# Chapter 3 - Product and Process Design

**Fundamentals of Operations Management**

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# Learning Objectives

- Define product design and explain its strategic impact on organizations
- Describe steps to develop a product design
- Using break-even analysis as a tool in selecting between alternative products
- Identify different types of processes and explain their characteristics

# Learning Objectives – con't

- Understand how to use a process flowchart
- Understand how to use process performance metrics
- Understand current technology advancements and how they impact process and product design
- Understand issues impacting the design of service operations

# Product & Process Design - Introduction

**Product design** – the process of defining all of the companies product characteristics.

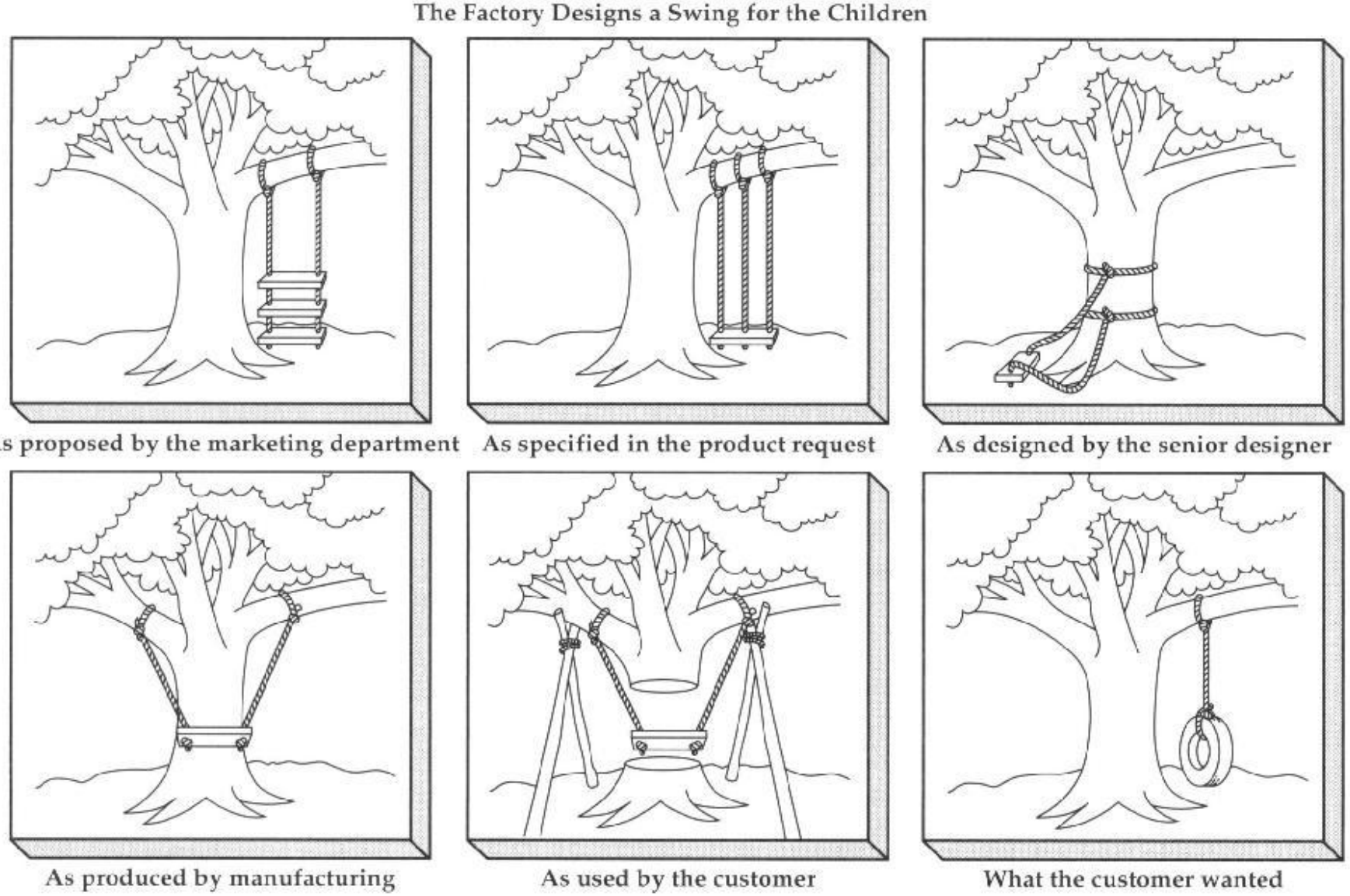
- Product design must support product manufacturability (the ease with which a product can be made)
- Product design defines a product's characteristics of:

•appearance,
•materials,
•dimensions,
•tolerances, and
•performance standards.

Process Design – the development of the process necessary to produce the designed product.

**FIGURE 3.1**

*Lack of cooperation in designing a swing.*



# Design of Services versus Goods

- Service design is unique in that the service and entire service concept are being designed
  - must define both the service and concept
    - Physical elements, aesthetic & psychological benefits
      - e.g. promptness, friendliness, ambiance
  - Product and service design must match the needs and preferences of the targeted customer group

# What is a good design?

- Product Selection: qualities of a well-designed product
  - Useful – satisfies customer's expectations/wants/needs
  - Desirable – aesthetically appealing
  - Producible – easy and economical to manufacture
  - Profitable – generates profit
  - Differentiable – unique and different from rival products

# The Product Design Process

Step 1 - Idea Development - Someone thinks of a need and a product/service design to satisfy the need: customers, marketing, engineering, competitors, benchmarking, reverse engineering, etc. help in idea development.

Step 2 - Product Screening - Every business needs a formal/structured evaluation process: fit with facility and labor skills, size of market, contribution margin, break-even analysis, return on sales

Step 3 – Preliminary Design and Testing - Technical specifications are developed, prototypes built, testing starts

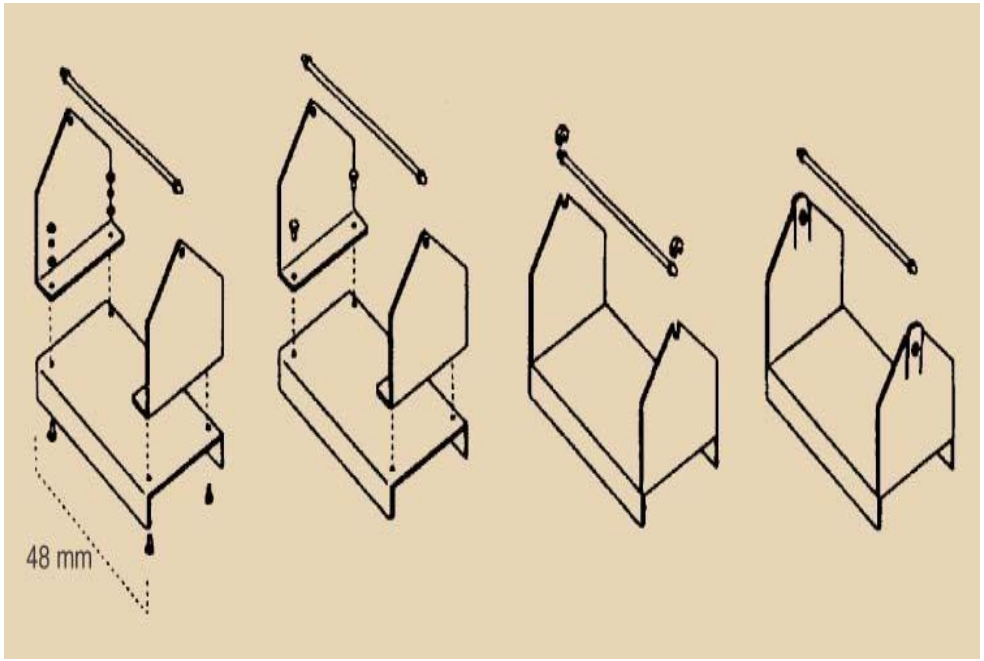
Step 4 – Final Design - Final design based on test results, facility, equipment, material, & labor skills defined, suppliers identified

# Objectives of Product Design

- Satisfying customers' needs and wants
- Enhancing existing products to increase value or utility
- Ensuring quality through better designs
- Minimising costs
- Simplifying product
- Improving usability, reliability, functionality, aesthetics, etc.

