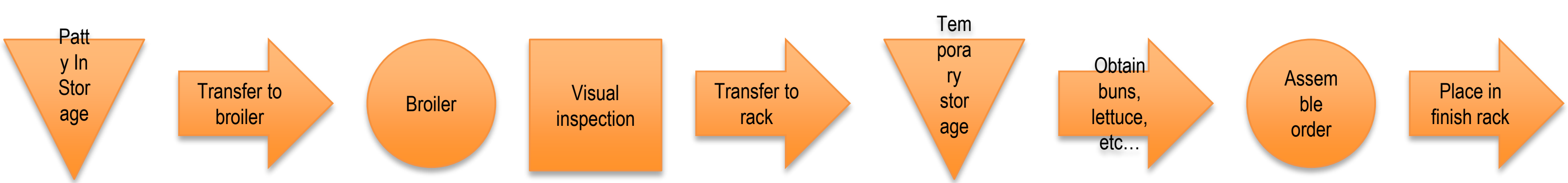
Figure 7.5



Service Blueprinting

- Focuses on the customer and provider interaction
- Defines three levels of interaction
- Each level has different management issues
- Identifies potential failure points

Process Redesign

- The fundamental rethinking of business processes to bring about dramatic improvements in performance
- Relies on reevaluating the purpose of the process and questioning both the purpose and the underlying assumptions
- Requires reexamination of the basic process and its objectives
- Focuses on activities that cross functional lines
- Any process is a candidate for redesign

Layout Strategies

9

Strategic Importance of Layout Decisions

- Develop an effective and efficient layout that will meet the firm's competitive requirements

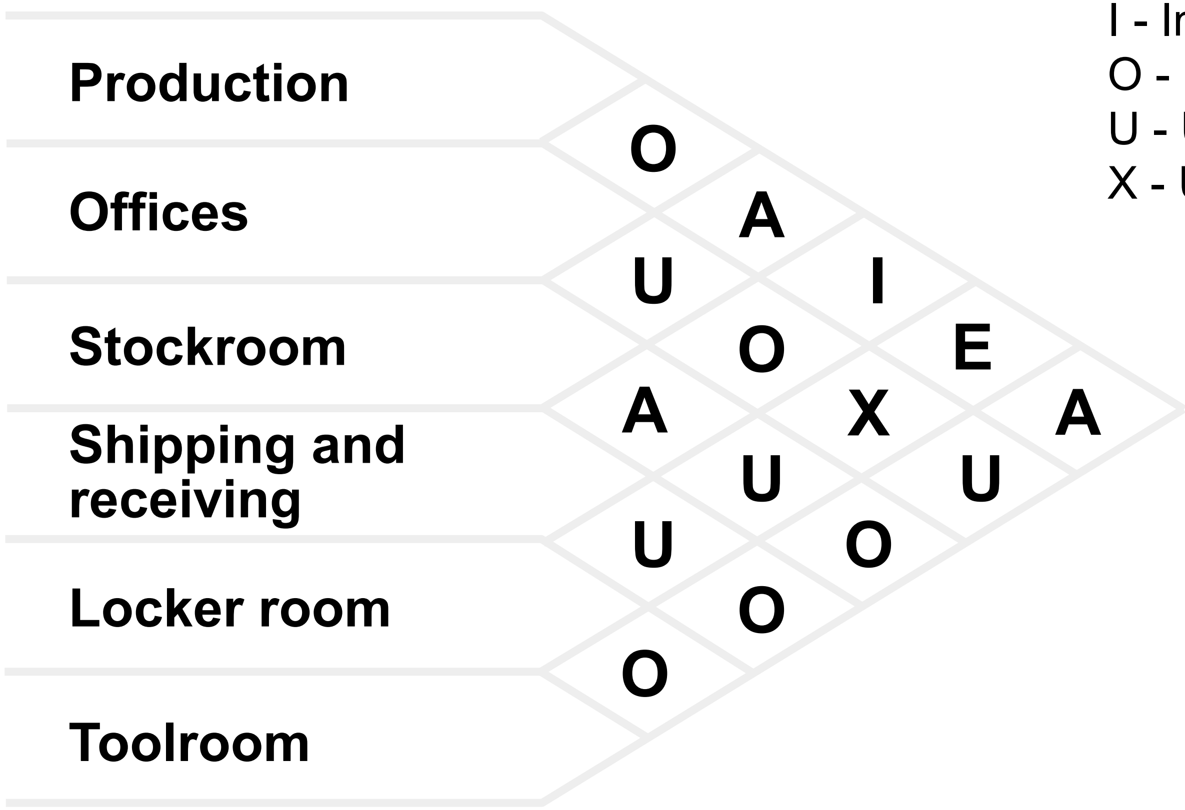
Layout Design Considerations

- Higher utilization of space, equipment, and people
- Improved flow of information, materials, or people
- Improved employee morale and safer working conditions
- Improved customer/client interaction
- Flexibility

Types of Layout

1. Office layout
2. Retail layout
3. Warehouse layout
4. Fixed-position layout
5. Process-oriented layout
6. Work-cell layout
7. Product-oriented layout

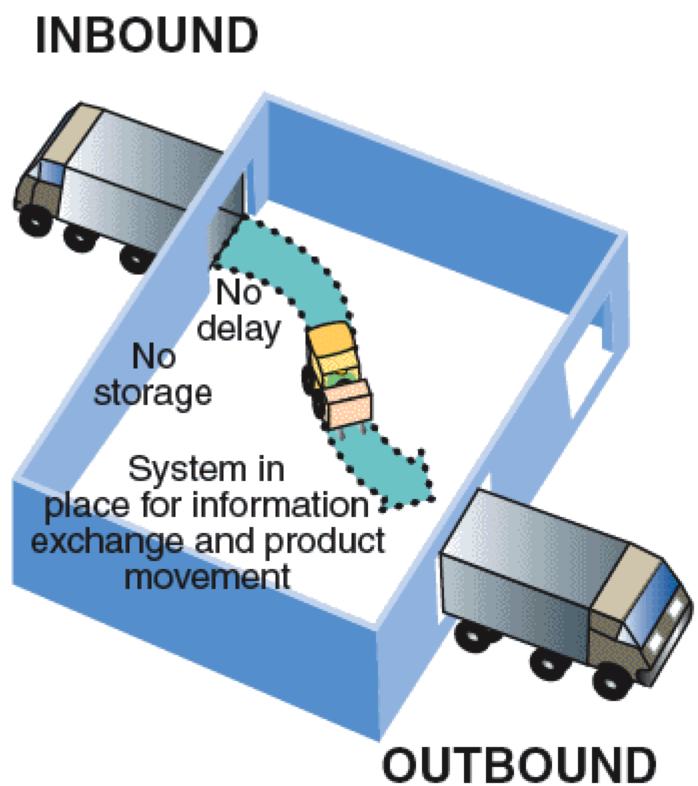
Relationship Diagramming Example



A - Absolutely necessary
E - Especially important
I - Important
O - Okay
U - Unimportant
X - Undesirable

Cross-Docking

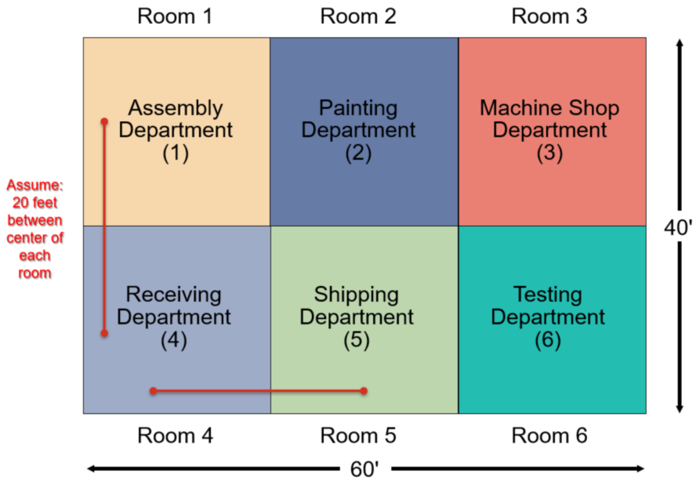
- Materials are moved directly from receiving to shipping and are not placed in storage in the warehouse
- Requires tight scheduling and accurate shipments, bar code or RFID identification used for advanced shipment notification as materials are unloaded



Process Layout Example

Answer the following questions for a 60 by 40 foot facility divided into 6 equal sections with the loads per week movement charts below. Assume the cost for each move is 3 dollars. Traffic never flows diagonally.

1. What is the optimal arrangement of rooms?
2. What is the expected cost?



Area	Loads
Assembly to Paint	75
Assembly to Machine Shop	89
Assembly to Receiving	0
Assembly to Shipping	0
Assembly to Testing	23
Paint to Machine Shop	34
Paint to Receiving	63
Paint to Shipping	10

Area	Loads
Paint to Testing	0
Machine Shop to Receiving	13
Machine Shop to Shipping	2
Machine Shop to Testing	123
Receiving to Shipping	72
Receiving to Testing	0
Shipping to Testing	0

Work Cells

- Reorganizes people and machines into groups to focus on single products or product groups
- Group technology identifies products that have similar characteristics for particular cells
- Volume must justify cells
- Cells can be reconfigured as designs or volume changes

Staffing and Balancing Work Cells

Determine the Takt time

$$\text{Takt time} = \frac{\text{Total work time available}}{\text{Units required to satisfy customer demand}}$$

Determine the number of operators required

$$\text{Workers required} = \frac{\text{Total operation time required}}{\text{Takt time}}$$

Cycle Time – C_d

Variable	Data
Production Time	8 hours (480 minutes)
Desired Output	120 units

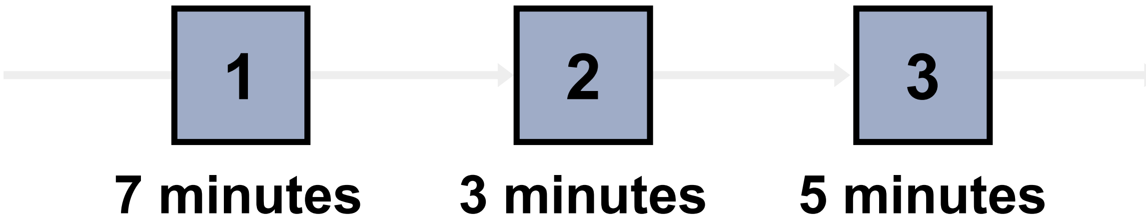
$$C_d = \frac{\text{production time available}}{\text{desired units of output}}$$

$$C_d = \frac{(8 \text{ hours x } 60 \text{ minutes / hour})}{(120 \text{ units})}$$

$$C_d = \frac{480}{120} = 4 \text{ minutes/unit}$$

Flow Time vs Cycle Time

Cycle time = max time spent at any station



Cycle time = max (7, 3, 5) = 7 minutes

Line Balancing Process

1. Draw and label a precedence diagram
2. Calculate the desired cycle time required for the line
3. Calculate the theoretical minimum number of workstations
4. Group elements into workstations, recognizing cycle time and precedence constraints
5. Calculate the efficiency of the line
6. Stop if…
   - Theoretical minimum number of workstations

   OR
   - Acceptable efficiency level reached
     - If not, go back to step 4

Wing Component Example

TABLE 9.2	Precedence Data for Wing Component	
TASK	ASSEMBLY TIME (MINUTES)	PREDECESSOR
A	10	–
B	11	A
C	5	B
D	4	B
E	11	A
F	3	C, D
G	7	F
H	11	E
I	3	G, H
Total time	65	

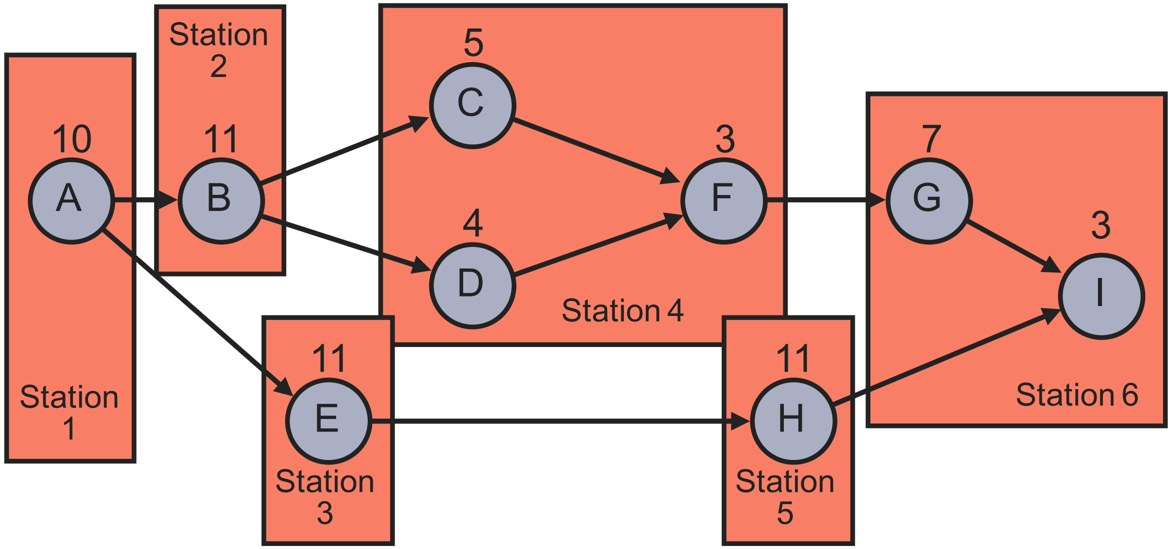
Cycle time:
12 minutes per unit

Efficiency:
90%

Min workstations:
6 stations

Idle Time:
7 minutes

480 available mins per day
40 units required



Sample HW Problem – Solution

Stanford Rosenberg Computing wants to establish an assembly line for producing a new product, the Personal Digital Assistant (PDA). The tasks, task times, and immediate predecessors for the tasks are as follows:

Task	Time (sec)	Immediate Predecessor
A	12	–
B	14	A
C	8	A
D	5	B, C
E	20	D

Rosenberg's goal is to produce 180 PDAs per hour.

a) The cycle time for the production of a PDA = 20.00 seconds *(round your response the nearest whole number).*

b) The theoretical minimum number of workstations that Rosenberg can achieve in this assembly line = 3 *(round your response up to the next whole number).*

c) For one to assign the tasks to the actual workstations and be able to use the "theoretical minimum" number, the activity assignment should be:

Workstation #	Tasks Assigned to Workstation	
1	A	C
2	B	D
3	E	

Were you able to assign all the tasks to the theoretical minimum number of workstations? Yes

Location Strategies

8

Transportation Models

C

MODULE

LOCATION

Strategic Importance of Location

- The objective of location strategy is to maximize the benefit of location to the firm
- Options include
  - Expanding existing facilities
  - Maintain existing and add sites
  - Closing existing and relocating
- Once committed to a location, many resource and cost issues are difficult to change

TRANSPORTATION

Transportation Modeling

- An iterative procedure that finds the least costly means of moving products from a series of sources to a series of destinations
- Can be used to help resolve distribution and location decisions

Transportation Modeling

- A special class of linear programming
- Need to know
  1. The *origin points* or *sources*
  2. Capacity or supply per period at each origin
  3. The *destinations*
  4. Demand per period at each destination
  5. The cost of shipping one unit from each origin to each destination

What is the lowest cost?