# Factors Impacting Product Design

- Must **Design for Manufacturing** – **DFM**
- **Guidelines to produce a product easily and profitably**
  - **Simplification - Minimize parts**
  - **Standardization -Design parts for multiple applications**
  - **Use modular design**
  - **Simplify operations**



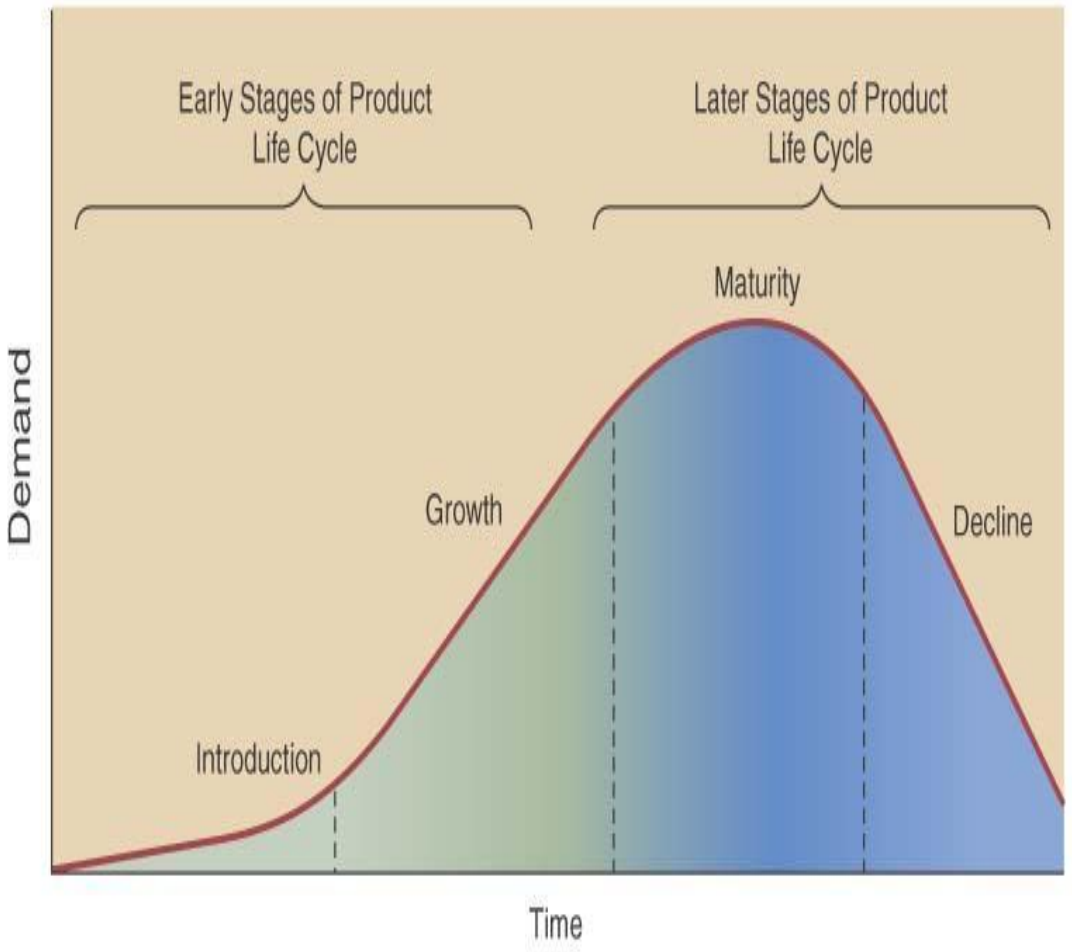
# Product Selection

Product selection strategy involves considering:

- investment required
- market share
- product life cycle
- and product lines (products that are compatible)
- competitive advantage

# Product Life Cycle

- **Product life cycle – series of changing product demand**
- **Consider product life cycle stages**
  - **Introduction**
  - **Growth**
  - **Maturity**
  - **Decline**
- **Facility & process investment depends on life cycle**



# Generating New Products

Products have a limited life-cycle and they die after a certain time. Therefore firms, look for **new product opportunities**.

New Opportunities Emerge due to:

- Change in customer's preference
- Economic change
- social and demographic change
- technological change
- Political/Legal changes

# Product Development

Product Development System

- Needs Identification
- Advance Product Planning (Feasibility Study)
- Advance Design
- Detailed engineering design
- Production Process Design and Development
- Product Evaluation and Improvement
- Product Use and Support

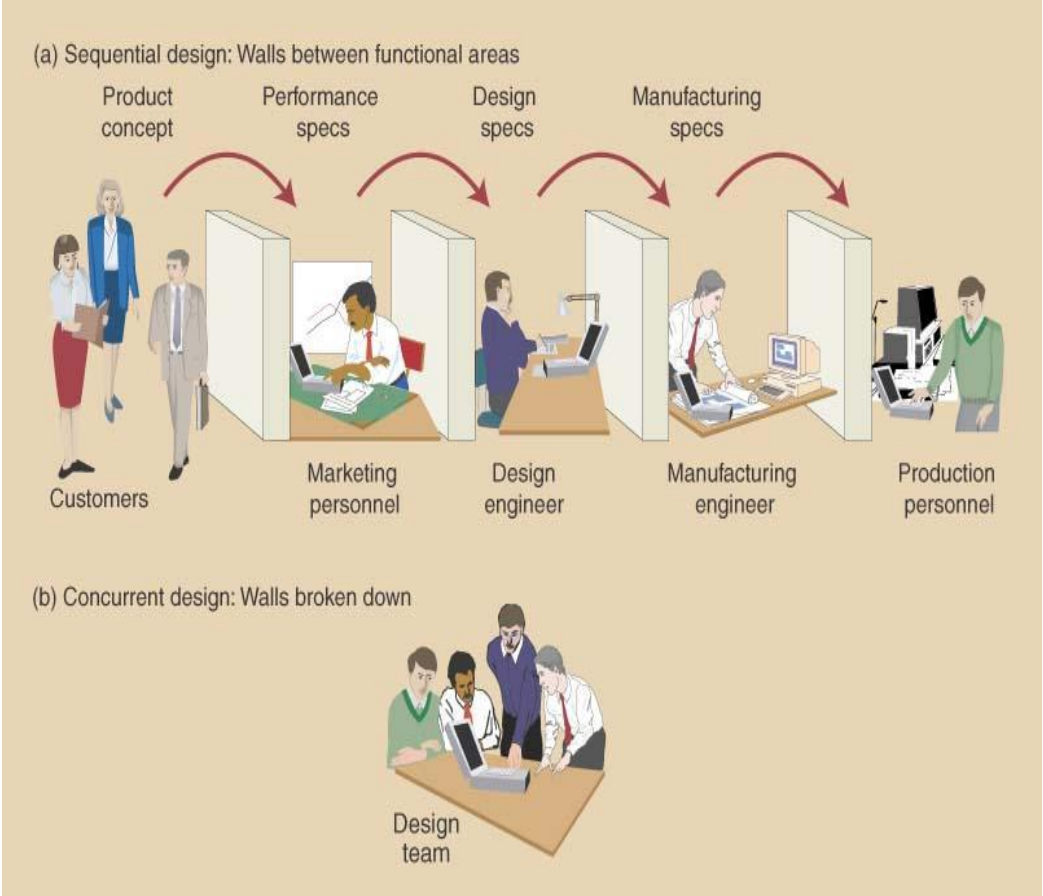
# Concurrent Engineering

**Old "over-the-wall" sequential design process should not be used**

- Each function did its work and passed it to the next function

**Replace with a Concurrent Engineering process**

- All functions form a design team that develops specifications, involves customers early, solves potential problems, reduces costs, & shortens time to market



# Remanufacturing

Uses components of old products in the production of new ones and has:

- Environmental benefits
- Cost benefits

Good for:

- Computers, televisions, automobiles

# Issues for Product Design

- Robust design – small change in production or assembly do not affect the product. The product performs well in a variety of environmental conditions. Example: sports shoes, umbrella, etc
- Modular Design – component parts are grouped into modules for easy replacement or interchange. E.g., computers, cars, bikes

# Issues for Product Design

- Computer-Aided Design – CAD uses three dimension drawing to design a product.
- Computer-Aided Manufacturing – Specialised computer programs used to control the manufacturing process.

# Issues for Product Design

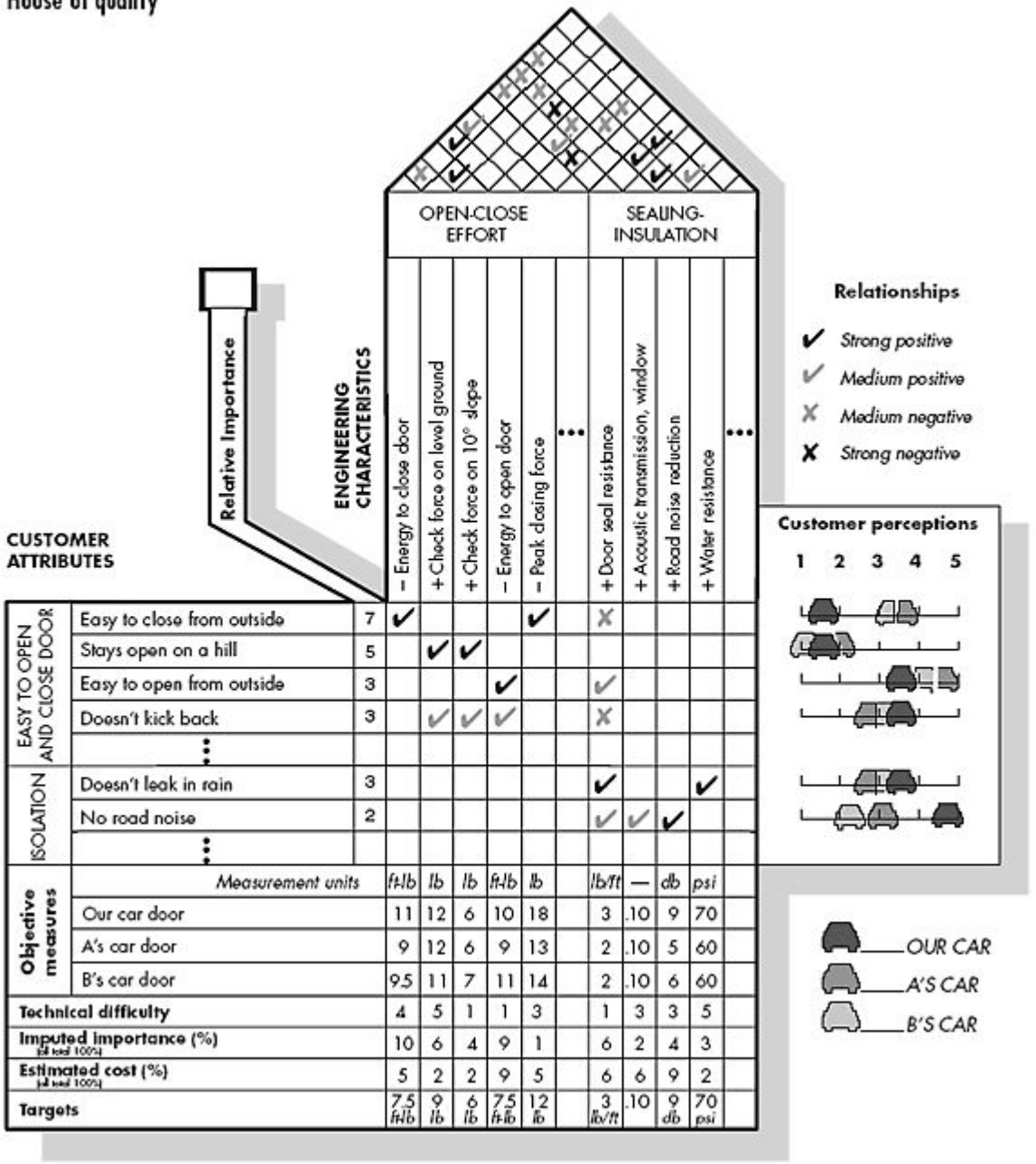
- Ethics and Environmentally Friendly Design – Products are designed by considering highly ethical standards and environment-friendly raw-materials to promote sustainability
- Global Product Design – Designers from different countries collaborate to design a product through use of IT.