Data				
COSTS	Albuquerque	Boston	Cleveland	Supply
Des Moines	5	4	3	100
Evansville	8	4	3	300
Fort Lauderdale	9	7	5	300
Demand	300	200	200	700 \ 700

The problem is balanced.

Shipments	Albuquerque	Boston	Cleveland	Row Total
Des Moines	100			100
Evansville		200	100	300
Fort Lauderdale	200		100	300
Column Total	300	200	200	700 \ 700

Total Cost	3900

Unbalanced Demand/Supply

From \ To	(A) Albuquerque	(B) Boston	(C) Cleveland	Dummy	Factory capacity
(D) Des Moines	250 ($5)	($4)	($3)	(0)	250
(E) Evansville	50 ($8)	200 ($4)	50 ($3)	(0)	300
(F) Fort Lauderdale	($9)	($7)	150 ($5)	150 (0)	300
Warehouse requirement	300	200	200	150	850

Data

COSTS	Albuquerque	Boston	Cleveland	Warehouse	Supply	
Des Moines	5	4	3	0	250	<-- New Supply
Evansville	8	4	3	0	300	
Fort Lauderdale	9	7	5	0	300	
Demand	300	200	200	150	850 \ 850	

Practice Quiz Problem

A firm has established a distribution network for the supply of a raw material critical to its manufacturing. Currently there are two origins for this raw material, which must be shipped to three manufacturing plants. The current network has the following characteristics:

COSTS	Plant 1	Plant 2	Plant 3	Supply
Raw material source 1	$6	$8	$9	400
Raw material source 2	$4	$7	$3	600
Demand	500	500	500	1500 \ 1000

The firm has identified two potential sites for a third raw material source; these are identified as Candidate A and Candidate B. From A, the costs to ship would be $9 to Plant 1, $10 to Plant 2, and $12 to Plant 3. From B, these costs would be $11, $14, and $8. The new source, wherever it is located, will have a capacity of 500 units. Solve with the transportation method. Which site should be selected?

Managing Quality

6

Defining Quality

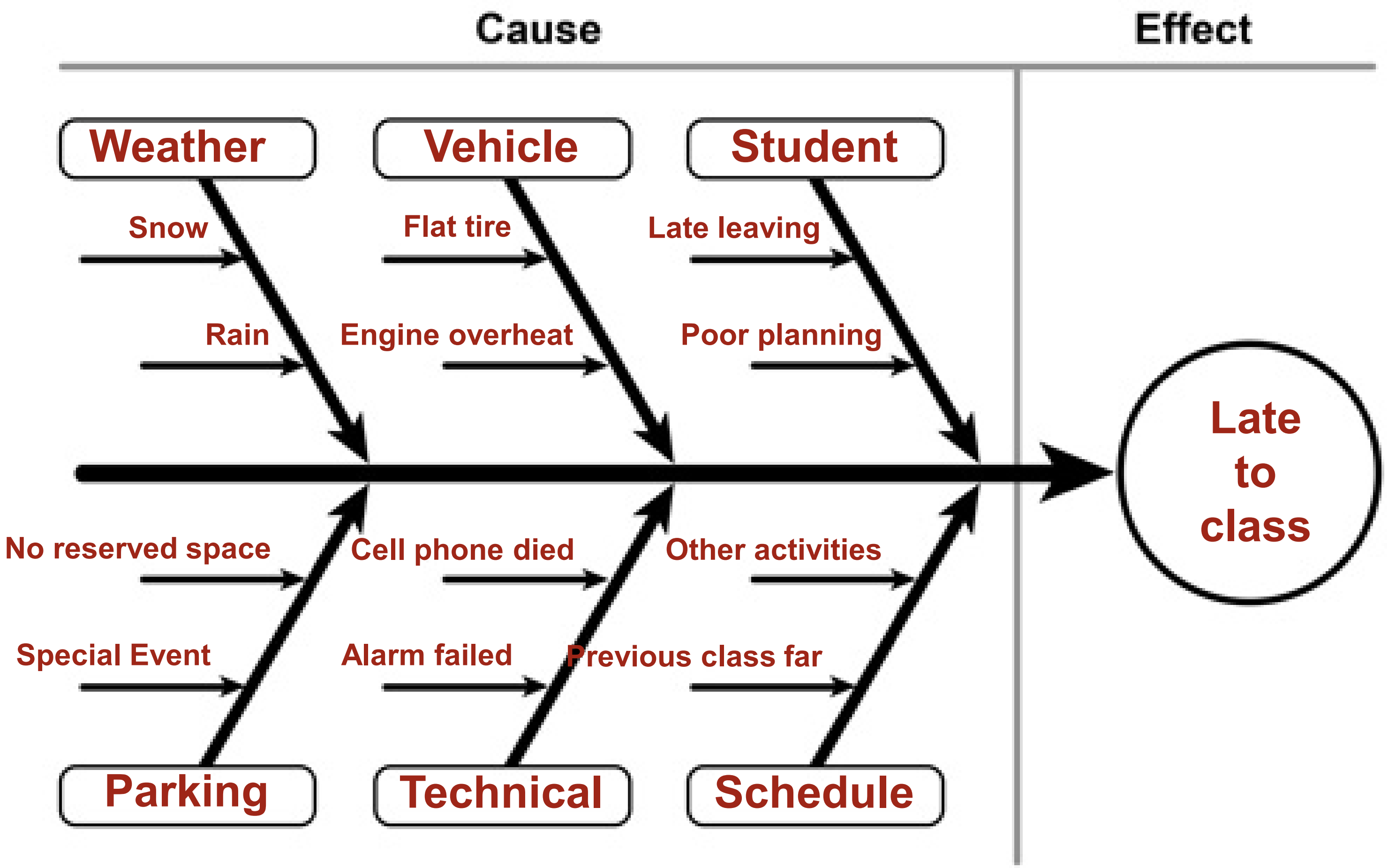
- The totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs

  – *American Society for Quality*

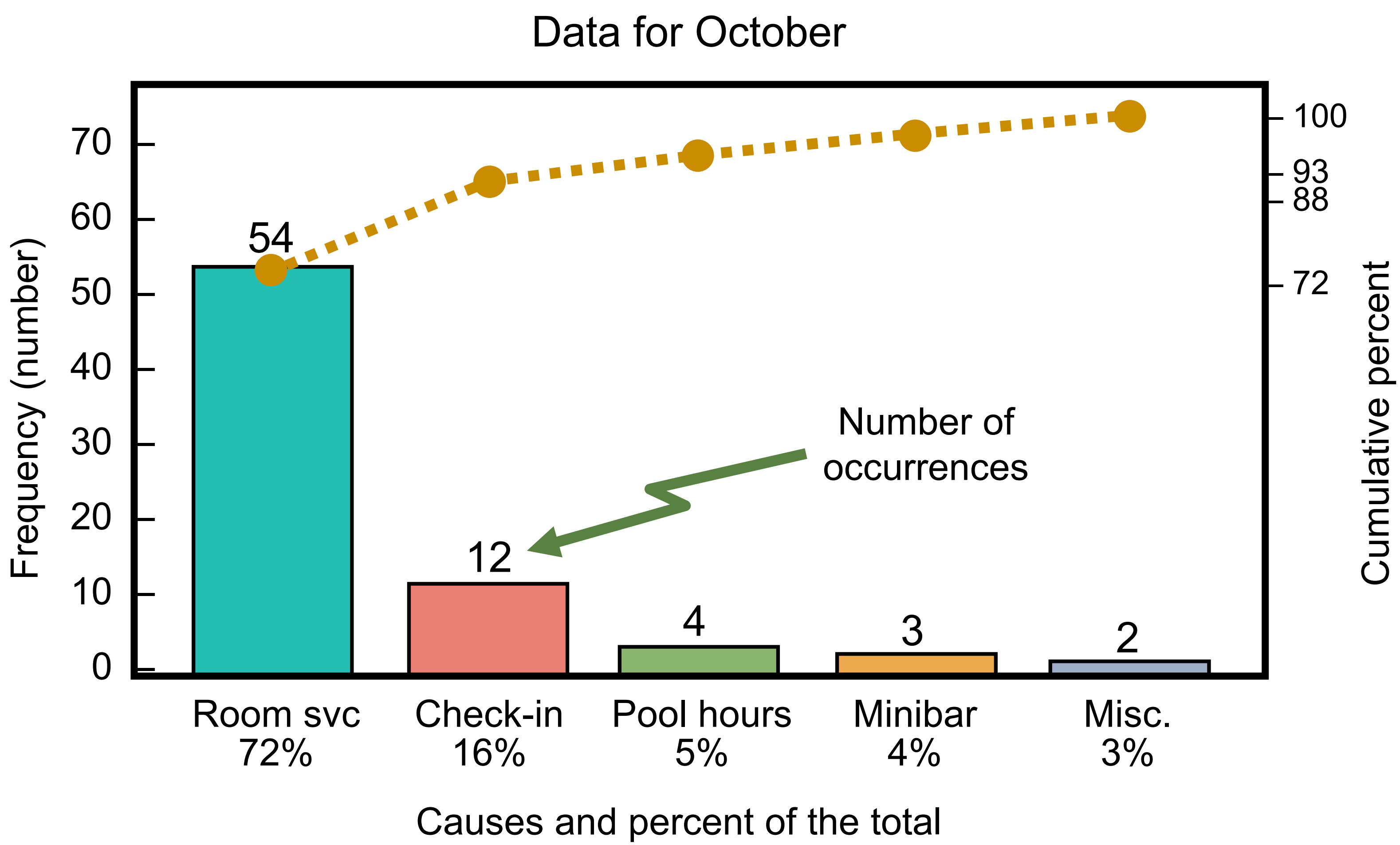
TQM Tools

- Tools for Generating Ideas
  - Check Sheet
  - Scatter Diagram
  - Cause-and-Effect Diagram
- Tools to Organize the Data
  - Pareto Chart
  - Flowchart (Process Diagram)
- Tools for Identifying Problems
  - Histogram
  - Statistical Process Control Chart

Fishbone Problem



Pareto Charts



Statistical Process Control (SPC)

- Variability is inherent in every process
  - Natural causes
    - Random
  - Assignable causes
    - Non-random

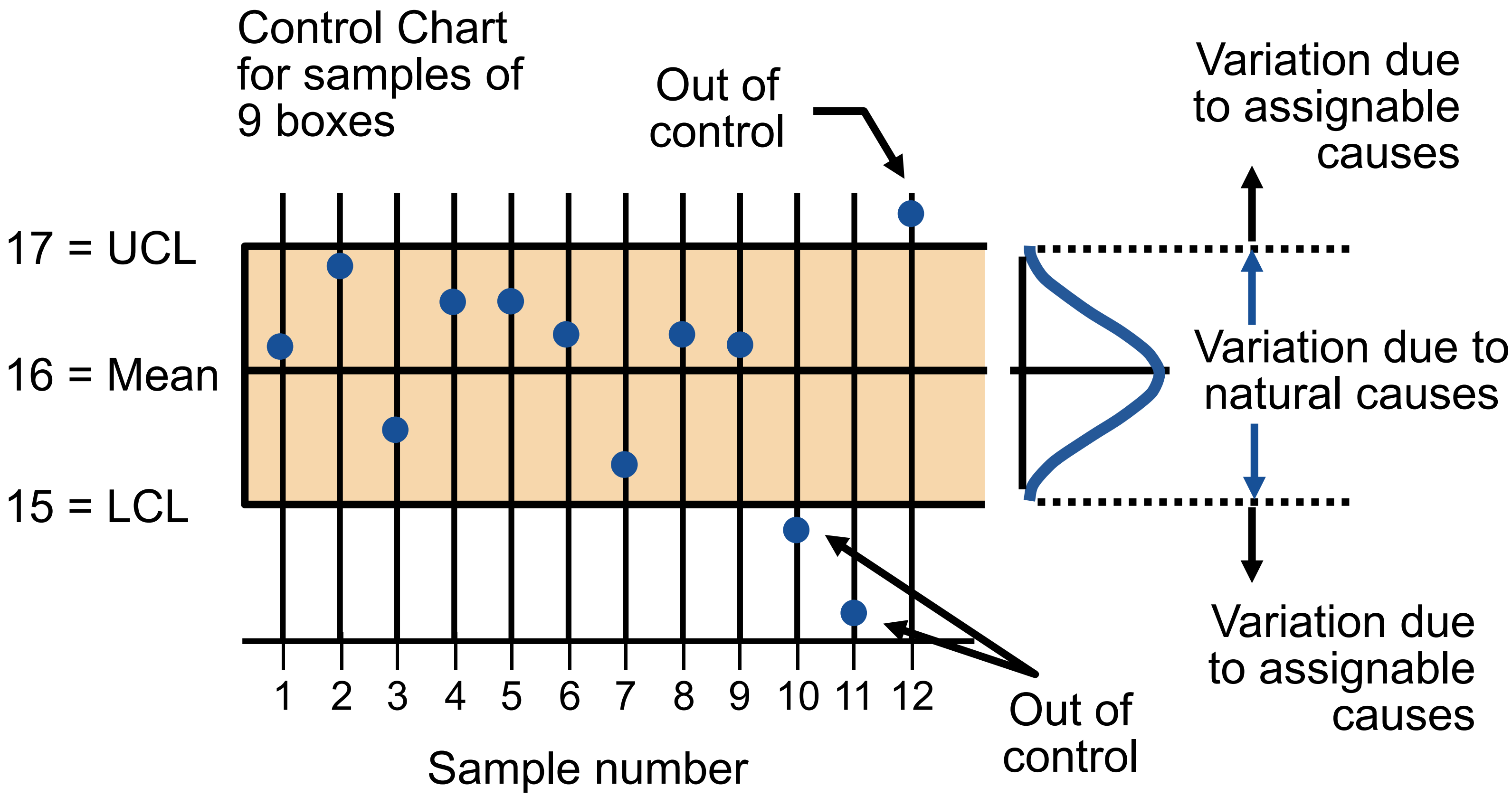
- Provides a statistical signal when assignable causes are present
- Detect and eliminate assignable causes of variation