# Quality Function Deployment (QFD)

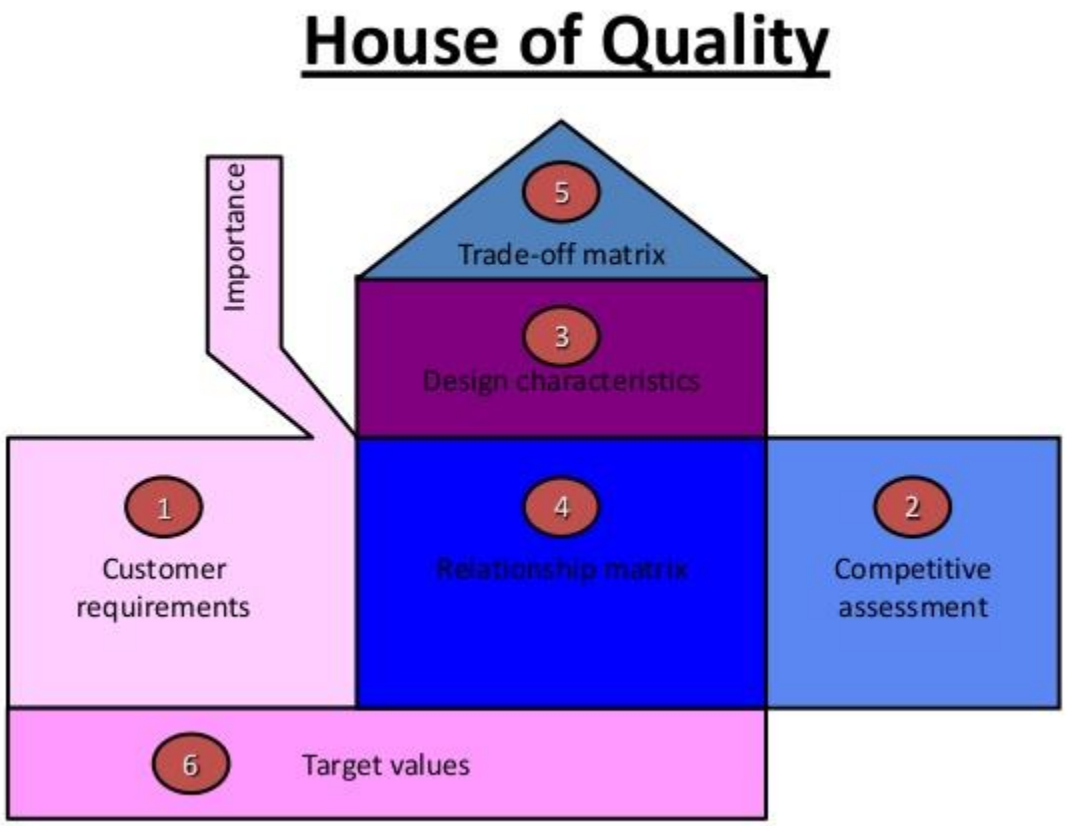
## House of Quality Matrix

EXHIBIT X

House of quality



# House of Quality (Simplified)

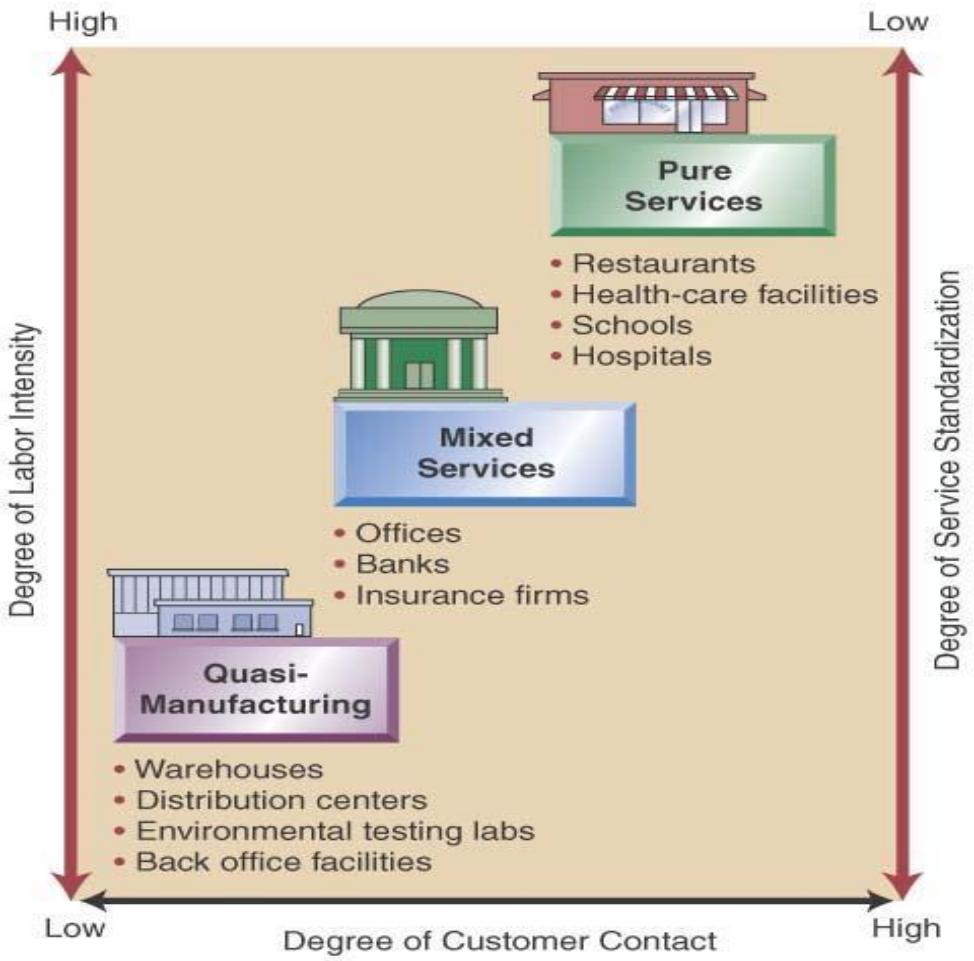


# Designing Services: How do they Differ from Manufacturing?

- Service is an act - something that is done to or for a customer
- Services are different from manufacturing as they;
  - Produce intangible products
  - Difficult to describe
  - Involve a high degree of customer contact
- Services are classified based upon degree of customer contact

# Designing Services

- **Service Characteristics**
  - Pure services
  - Quasi-Manufacturing
  - Mixed services
- **Service Package**
  - The physical goods
  - The sensual benefits
  - The psychological benefits
- **Differing designs**
  - Substitute technology for people
  - Get customer involved
  - High customer attention



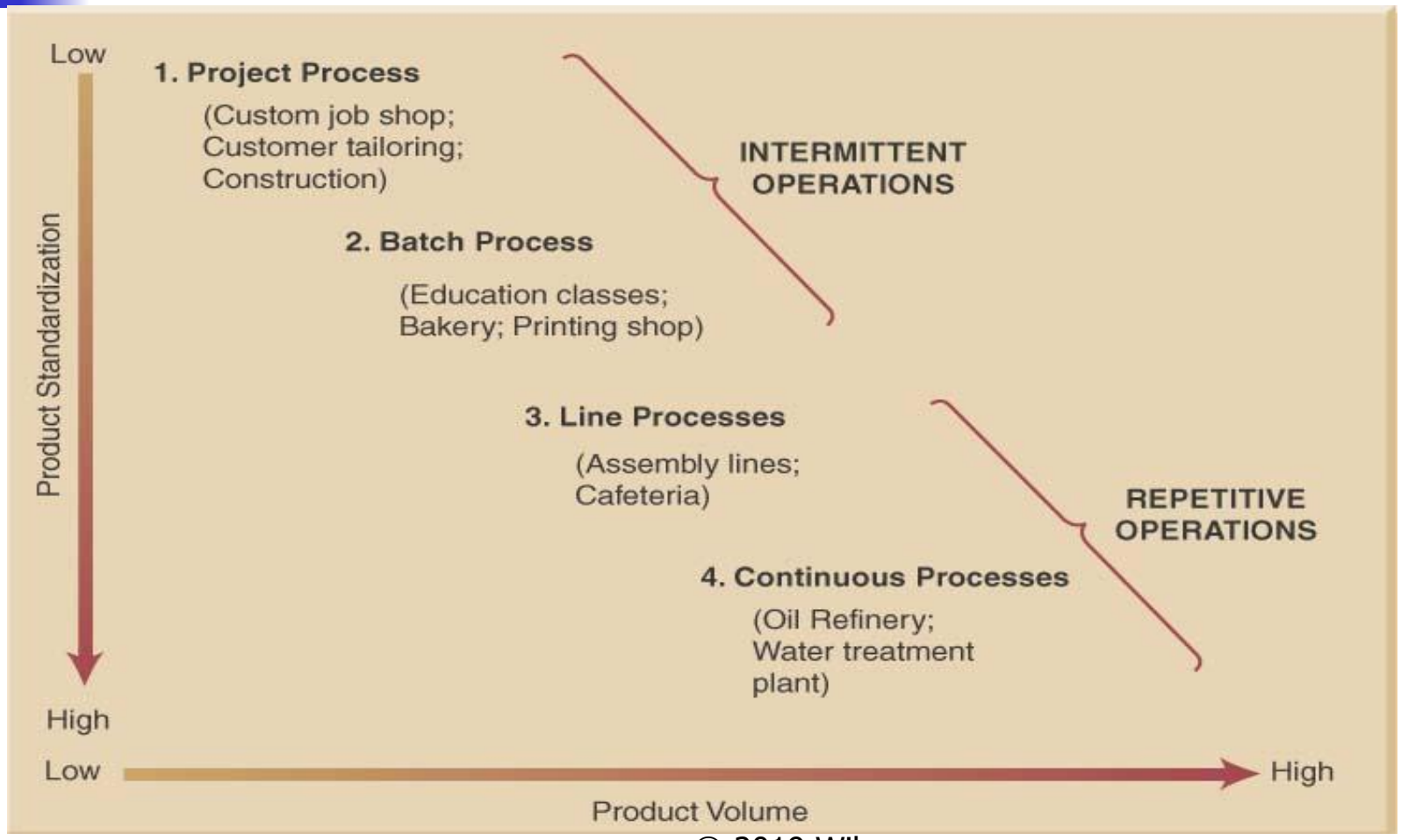
# Intermittent and Repetitive Operations

| Decision | Intermittent Operations | Repetitive Operations |
|---|---|---|
| Product variety | Great | Small |
| Degree of standardization | Low | High |
| Organization of resources | Grouped by function | Line flow to accommodate processing needs |
| Path of products through facility | In a varied pattern, depending on product needs | Line flow |
| Factor driving production | Customer orders | Forecast of future demands |
| Critical resource | Labor-intensive operation (worker skills important) | Capital-intensive operation (equipment automation, technology important) |
| Type of equipment | General-purpose | Specialized |
| Degree of automation | Low | High |
| Throughput time | Longer | Shorter |
| Work-in-process inventory | More | Less |

# Process Selection Types

- Process types can be:
  - **Project** process – make a one-at-a-time product exactly to customer specifications
  - **Batch** process – small quantities of product in groups or batches based on customer orders or specifications
  - **Line** process – large quantities of a standard product
  - **Continuous** process – very high volumes of a fully standard product
  - **Mass customization** – customized product in the price of standardized high volume production (uses agile processes, highly challenging)
- Process types exist on a continuum

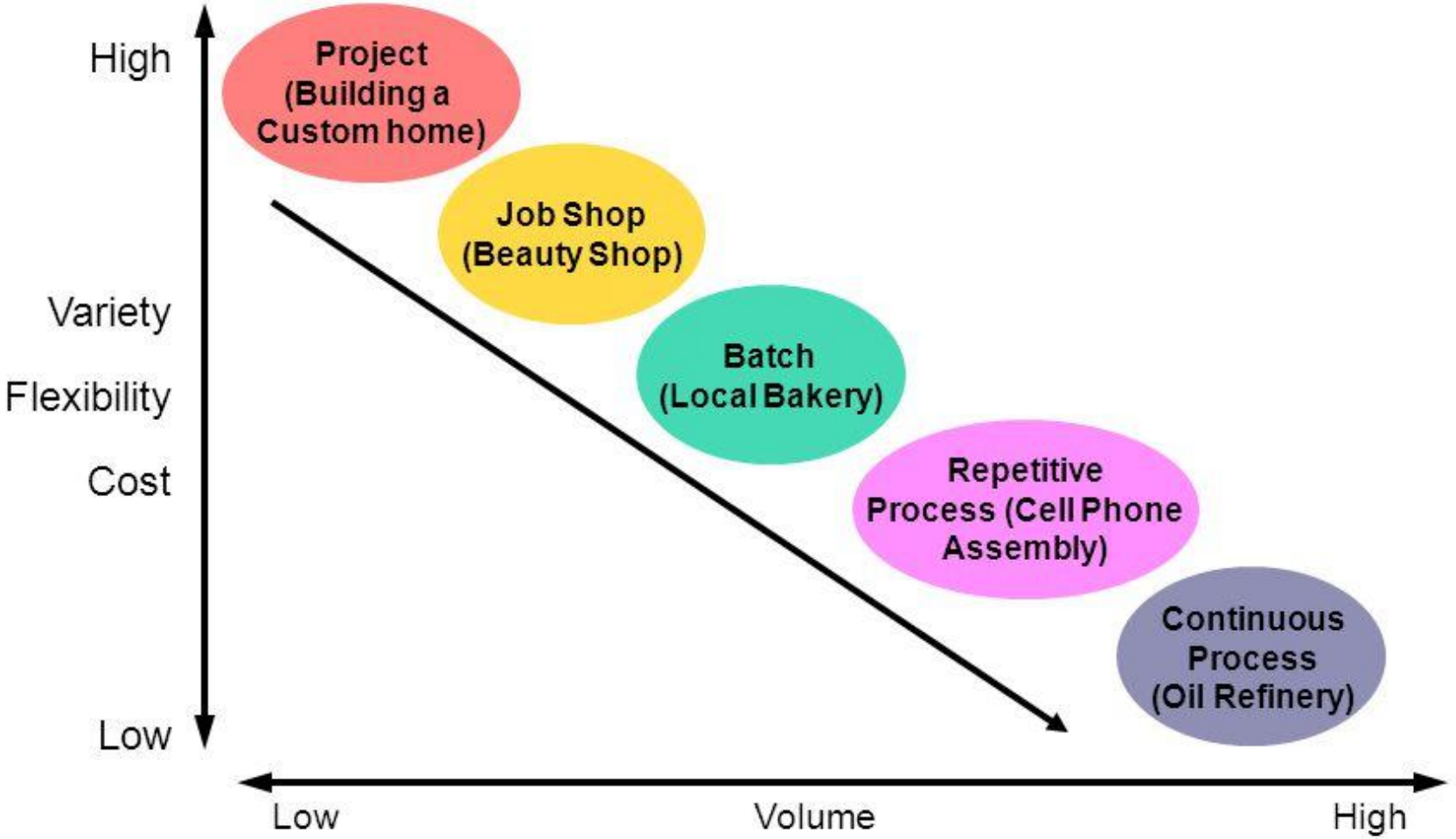
# Underlying Process Relationship Between Volume and Standardization Continuum



# Process Selection Considerations

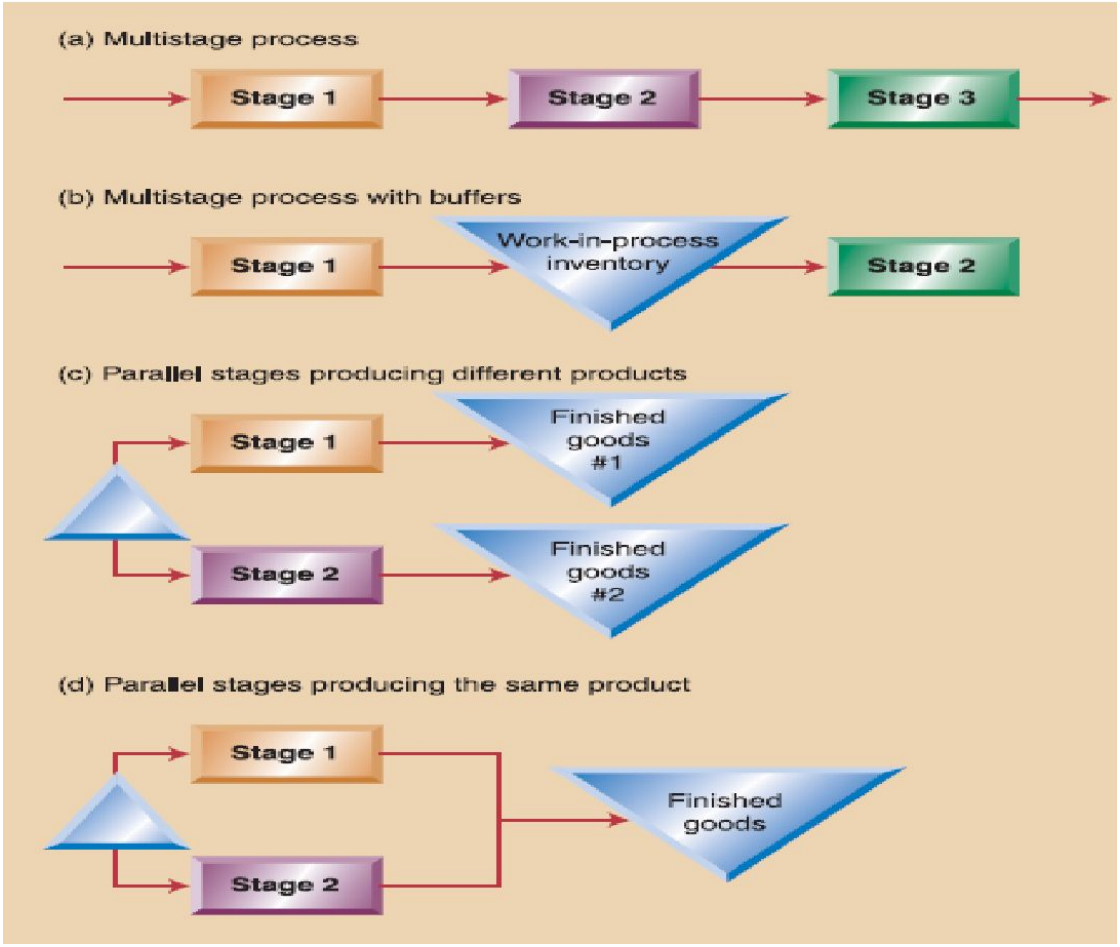
- **Process selection is based on five considerations**
  1. Type of process; range from intermittent to repetitive or continuous
  2. Degree of vertical integration
  3. Flexibility of resources
  4. Mix between capital & human resources
  5. Degree of customer contact

# Product-Process Matrix



# Process Design Tools

Often stages in the production process can be performed in parallel, as shown here in (c) and (d). The two stages can produce different products (c) or the same product (d).