Variability

- Random
  - Caused by nature
    - Weather
  - Common causes
    - Variation in material
  - Inherent in a process
    - Sampling protocol
  - *Can be eliminated only through improvements in the system*

- Non-Random
  - Special causes
    - Tampering
    - New process
  - Due to identifiable factors
    - Change in personnel
    - Part wear
  - *Can be modified through operator or management action*

Control Chart Overview



***For this class…use Excel to plot control charts

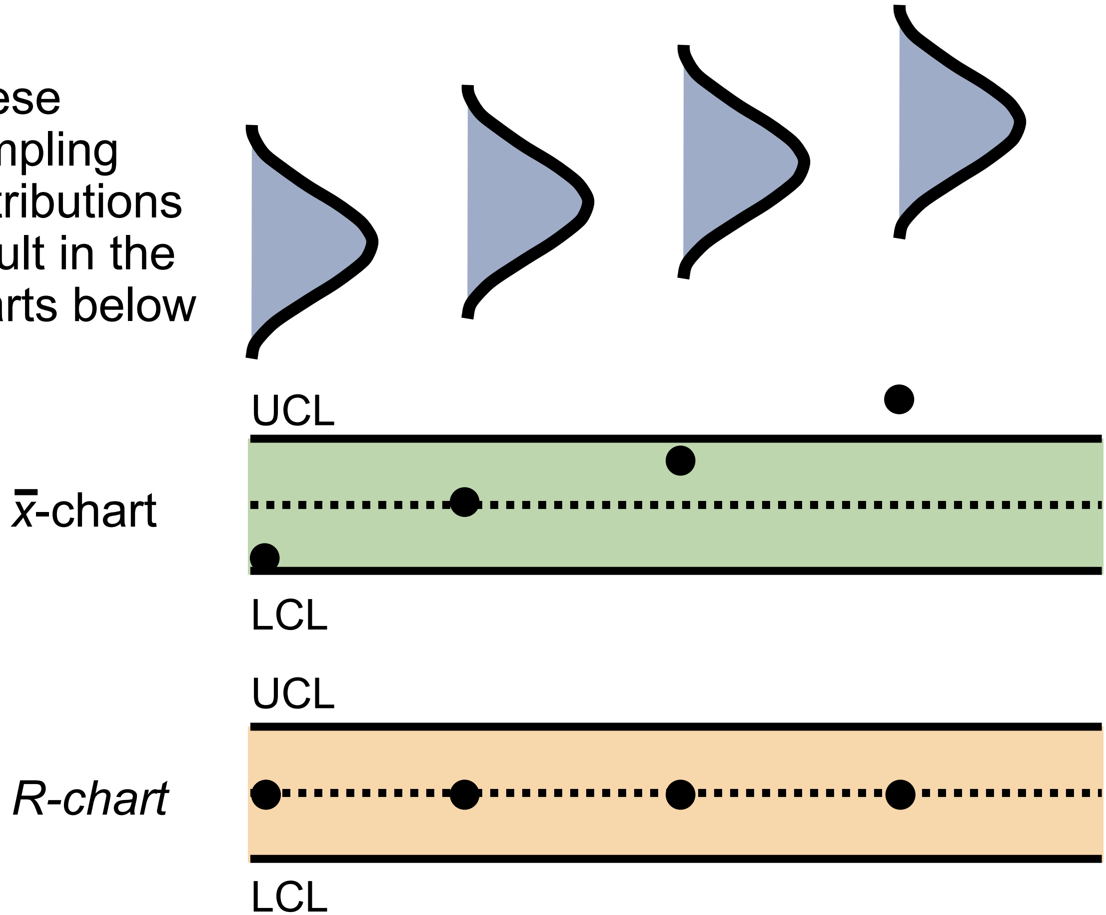
Control Chart Type

- Variables
  - Mean chart ($\bar{x}$ -Chart)
    - uses average of a sample
  - Range chart (R-Chart)
    - uses amount of dispersion in a sample
- Attributes
  - p-charts
    - Uses portion defective in a sample
  - c-charts
    - Uses number of defects in an item
- Use different charts for each type

Mean and Range Charts

(a)

These sampling distributions result in the charts below



(Sampling mean is shifting upward, but range is consistent)

($\bar{x}$-chart detects shift in central tendency)

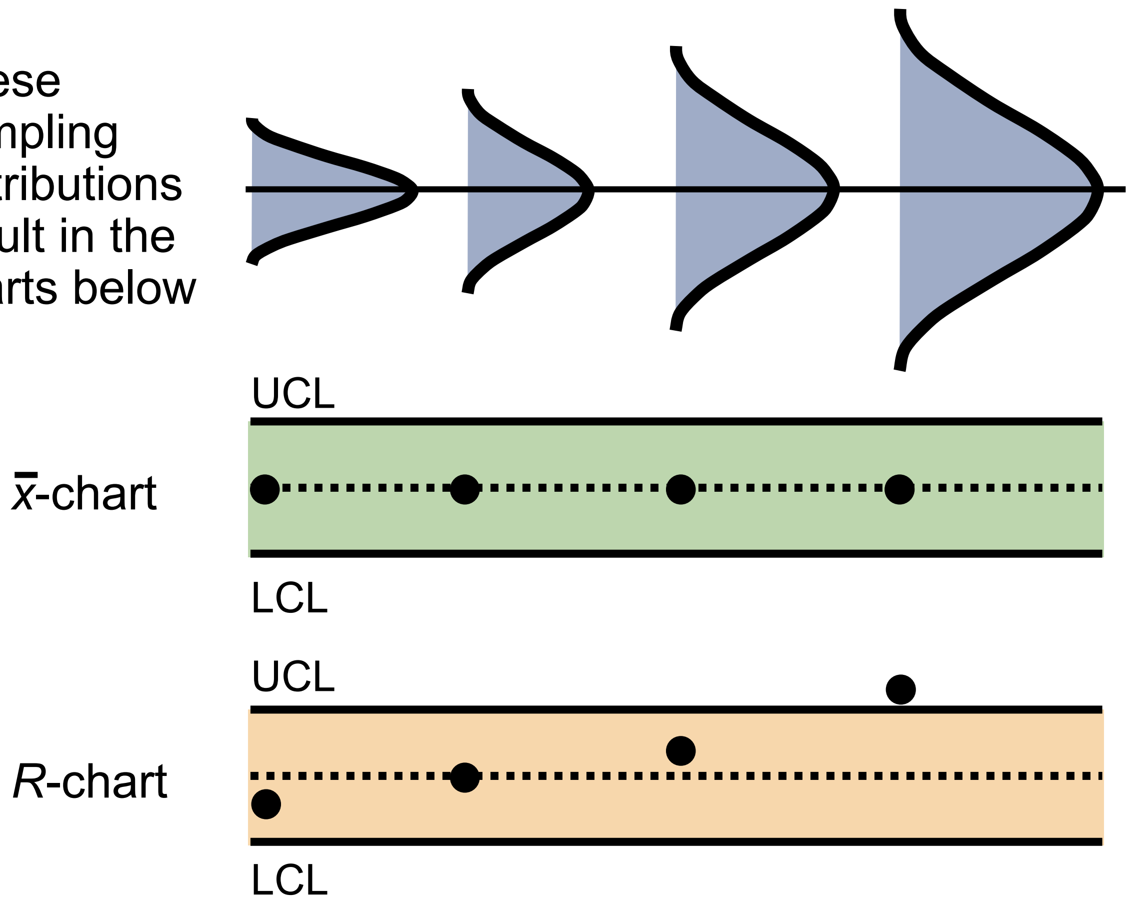
(*R*-chart does not detect change in mean)

Figure S6.5

Mean and Range Charts

(b)

These sampling distributions result in the charts below



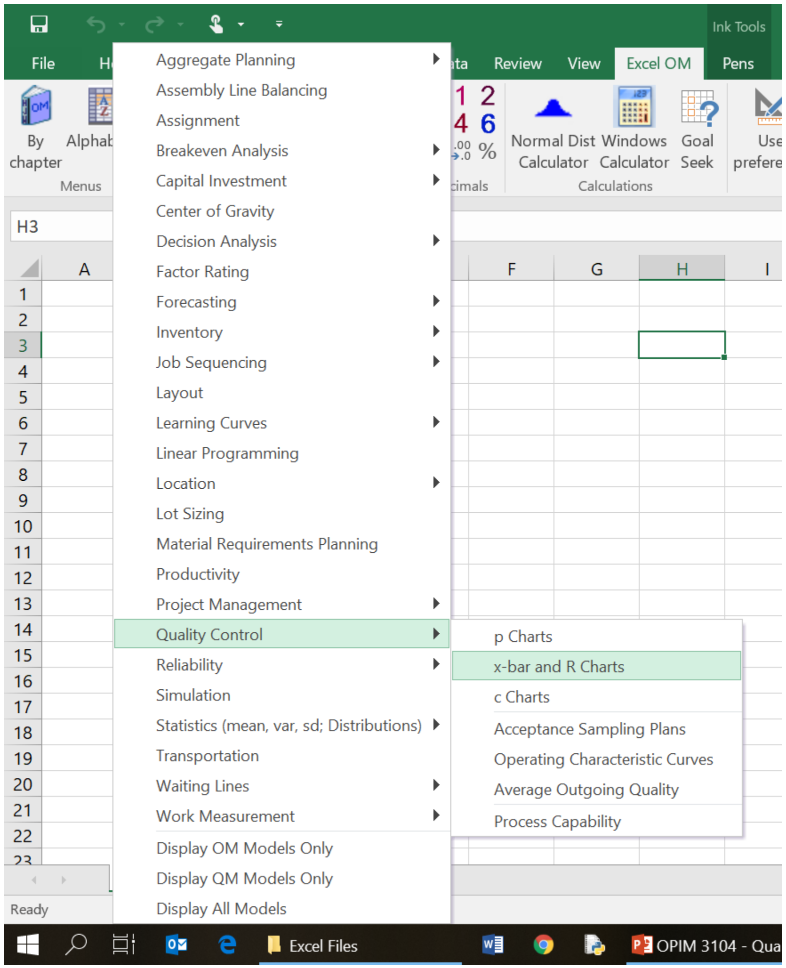
(Sampling mean is constant, but dispersion is increasing)

($\bar{x}$-chart indicates no change in central tendency)

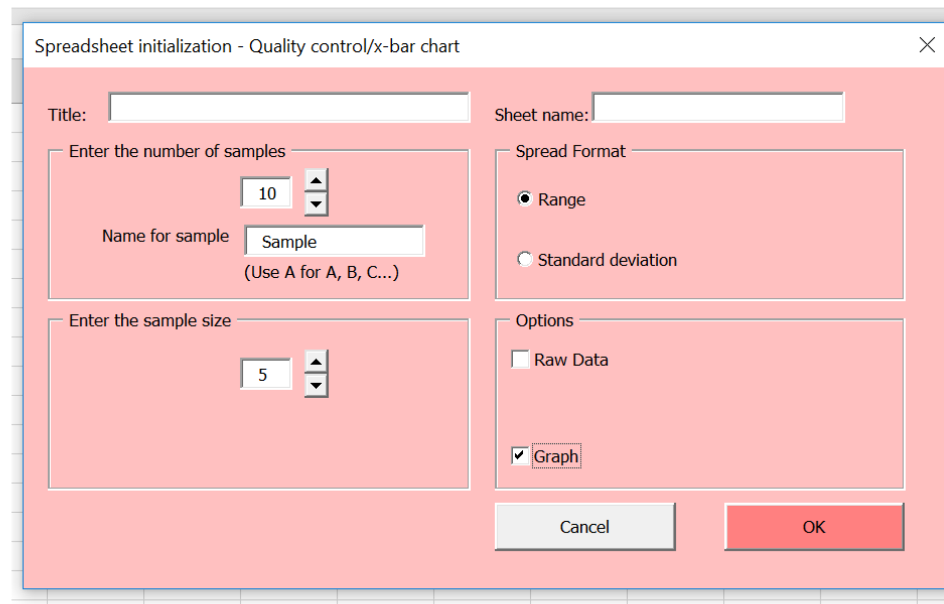
(R-chart detects increase in dispersion)

Figure S6.5

Excel OM Use



Ink Tools
File
Review
View
Excel OM
Pens
By chapter
Menus
Normal Dist Calculator
Windows Calculator
Goal Seek
Calculations
H3
Aggregate Planning
Assembly Line Balancing
Assignment
Breakeven Analysis
Capital Investment
Center of Gravity
Decision Analysis
Factor Rating
Forecasting
Inventory
Job Sequencing
Layout
Learning Curves
Linear Programming
Location
Lot Sizing
Material Requirements Planning
Productivity
Project Management
Quality Control
Reliability
Simulation
Statistics (mean, var, sd; Distributions)
Transportation
Waiting Lines
Work Measurement
Display OM Models Only
Display QM Models Only
Display All Models
p Charts
x-bar and R Charts
c Charts
Acceptance Sampling Plans
Operating Characteristic Curves
Average Outgoing Quality
Process Capability
Ready
Excel Files
OPIM 3104 - Qua



Spreadsheet initialization - Quality control/x-bar chart
Title:
Sheet name:
Enter the number of samples
10
Name for sample
Sample
(Use A for A, B, C...)
Spread Format
Range
Standard deviation
Enter the sample size
5
Options
Raw Data
Graph
Cancel
OK

Which Control Chart to Use

TABLE S6.3	Helping You Decide Which Control Chart to Use
VARIABLE DATA USING AN $\bar{x}$-CHART AND *R*-CHART	
1. Observations are ***variables***	
2. Collect 20 – 25 samples of *n* = 4, or *n* = 5, or more, each from a stable process and compute the mean for the $\bar{x}$-chart and range for the *R*-chart	
3. Track samples of *n* observations	

Examples

- Length
- Width
- Distance

Which Control Chart to Use

TABLE S6.3	Helping You Decide Which Control Chart to Use
ATTRIBUTE DATA USING A *P*-CHART	
1. Observations are ***attributes*** that can be categorized and a total number determined 2. We deal with fraction, proportion, or **percent defectives** 3. There are several samples, with many observations in each	

Examples

- Cell phones that don't work compared to those that do
- Pages in a report that have errors compared to total pages in the report

Which Control Chart to Use

TABLE S6.3	Helping You Decide Which Control Chart to Use
ATTRIBUTE DATA USING A *C*-CHART	

1. Observations are ***attributes*** whose defects per unit of output can be counted
2. We deal with the **number counted**, which is a small part of the possible occurrences
3. Defects may be: number of blemishes on a desk; flaws in a bolt of cloth; crimes in a year; broken seats in a stadium; typos in a chapter of this text; or complaints in a day

Examples

- Cracks on a cell phone screen
- Number of buttons that don't work
- Number of words per page that are wrong

Process Capability

- The natural variation of a process should be small enough to produce products that meet the standards required
- A process in statistical control does not necessarily meet the design specifications
- Process capability is a measure of the relationship between the natural variation of the process and the design specifications

Waiting-Line Models

D

MODULE

NOTE: Queue = Waiting Line

Queuing Theory

- The study of waiting lines
- Waiting lines are common situations
- Occur in
  - Manufacturing
  - Service

- This is a customer facing operation
  - Product many times judged based on waiting

Parts of a Waiting Line

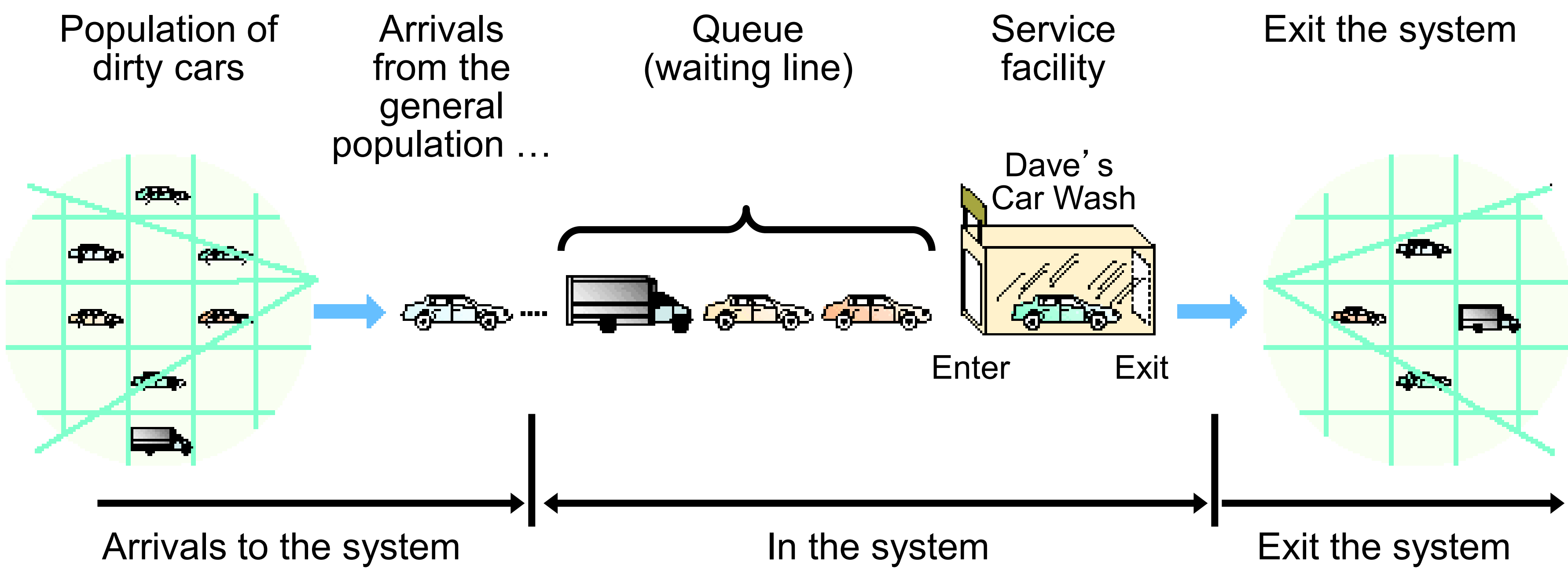


Figure D.1

Arrival Characteristics

- Size of the arrival population
  - Unlimited (infinite) or limited (finite)
- Pattern of arrivals
  - Scheduled or random, often a Poisson distribution
    - Constant and known rate independent of other events
- Behavior of arrivals
  - Wait in the queue and do not switch lines
  - No balking or reneging

Waiting-Line Characteristics

- Queue length
  - – Limited or unlimited
- Queue discipline
  - – First-in, first-out (FIFO) is most common
- Priority rules
  - – For example: Hospitals us a triage system

Service Characteristics

- Queuing system designs
  - Single-server system, multiple-server system
  - Single-phase system, multiphase system
- Service time distribution
  - Constant service time
  - Random service times
- Statistical distribution of service
  - Service rate
    - Where, when, and how much
- Service costs

Queue Performance Variables

1. Arrival rate (λ)
2. Service rate (μ)
3. Number of servers
4. Server cost ($/time)
5. Waiting cost ($/time)
   - Based on lost customers who balk or renege
6. Average server utilization (ρ)
7. Average queue length/number (L_q)
8. Average system length/number (L_s)
9. Average time in queue (W_q)
10. Average time in system (W_s)
11. Probability service facility will be idle (P_0)%
12. Cost of waiting
13. Cost of system

Calculated using ExcelOM

14. Probability of a specific number of customers in the system

= Probability of more than k units in the system, where n is the number of units in the system

$$P_{n>k} = \left[\frac{\lambda}{\mu}\right]^{k+1}$$

Queuing Models

- The four queuing models that follow all assume:

    1. Poisson distribution arrivals
    2. FIFO discipline
    3. A single-service phase

Queuing Models

MODEL	NAME	EXAMPLE	NUMBER OF SERVERS (CHANNELS)	NUMBER OF PHASES	ARRIVAL RATE PATTERN	SERVICE TIME PATTERN	POPULATION SIZE
A	Single-server system (M/M/1)	Information counter at department store	Single	Single	Poisson	Negative exponential	Unlimited
B	Multiple-server (M/M/S)	Airline ticket counter	Multi-server	Single	Poisson	Negative exponential	Unlimited
C	Constant-service (M/D/1)	Automated car wash	Single	Single	Poisson	Constant	Unlimited
D	Finite population (M/M/1 with finite source)	Shop with only a dozen machines that might break	Single	Single	Poisson	Negative exponential	Limited

- *All assume FIFO*

Model A – Single-Server

TABLE D.3		Queuing Information for Model A: Single-Server System, M/M/1
λ	=	average number of arrivals per time period
μ	=	average number of people or items served per time period (average service rate)
L_s	=	average number of units (customers) in the system (waiting and being served)
W_s	=	average time a unit spends in the system (waiting time plus service time)
L_q	=	average number of units waiting in the queue
W_q	=	average time a unit spends waiting in the queue
P	=	utilization factor for the system:
P_0	=	Probability of 0 units in the system (that is, the service unit is idle)
$P_{n>k}$	=	probability of more than *k* units in the system, where *n* is the number of units in the system

NOTE: For reference, equations can be found in the book

Single-Server Example Cost

The car mechanic has estimated the following cost data:

- Customer dissatisfaction and lost goodwill = \$15 per hr
- Mechanic's salary = \$88 per day

1. What is the cost, per day, to the mechanic for people to wait in the queue?
2. What is the total cost, per day, including servicing?

Total expected waiting costs = \$248 per day

Total system costs = \$328 per day

Multiple-Server Model

TABLE D.4	Additional Queuing Information for Model B: Multiple-Server System, also Called M/M/S
M = number of servers (channels) open	

Multiple-Server Example Cost

The car mechanic has estimated the following cost data:

- Customer dissatisfaction and lost goodwill = $15 per hr
- Mechanic's salary = $88 per day

1. What is the cost, per day, to the mechanic for people to wait in the queue?
2. What is the total cost, per day, including servicing?

Total expected waiting costs = $186 per day

Total system costs = $266 per day

Examples Comparison

Metric	One Mechanic	Two Mechanics
Server Utilization (ρ)	67%	33%
System Empty (P_0)	33%	50%
Length Queue (L_q)	1.33 cars	0.08 cars
Length system (L_s)	2.00 cars	0.75 cars
Time Queue (W_q)	40 minutes	3 minutes
Time System (W_s)	60 minutes	23 minutes
Cost Waiting	$248	$186
Cost System	$328	$266

Which model is better?

Constant-Service-Time Example

Trucks currently wait 15 minutes on average
Truck and driver cost $60 per hour
Automated compactor service rate (μ) = 12 trucks per hour
Arrival rate (λ) = 8 per hour
Compactor costs $3 per truck

Complete the table below.

Current waiting cost per trip = (1/4 hr)($60) = $15 /trip

	Constant Service
P_0	33%
L_s	1.33
W_s	10.0 min
L_q	0.67
W_q	5.0 min
System Cost	$23.00

Finite-Population Model

- Assumptions
  1. There is only one server
  2. The population of units seeking service is finite
  3. Arrivals follow a Poisson distribution
  4. Customers are served on a first-come, first-served basis

Finite-Population Example

For the previous situation, the company wants to know how much the printer servicing is costing the company per hour.

- L_s = 0.64 printers
- Alternative printing methods cost per hour = $120
- Technician cost per hour = $25

Hourly cost computed as below:

- (Units in system)(Downtime cost) + Service cost

Hourly cost = (Average number of printers down)(Cost per downtime hour) + Cost per technician hour

= (0.64)($120) + $25

= $76.80 + $25.00

= $101.80 per hour

Lean Operations

16

Lean Operations

- Supply the customer with exactly what the customer wants when the customer wants it, without waste, through continuous improvement
- Driven by "pulling" customer orders