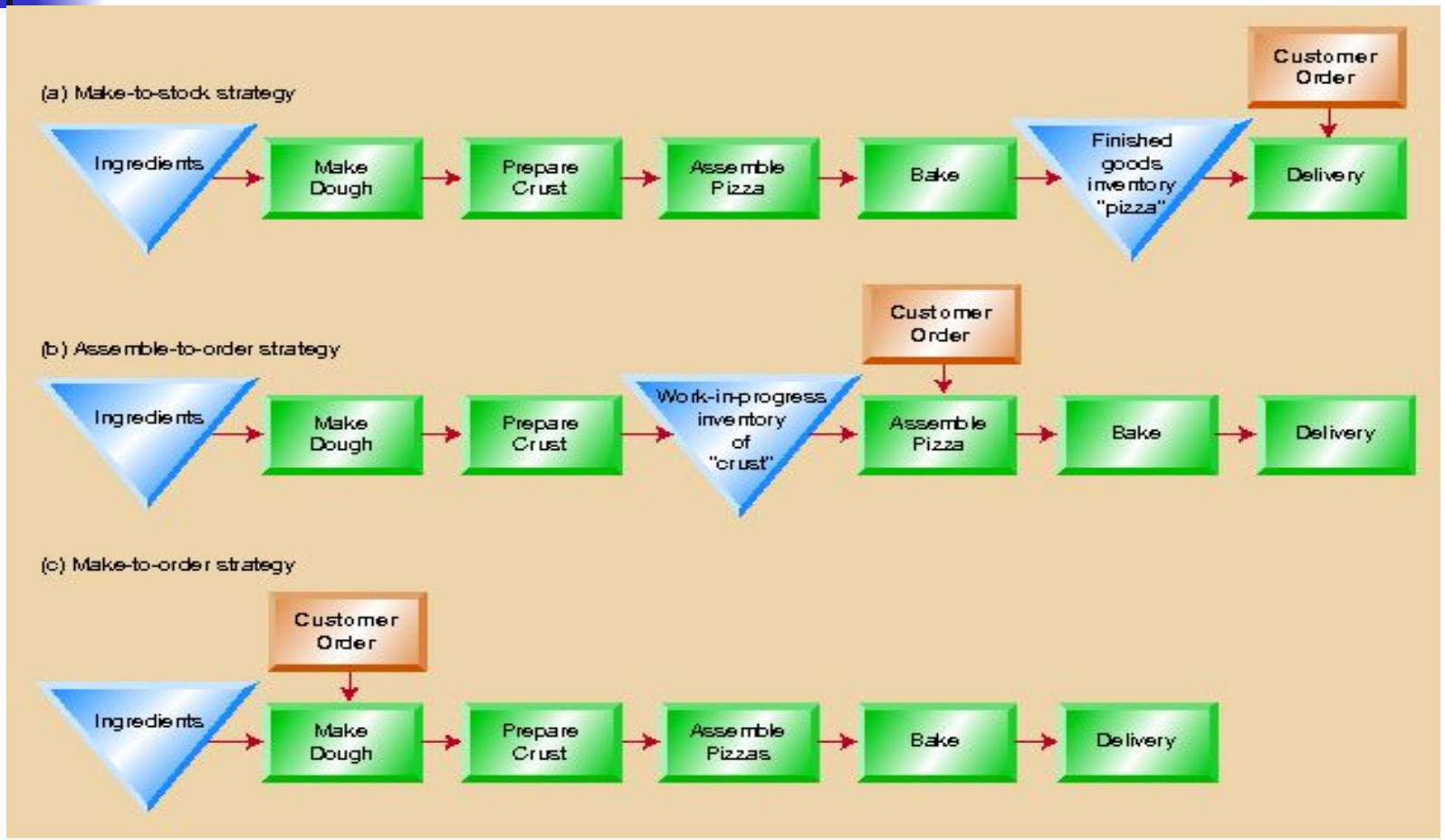


# Designing Processes

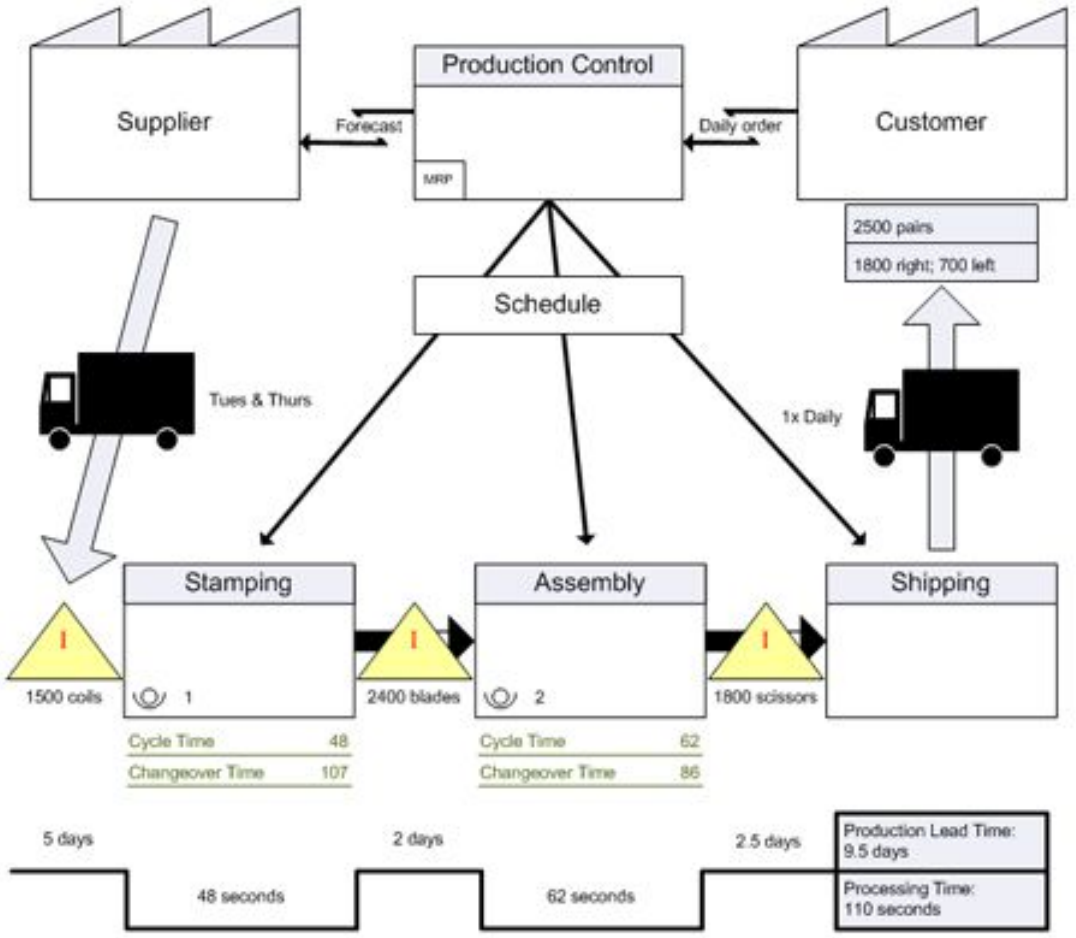
- Process analysis and design tools include
  - Flowcharts
  - value-stream mapping
  - Time-function mapping
  - Process charts
  - Service blueprinting
- Design considerations include
  - Make-to-stock strategy
  - Assemble-to-order strategy
  - Make-to-order strategy

See flowcharts for different product strategies at Antonio's Pizzeria (next slide)