Reduce Variability

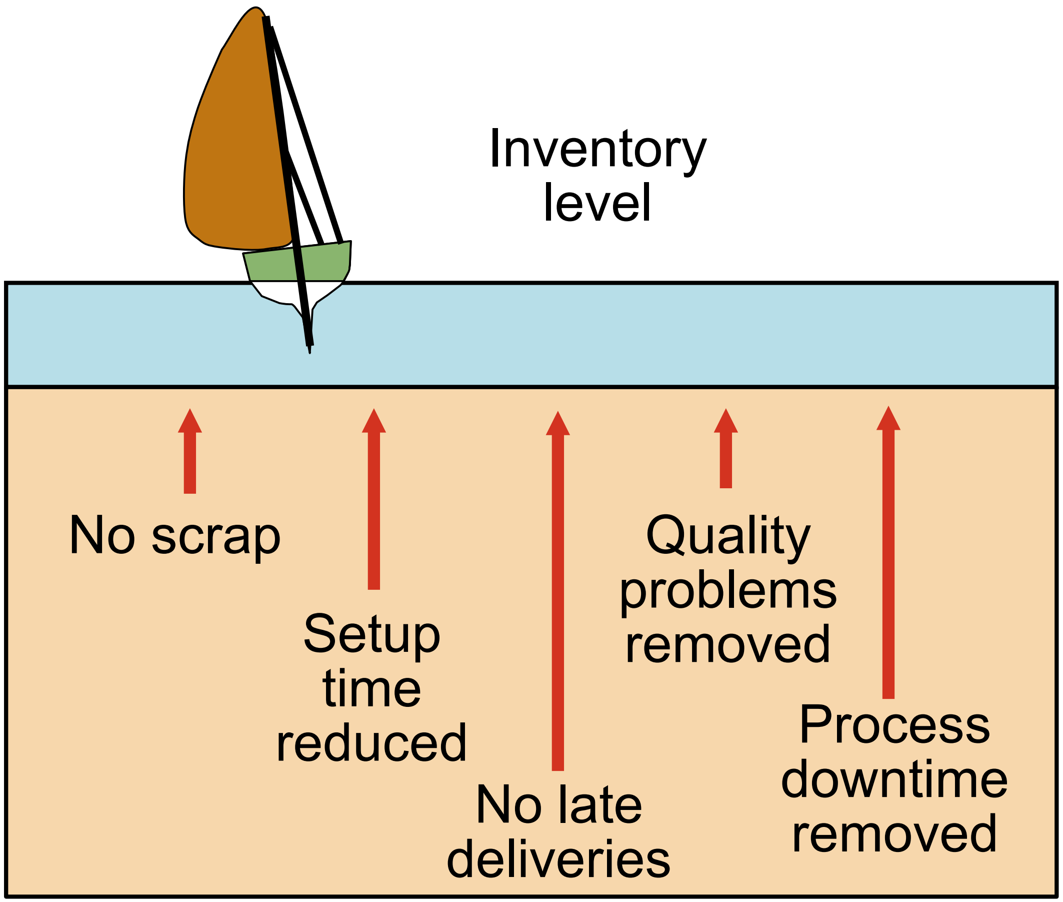
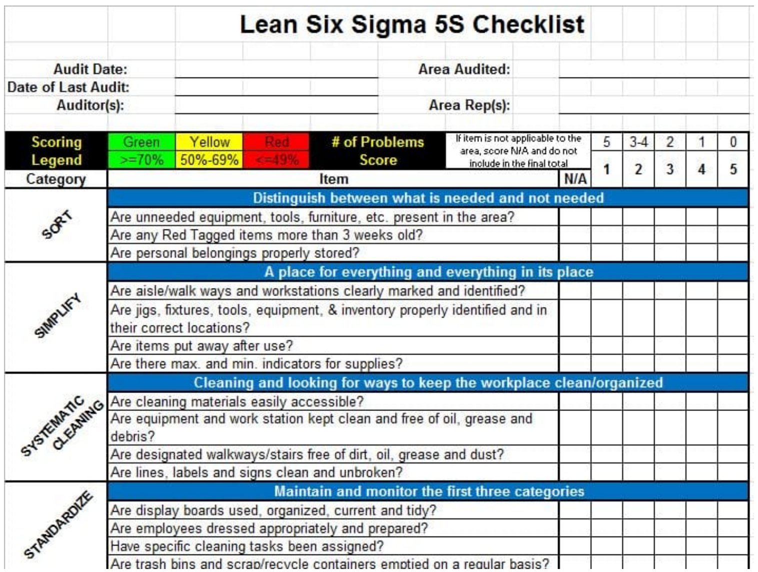


Figure 16.3

Ohno's Seven Wastes

- Overproduction
- Queues
- Transportation
- Inventory
- Motion
- Overprocessing
- Defective products

5S Charts



Lean Six Sigma 5S Checklist

Audit Date: ____ Area Audited: ____

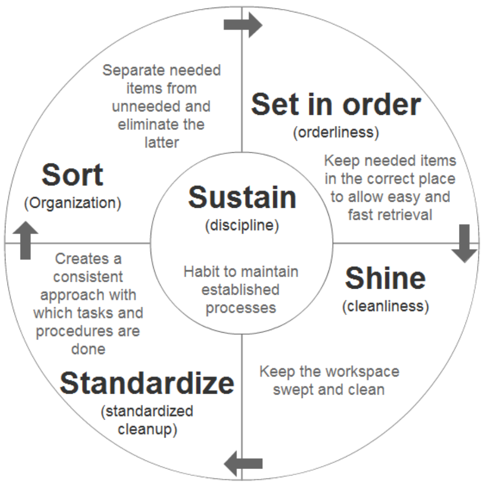
Date of Last Audit: ____

Auditor(s): ____ Area Rep(s): ____

Scoring Legend	Green >=70%	Yellow 50%-69%	Red <=49%	# of Problems Score	If item is not applicable to the area, score N/A and do not include in the final total	5	3-4	2	1	0
						1	2	3	4	5

Category	Item	N/A	1	2	3	4	5
	Distinguish between what is needed and not needed						
SORT	Are unneeded equipment, tools, furniture, etc. present in the area?						
	Are any Red Tagged items more than 3 weeks old?						
	Are personal belongings properly stored?						
	A place for everything and everything in its place						
SIMPLIFY	Are aisle/walk ways and workstations clearly marked and identified?						
	Are jigs, fixtures, tools, equipment, & inventory properly identified and in their correct locations?						
	Are items put away after use?						
	Are there max. and min. indicators for supplies?						
	Cleaning and looking for ways to keep the workplace clean/organized						
SYSTEMATIC CLEANING	Are cleaning materials easily accessible?						
	Are equipment and work station kept clean and free of oil, grease and debris?						
	Are designated walkways/stairs free of dirt, oil, grease and dust?						
	Are lines, labels and signs clean and unbroken?						
	Maintain and monitor the first three categories						
STANDARDIZE	Are display boards used, organized, current and tidy?						
	Are employees dressed appropriately and prepared?						
	Have specific cleaning tasks been assigned?						
	Are trash bins and scrap/recycle containers emptied on a regular basis?						

Kaizen 5S Framework



Lean Operations

- **Just-in-time (JIT)** focuses on continuous forced problem solving
- **Toyota Production System (TPS)** emphasizes continuous improvement, respect for people, and standard work practices in an assembly-line environment

Lean Operations

- Encompasses JIT, TPS, Kanban…
- Sustains competitive advantage and increases return to stakeholders
- Three fundamental issues
  - Eliminate waste
  - Remove variability
  - Improve throughput

Setup Time Example

D = Annual demand = 400,000 units
d = Daily demand = 400,000/250 = 1,600 per day
p = Daily production rate = 4,000 units
Q_p = EOQ desired = 400 units
H = Holding cost = $20 per unit
S = Setup cost (to be determined)
R = Hourly rate for setup personnel = $30

$$Q_p^* = \sqrt{\frac{2DS}{H\left[1-(d/p)\right]}} \qquad Q_p^2 = \frac{2DS}{H\left[1-(d/p)\right]}$$

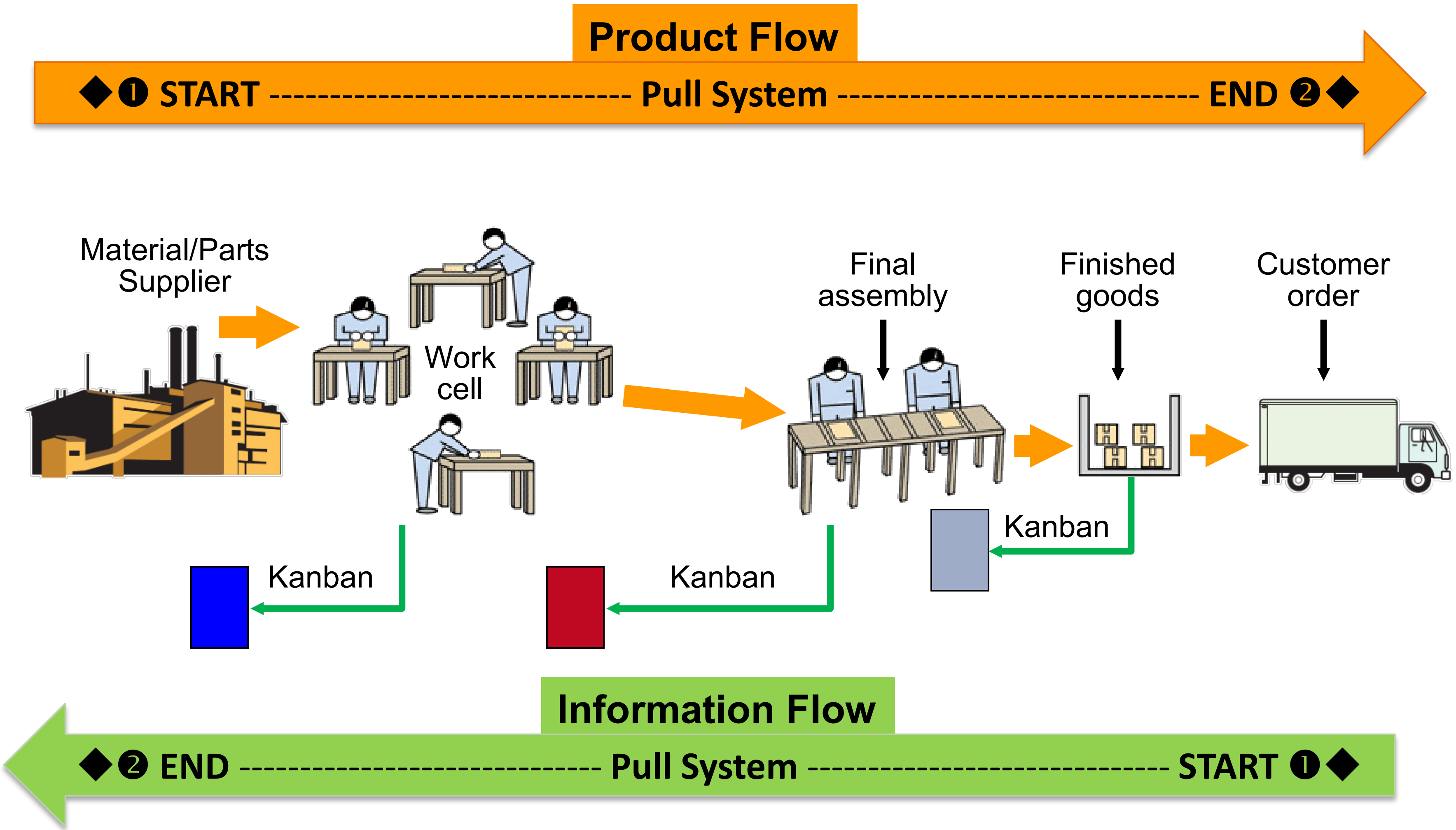
$$S = \frac{\left(Q_p^2\right)\left(H\right)\left(1-d/p\right)}{2D} = \frac{(400)^2(20)(1-1{,}600/4{,}000)}{2(400{,}000)} = \$2.40$$

Setup time = $2.40/($30/hour) = 0.08 hr = 4.8 minutes

Kanban

- Japanese word for card
- The card is an authorization for the next container of material to be produced
- A sequence of kanbans pulls material through the process
- Many different sorts of signals are used, but the system is still called a kanban

Kanban



Product Flow
◆❶ START ------------------------------ Pull System ------------------------------ END ❷◆
Material/Parts Supplier
Work cell
Final assembly
Finished goods
Customer order
Kanban
Kanban
Kanban
Information Flow
◆❷ END ------------------------------ Pull System ------------------------------ START ❶◆

The Number of Kanban Cards or Containers

- Need to know the lead time needed to produce a container of parts
- Need to know the amount of safety stock needed

$$\text{Number of kanbans (containers)} = \frac{\text{Demand during lead time} + \text{Safety stock}}{\text{Size of container}}$$

Number of Kanbans Example

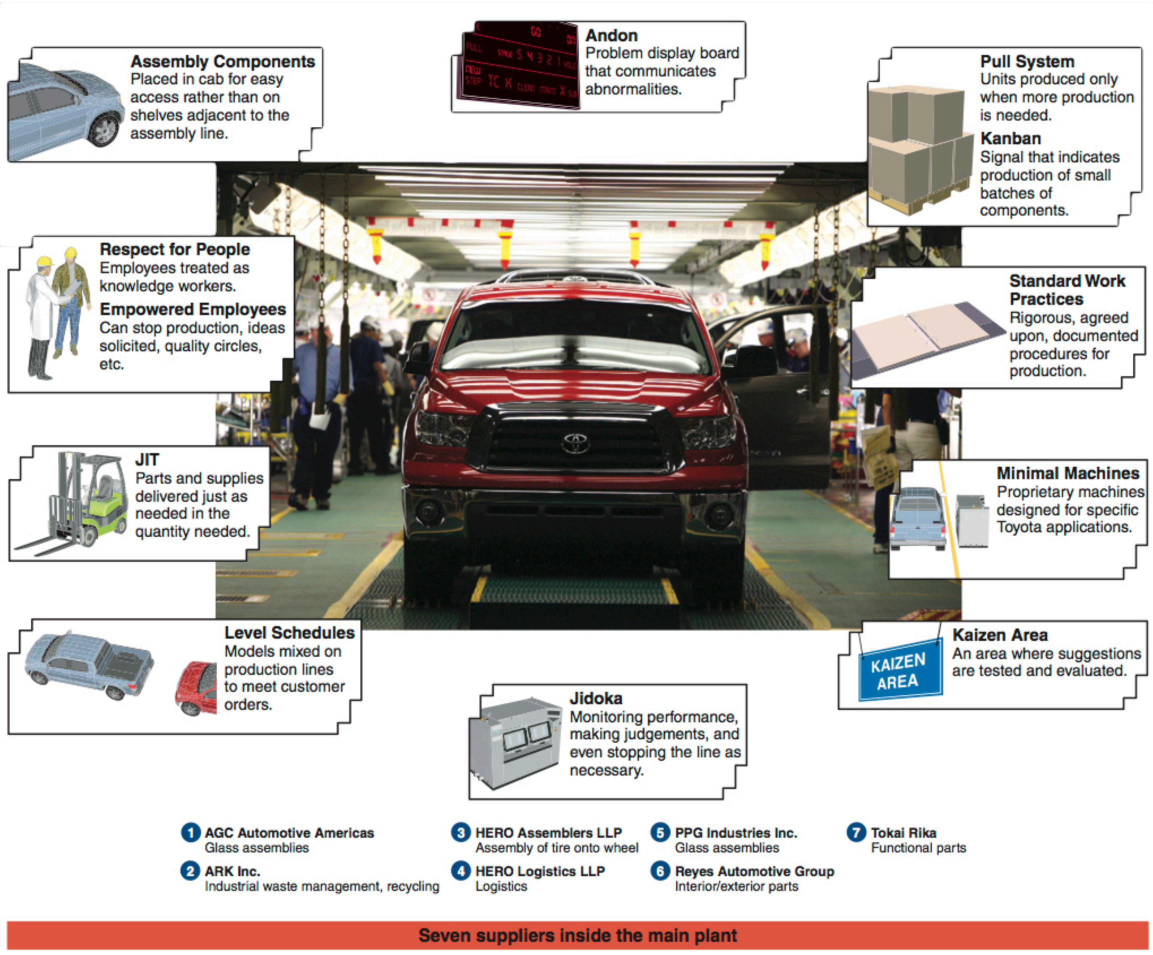
Daily demand	= 500 cakes
Production lead time (Wait time + Material handling time + Processing time)	= 2 days
Safety stock	= 1/2 day
Container size	= 250 cakes

Demand during lead time = 2 days x 500 cakes = 1,000

Safety stock = ½ x Daily demand = 250

$$\text{Number of kanbans} = \frac{1{,}000 + 250}{250} = 5$$

TPS Elements



https://www.youtube.com/watch?v=cAUXHJBB5CM

Lean in Services

- The Lean techniques used in manufacturing are used in services
  - Report generation
  - Service time
  - Staffing numbers

Process Improvement

- Lean is implemented through process improvement events
  - Goal = investigate one business or technical process or function
  - How = Many meetings
    - Map out current issues
    - Plan potential solutions
    - Implement solutions
    - Monitor progress
    - Determine if further improvement needed

Decision-Making Tools

A

MODULE

Golden Rule…

- Approximately right but not absolutely wrong

Decision Making Terms

- Alternative
  - A course of action or strategy that may be chosen by the decision maker
    - Left or Right
    - Build small or large factory
- State of nature
  - An occurrence or a situation over which the decision maker has little or no control
    - Gravity = 9.8 m/s
    - Stock market increases

Payoff Table

- Payoff table
  - Method for organizing and illustrating payoffs from different decisions given various states of nature
- Payoff
  - Outcome of a decision

	States Of Nature	
Decision	**a**	**b**
1	Payoff 1a	Payoff 1b
2	Payoff 2a	Payoff 2b

Expected Value – Bank Example

Assume for our previous example that there is a 50% chance of a decline, a 35% of stable rates, and a 15% chance of an increase

Compute the following expected values for each decision

	Interest Rates					
Projects	*Decline*		*Stable*		*Increase*	*EV*
Office park	*0.5 x 0.5*	*+*	*1.7 x 0.35*	*+*	*4.5 x 0.15*	*= 1.52*
Office Bldg	*1.5*		*1.9*		*2.4*	*1.78*
Warehouse	*1.7*		*1.4*		*1.0*	*1.49*
Shop. Ctr.	*0.7*		*2.4*		*3.6*	*1.73*
Condos	*3.2*		*1.5*		*0.6*	*2.22*

Using these probabilities we would select Condos

ExcelOM – Expected Value

- Enter the previous problem into ExcelOM

Decision Tables

Data

Profit	Decline	Stable	Increase		EMV	Minimum	Maximum
Probability	0.5	0.35	0.15				
Office Park	0.5	1.7	4.5		1.52	0.5	4.5
Office Bldg	1.5	1.9	2.4		1.78	1.5	2.4
Warehouse	1.7	1.4	1.0		1.49	1	1.7
Shop. Ctr.	0.7	2.4	3.6		1.73	0.7	3.6
Condos	3.2	1.5	0.6		2.22	0.6	3.2
				Maximum	**2.22**	**1.5**	**4.5**

(Results: EMV, Minimum, Maximum)

Expected Value of Perfect Information

EVPI is the difference between the payoff under certainty and the payoff under risk

EVPI = Expected value with perfect information – Maximum EMV

Expected value *with* perfect information (EVwPI) = (Best outcome or consequence for 1st state of nature) x (Probability of 1st state of nature)

+ Best outcome for 2nd state of nature)

x (Probability of 2nd state of nature)

+ … + Best outcome for last state of nature)

x (Probability of last state of nature)

ExcelOM – Expected Value

- Enter the previous problem into ExcelOM

Data					Results				
Profit	**Decline**	**Stable**	**Increase**		**EMV**	**Minimum**	**Maximum**		
Probability	0.5	0.35	0.15						
Office Park	0.5	1.7	4.5		1.52	0.5	4.5		
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Shop. Ctr.	0.7	2.4	3.6		1.73	0.7	3.6		
Condos	3.2	1.5	0.6		2.22	0.6	3.2		
				Maximum	**2.22**	**1.5**	**4.5**		
Expected Value of Perfect Information									
Column best	3.2	2.4	4.5		**3.12**	**<-Expected value WITH perfect information**			
					2.22	**<-Best expected value**			
					0.9	**<-Expected value OF perfect information**			

**Corrected from video*

Decision Trees

- Information in decision tables can be displayed as decision trees
- A decision tree is a graphic display of the decision process that indicates decision alternatives, states of nature and their respective probabilities, and payoffs for each combination of decision alternative and state of nature
- Appropriate for showing sequential decisions

Decision Tree Example

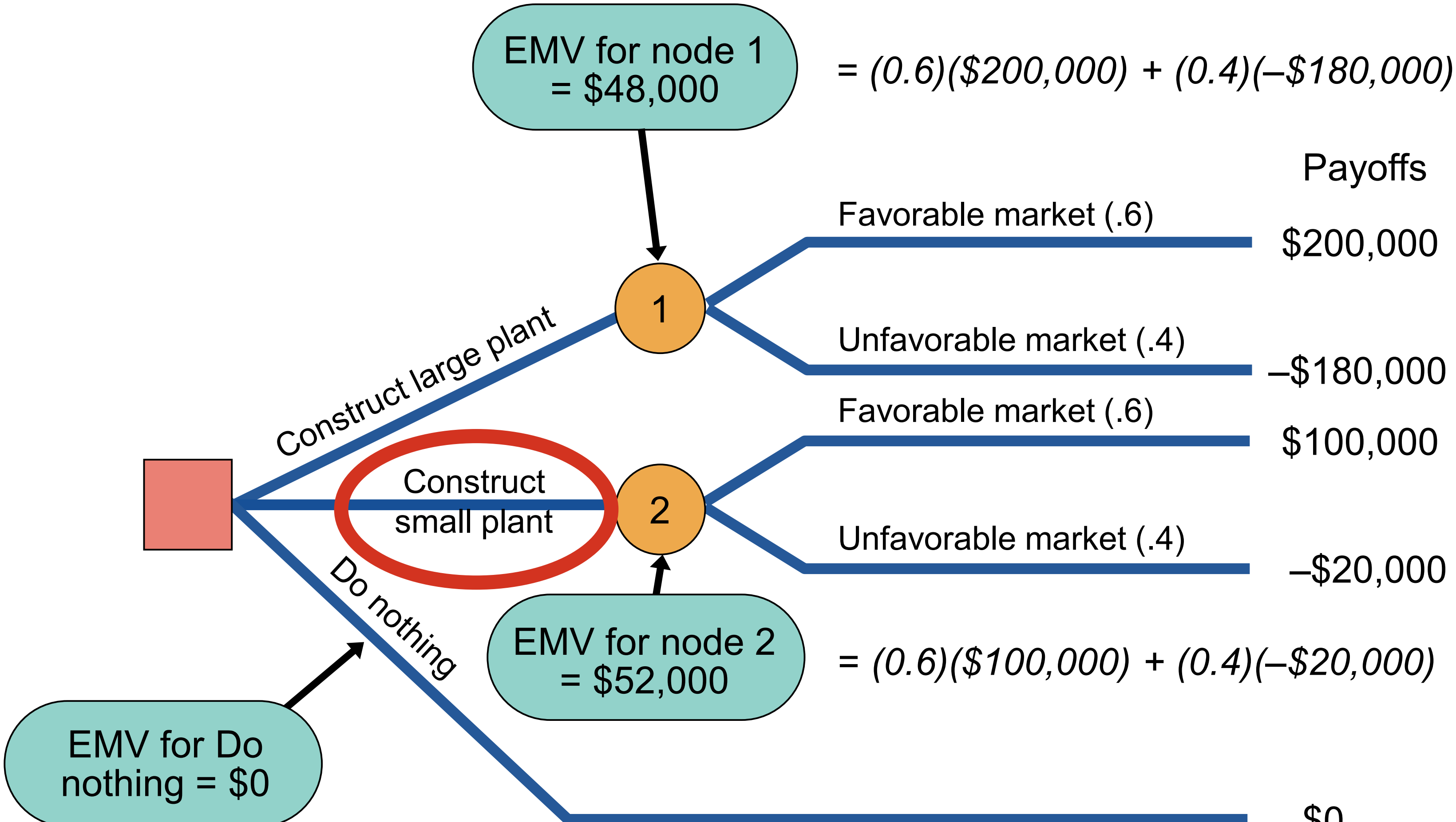


Figure A.2

Moving Averages

- MA is a series of arithmetic means
- Used if little or no trend
- Used often for smoothing
  - Provides overall impression of data over time
- 3 month moving average is common
  - Average the previous 3 months

$$\text{Moving average} = \frac{\sum \text{demand in previous } n \text{ periods}}{n}$$

Moving Average Forecast

- A product your factory produces has the following historical demand
  - What is the three month moving average for November?
  - Use ExcelOM

November = 110 units

Month	Demand
January	120
February	90
March	100
April	75
May	110
June	50
July	75
August	130
September	110
October	90

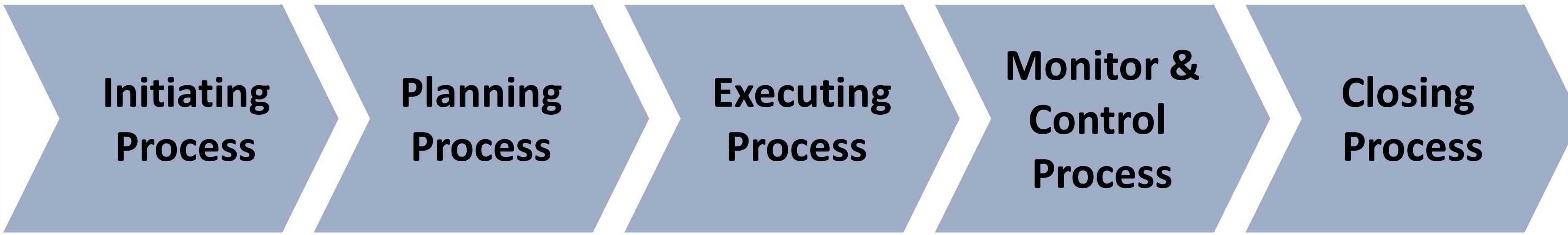
Project Management

3

Definition of a Project

- A project is a temporary endeavor undertaken to create a unique product, service, or result

Process Groups



Initiating – Defines / authorizes the project or project phase

Planning – Defines / refines objectives, plans course of action required to attain the objectives / scope that the project was undertaken to address

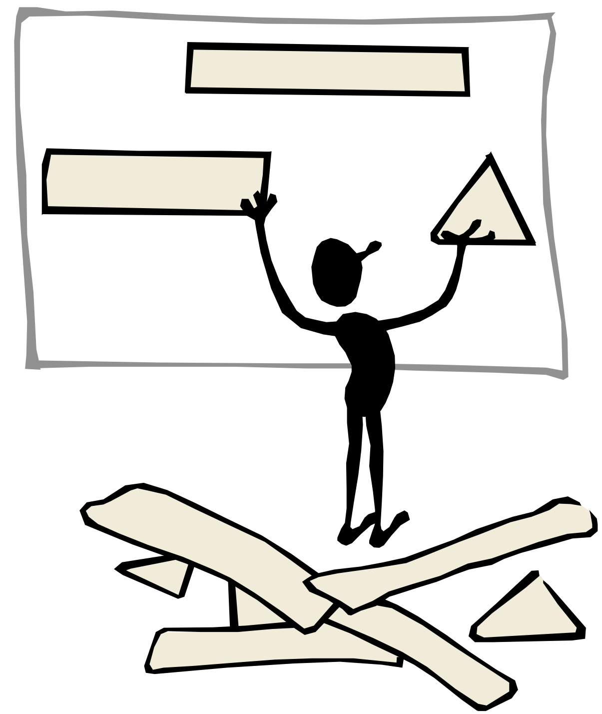
Executing – Integrates people and other resources to carry out the project management plan for the project.

Monitor & Controlling – Regularly measures and monitors progress, identifies variances so corrective action can be taken

Closing – Formalizes acceptance of the product, service or result and brings the project to an orderly end.

Characteristics of Projects

- The 3 Key Characteristics
  - Time
  - Budget
  - Scope



Operational Definition

- An operational definition is a description of something—such as a variable, term, or object—in terms of the specific process or set of validation tests used to determine its presence and quantity. Properties described in this manner must be publicly accessible so that persons other than the definer can independently measure or test for them at will. An operational definition is generally designed to model a conceptual definition.*
  – Consider the different temperature units (F, C, R, K)

PM's First Job

- Understand the **expectations** that the organization has for the project
- Ensure **stakeholder** needs are met
- Determine **budget/resources** needed
  - Budget
  - People
  - Equipment
- Identify who among **senior managers** has a major interest in the project
- Determine if anything about the project is **atypical**

Priority Matrix

	High	Medium	Low
Scope			
Time			
Cost			

- Goal, one *high,* one *medium*, one *low*
- Engage in the discussion early
- Better to have the understanding at the start
- Overdetermined?