# Flowchart for Different Product Strategies at Antonio's Pizzaria



# Value-Stream Mapping



# "Baseline" Time-Function Map

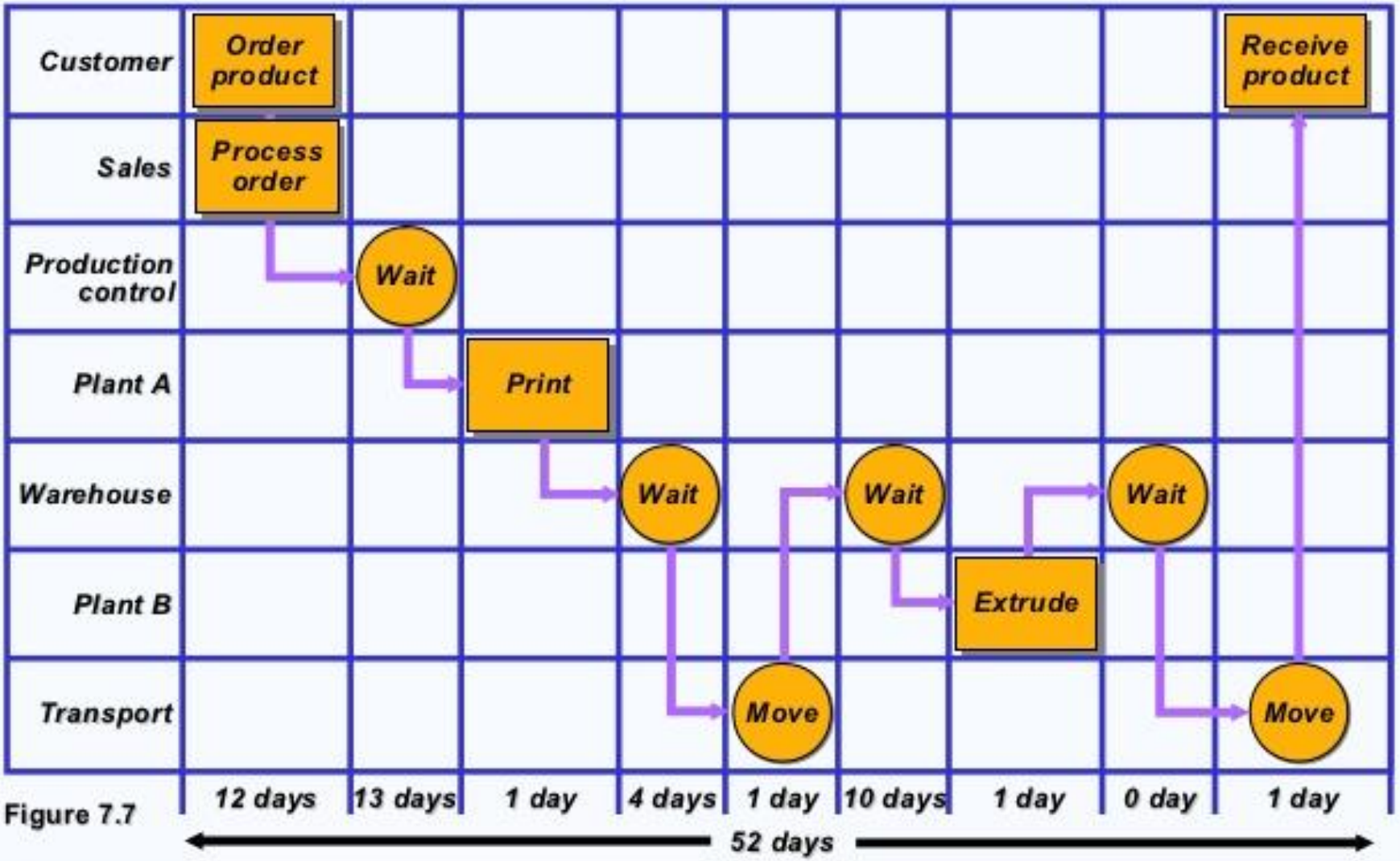
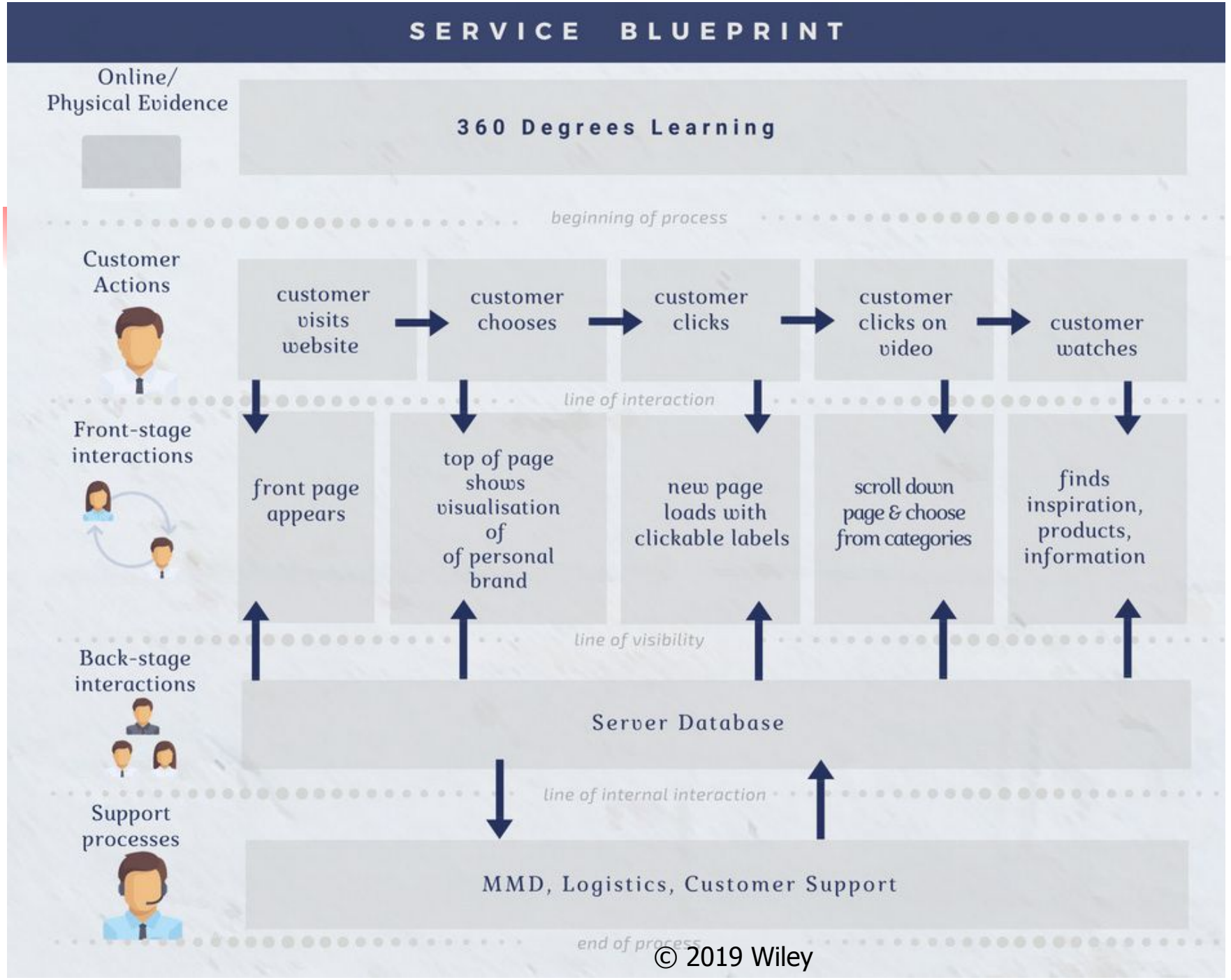
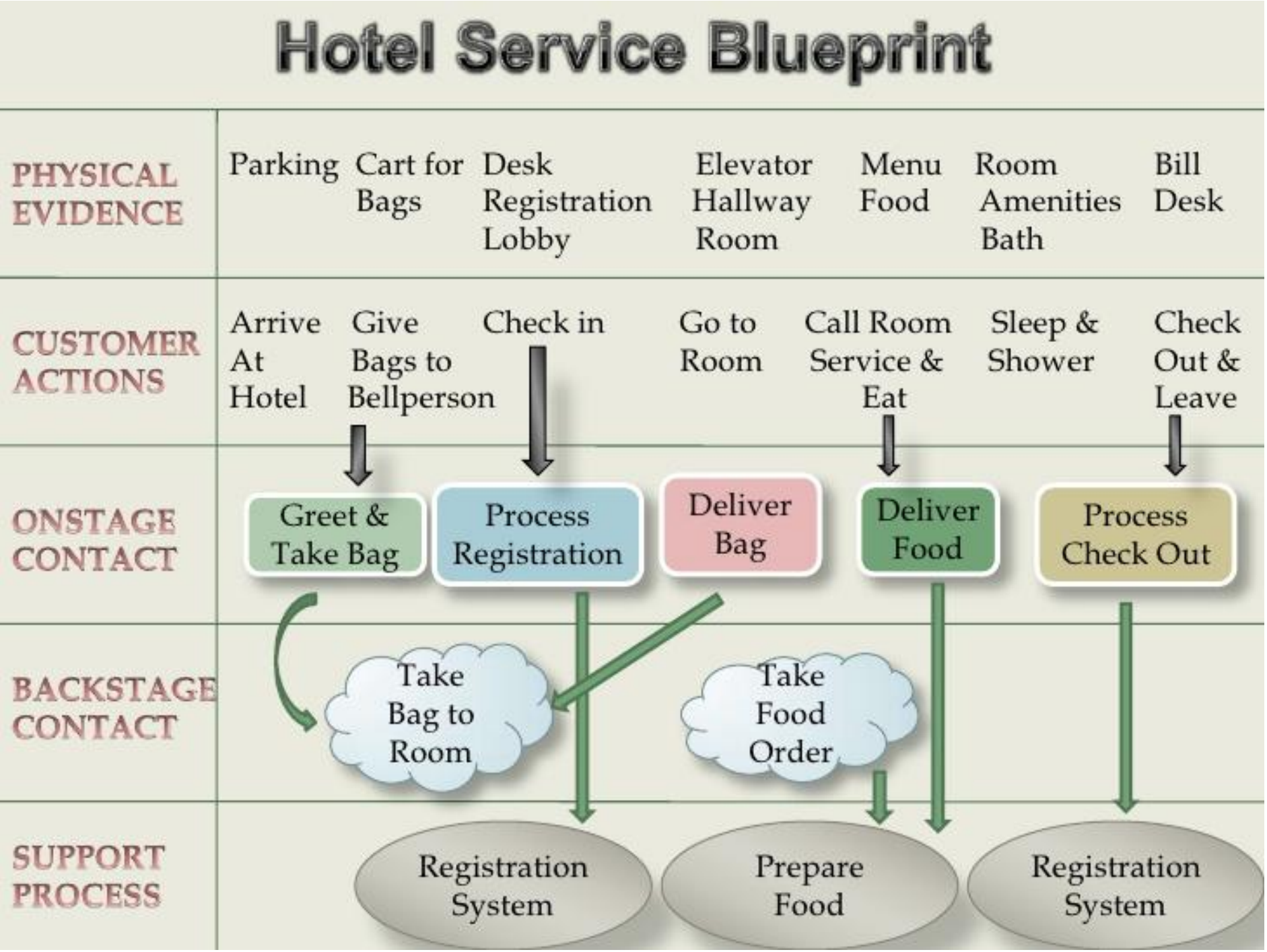