Operations vs Project Management

Attribute	Operation Management	Project Management
Time	On-going	Temporary
Budget	Predictable/Established	Per scope statement
Scope	Relatively defined	Complex, changing
Tasks	Repetitive/Cyclical	Unique
Staff	Stable	Established at project start
Definition of Success	Keep status quo	Delivery of scope
Leadership style	Manager	Leader (disruptive)
Impact on Company	Regular revenue supports need	Find funding and justify
Organization	Functional	Usually cross-functional

Calculating Activity Times

TE = Time Expected

$$TE = \frac{(1 \times Op) + (4 \times ML) + (1 \times P)}{(1 + 4 + 1)}$$

Activity	*Optimistic Time*	*Most Likely Time*	*Pessimistic Time*
a	10	22	22
b	20	20	20
c	4	10	16
d	2	14	32
e	8	8	20
f	8	14	20
g	4	4	4
h	2	12	16
i	6	16	38
j	2	8	14

Earned Value Analysis

- **Industry standard** way to
  - Measure a project's progress
  - Forecast its completion date and final cost
  - Provide schedule and budget variances along the way
- It's been around since the sixties.
  - "Cost/Schedule Control Systems Criteria" (C/SCSC)
- By integrating three measurements, EVA provides consistent, numerical indicators with which you can evaluate and compare projects.

EVA Integrates All Three

- **EVA compares the PLANNED amount of work with what has actually been COMPLETED, to determine if *COST* , *SCHEDULE, and WORK ACCOMPLISHED* are progressing as planned.**
- Work is “Earned” or credited as it is completed
- Different methods to determine % complete
  - 0% or 100%
  - 0%, 50% or 100%
  - 25%, 50%, 75%, 90% ...

Definitions & TLA’s

- AC: Actual Cost
- PV: Planned Value
- BAC: Budget at Completion
- EV: Earned Value (value completed) percent completion of work * planned cost
- SV: Schedule Variance = EV - PV
- CV: Cost Variance = EV – AC
- SPI: Schedule Performance Index = EV / PV
- CPI: Cost Performance Index = EV / AC

EVA Example

- A $10,000 software project is scheduled for 4 weeks.
- At the end of the third week, the project is 50% complete and the actual costs to date is $9,000
- Calculate BAC, PV, EV, and AC

  - Budget at Completion (BAC) = $10,000
  - Actual Cost (AC) = $9,000
  - Planned Value (PV) = $7,500
  - Earned Value (EV) = $5,000

Variances

- **Variances can help analyze a project**
  - A negative variance is bad
  - Cost and schedule variances are calculated as the earned value minus some other measure
- Will look at some of the more common ones

EVA Example Calculations

- Schedule Variance

  = EV – PV = \$5,000 – \$7,500 = - \$2,500
- Schedule Performance Index (SPI)

  = EV/PV = \$5,000 / \$7,500 = 0.67
- Cost Variance

  = EV – AC = \$5,000 - \$9,000 = - \$4,000
- Cost Performance Index (CPI)

  = EV/AC = \$5,000 / \$9,000 = 0.56

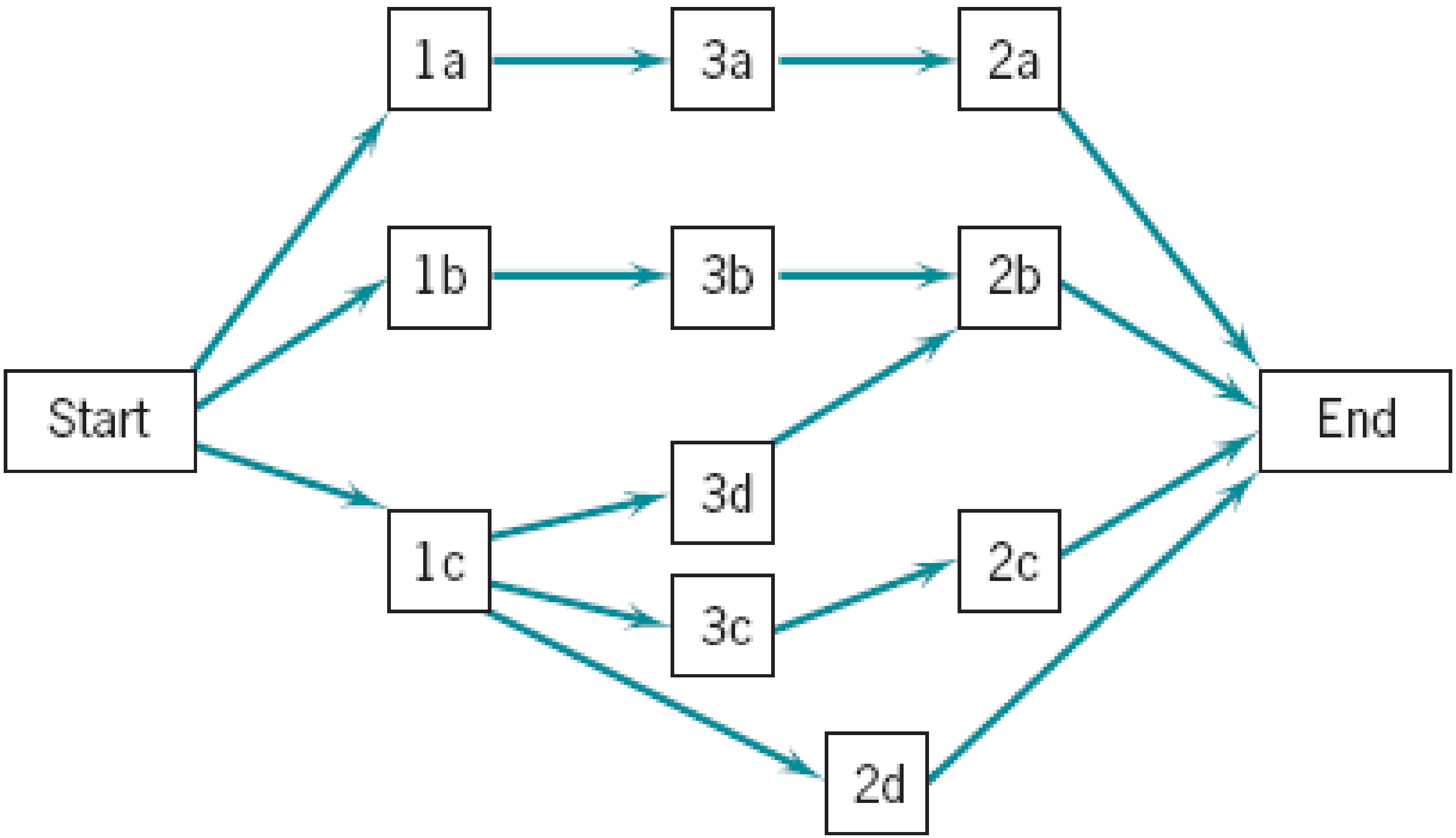
- Objective metrics indicate the project is behind schedule and over budget.
  - On-target projects have an SPI and CPI of 1 or greater

Shortcomings of Earned Value

- **Quantifying/measuring work progress can be difficult!!!!!!!!!!!!!!!!!!!!**

- Time required for data measurement, input, and manipulation can be considerable.

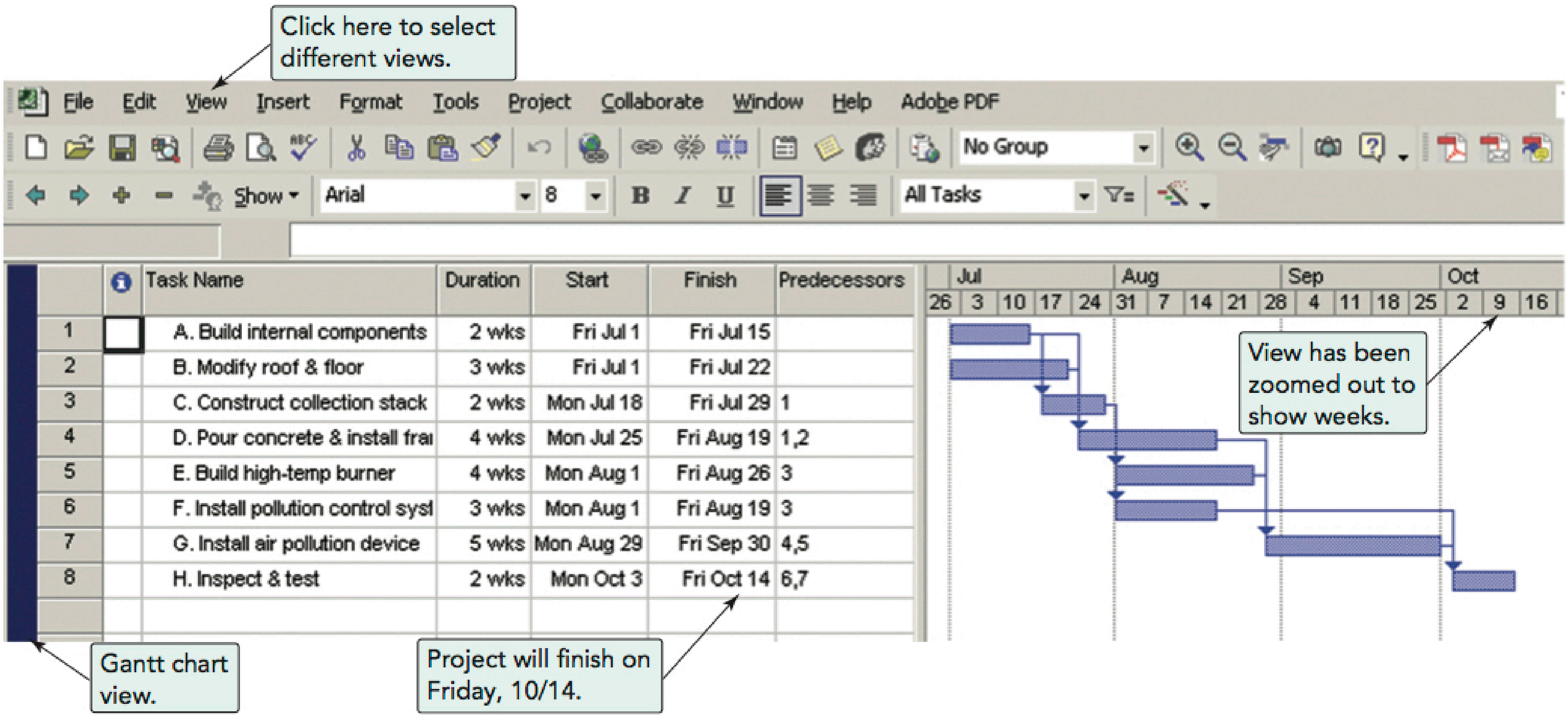
Network Diagram Format



Perform a Critical Path Analysis

- The critical path is the longest path through the network
- The critical path is the shortest time in which the project can be completed
- Any delay in critical path activities delays the project
- Critical path activities have no slack time

Using Microsoft Project



Project Plan

- Maps the project start to finish
- “Contains sufficient information that, at any time, the PM knows what remains to be done, when it needs dones, with what resource, by whom, when the task will be completed, and what specifications the output should meet.”1
- Organized by the PMI process groups with relevant knowledge areas discussed
- More detailed than the project charter

Applying Analytics to Big Data in Operations Management

MODULE G

Introduction to Big Data

- Big Data
  - The huge amount of production, consumer, and social media data collected in digital form
- Business Analytics
  - Uses tools and techniques to convert data into summary information and business insights for decision making
- Data Challenges
  - Gather the *right* data
  - *Apply* the best tools

Types of Analytics

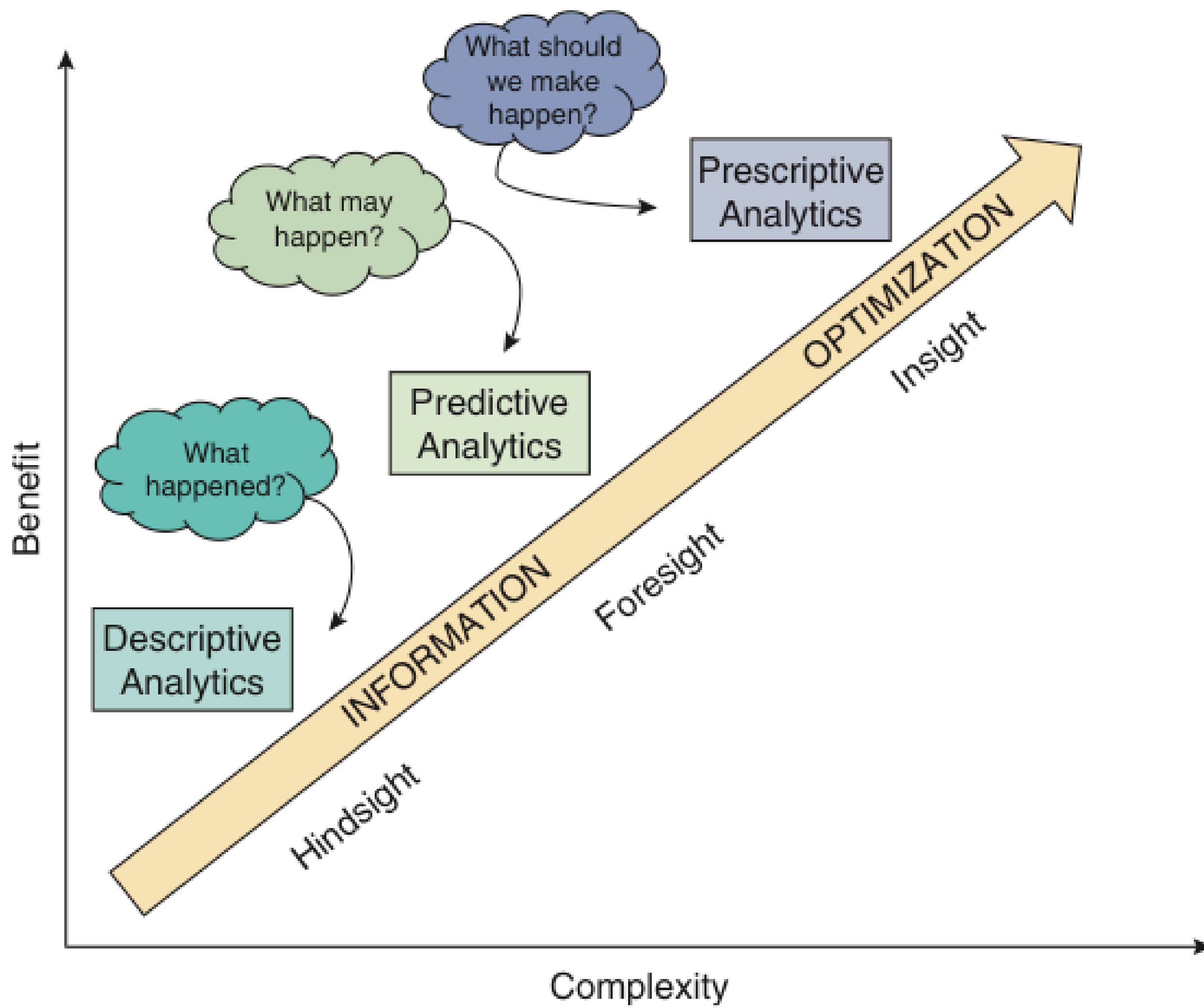
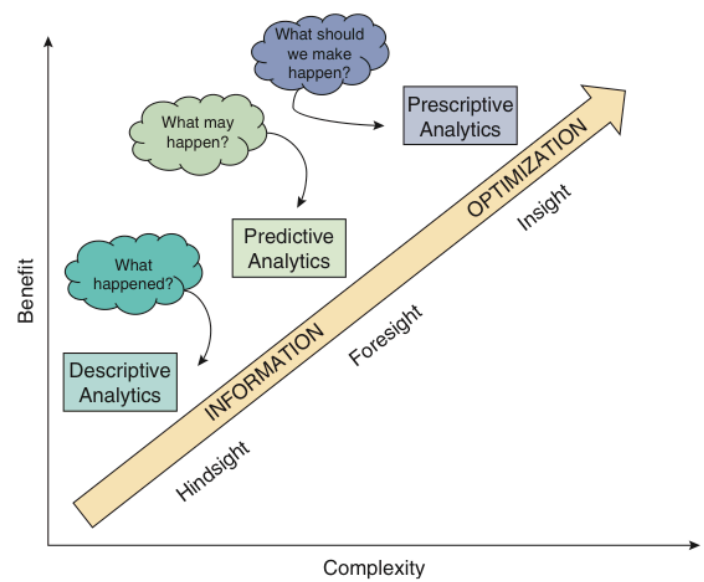


Figure G.1

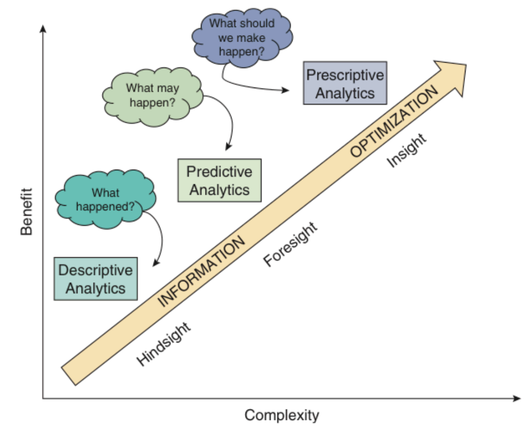
Data Management – Descriptive

1. *Completeness*: the degree to which all required data are present
2. *Consistency*: the degree to which data are equivalent across systems
3. *Accuracy*: The degree of conformity of a measure to a standard value



Data Visualization – Descriptive

- Data
  - Is a snapshot in time
  - Collection of “things”
    - Numbers, categories, colors, etc…
  - Foundation of every visualization



- Visualization
  - Helps show what otherwise would not be obvious
  - Nonlinear, iterative process to develop
  - Tells a story
  - Creative process
    - Changes for each dataset

Main Point

Basic Data Visualization

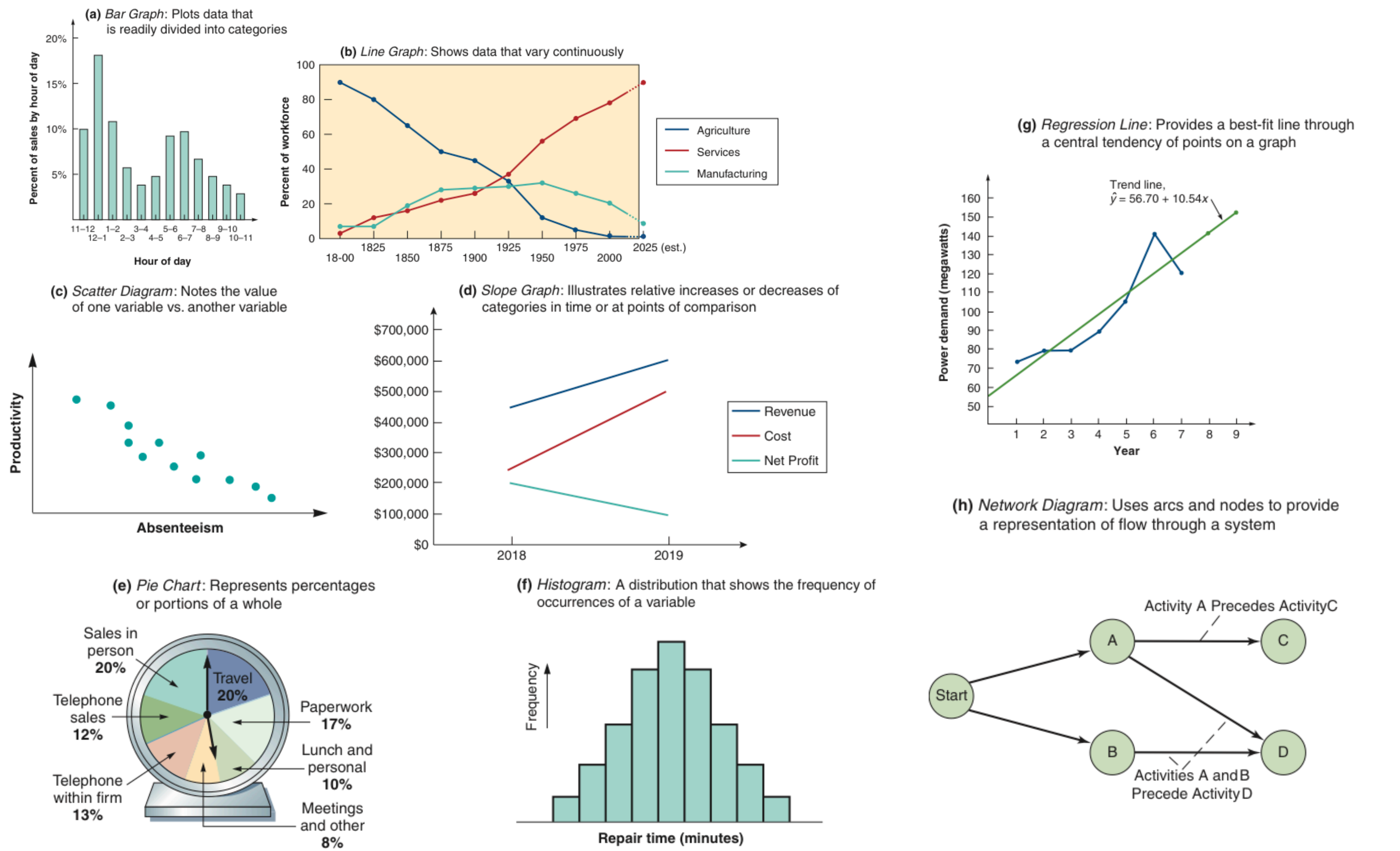


Figure G.7

Data Visualization

- Graphing Tips
  - Graphs should be self-explanatory
  - Ensure that multiple datasets on the same graph each have a key or legend
  - Do not overwhelm the viewer with too much data in a figure
  - Avoid 3-dimensional graphics
- Dashboards present an overview of important metrics

Common Tool – Tableau

- What is Tableau?
  - More sophisticated than Excel
  - More of a graphical interface (DOS vs Windows operating system)
- Used by United Nations for their visualizations
  - https://www.tableau.com/account/united-nations
- Go to Tableau's Visualization of the Day for ideas
  - https://public.tableau.com/en-us/gallery/?tab=viz-of-the-day&type=viz-of-the-day
- Try for free for 15 days
  - https://www.tableau.com/products/desktop/download
- Free training videos
  - Used extensively for this course
  - https://www.tableau.com/learn/training/20201

Let the Data Talk

- **Remember…It is not about what you want to see…it is about the story that the data tells.**
  - "The greatest value of a picture is when it forces us to notice what we never expected to see."
    - John W. Tukey, Exploratory Data Analysis (1977)

Predictive and Prescriptive Analytics

- Mapping and tracking
  - Sensors or video
  - Part or product movement
  - Customer movements
- Cohort analysis
  - Behavior of groups over time
- Cluster analysis
  - Identifies and organizes data into groups with similar attributes

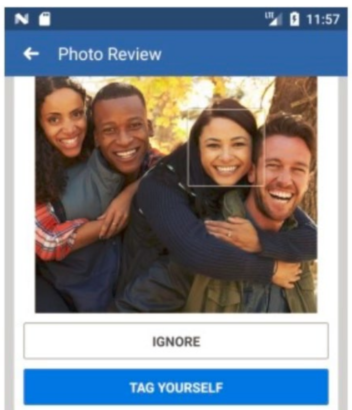
Neural Networks & Machine Learning

- Computer systems take large volumes of data and potential variables to form groupings of variables to identify complex associations
- Machine learning provides a vehicle to sift through vast amounts of data to provide insight

- *Slides based on*
  - *Charikar, Ma, Re, Stanford CS229: Machine Learning,*
  - *Eaton, UPenn, CIS 519, Introduction to Machine Learning*
  - *Balcan, CMU, CS 10-401, Machine Learning*
  - *Russell, UC Berkeley CS 194: Introduction to Machine Learning*
  - *Silver, UCL, COMPM050: Reinforcement Learning*
  - *Spiess, Stanford GSB, Applied Machine Learning: intro*

Examples of Supervised Learning

Face Detection and Recognition

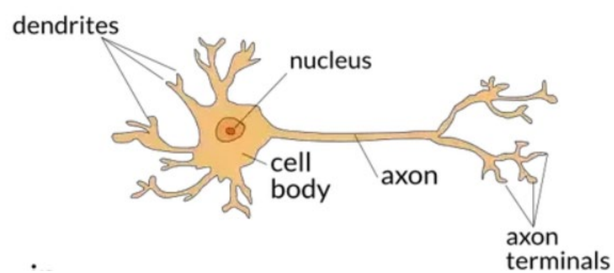


Automatic Speech Recognition

Figure credit: Facial recognition: It’s time for action, Microsoft

Biological Neural Networks

- Brain: very complex network/web of interconnected neurons
  - Consists of 10^{11} neurons of >20 types,
  - Signals are noisy electrical potentials
- Highly connected to others, and performs computations by combining signals from other neurons
- Outputs of these computations may be transmitted to one or more other neurons.



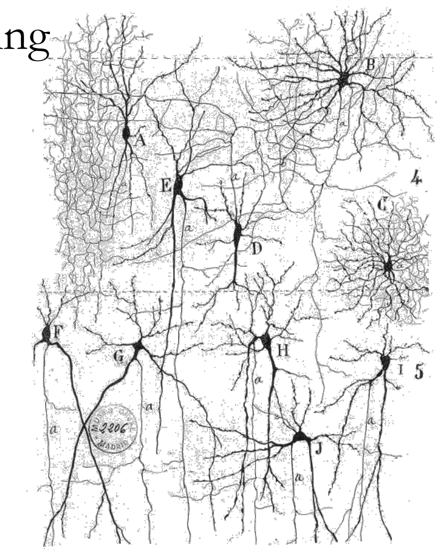


Figure credit: Wikipedia Neural Circuit

Artificial Neural Networks

- Artificial Neural Networks built out of a densely interconnected set of simple units
  - Oversimplification of real neurons, but its purpose is to develop understanding of what networks of simple units can do

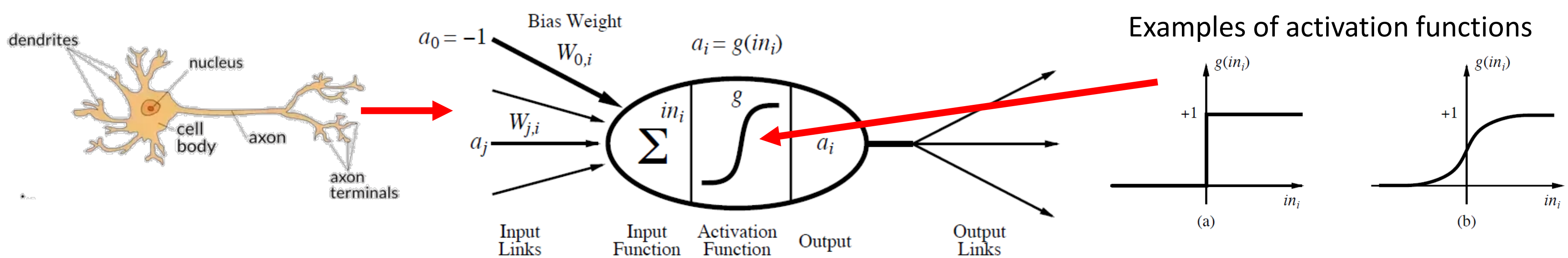


Figure credit: The differences between Artificial and Biological Neural Networks, Towards Data Science