Figure 7.7

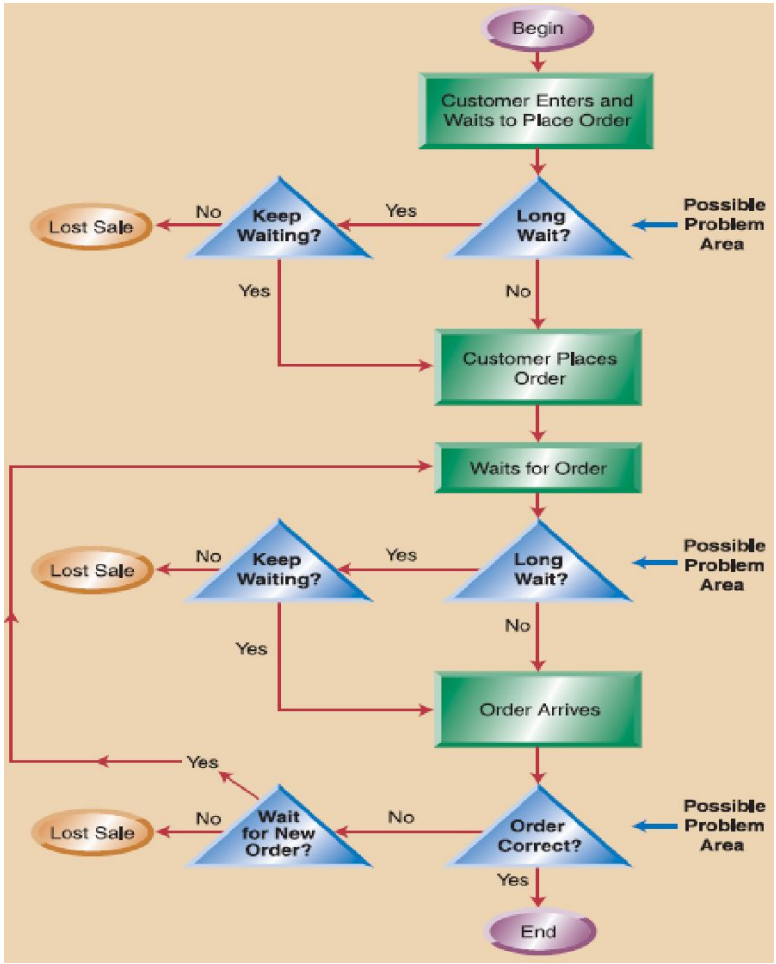

SERVICE BLUEPRINT
Online/ Physical Evidence
360 Degrees Learning
beginning of process
Customer Actions
customer visits website
customer chooses
customer clicks
customer clicks on video
customer watches
line of interaction
Front-stage interactions
front page appears
top of page shows visualisation of of personal brand
new page loads with clickable labels
scroll down page & choose from categories
finds inspiration, products, information
line of visibility
Back-stage interactions
Server Database
line of internal interaction
Support processes
MMD, Logistics, Customer Support
end of process

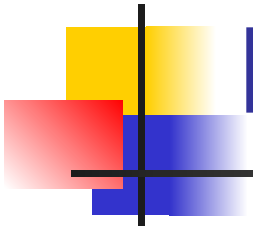
# Hotel Service Blueprint



# Process Flowchart of Customer Flow at Antonio's Pizzeria

A basic process performance metric is **throughput time**. A lower throughput time means that more products can move through the system. One goal of process improvement is to reduce *throughput time*.





# Process Performance Metrics

**Process performance metrics – defined**: Measurement of different process characteristics that tell us how a process is performing

- Determining if a process is functioning properly is required
- Determination requires measuring performance

# Process Performance Metrics

| Measure | Definition |
|---|---|
| 1. Throughput time | Average amount of time product takes to move through the system. |
| 2. Process velocity $= \frac{\text{Throughput time}}{\text{Value-added time}}$ | A measure of wasted time in the system. |
| 3. Productivity $= \frac{\text{Output}}{\text{Input}}$ | A measure of how well a company uses its resources. |
| 4. Utilization $= \frac{\text{Time a resource used}}{\text{Time a resource available}}$ | The proportion of time a resource is actually used. |
| 5. Efficiency $= \frac{\text{Actual output}}{\text{Standard output}}$ | Measures performance relative to a standard. |

# Linking Product Design & Process Selection

- Product design and process selection are directly linked
- Type of product selected defines type of operation required
- Type of operation available defines broader organizational aspects such as
  - Equipment required
  - Facility arrangement
  - Organizational structure

# Linking Design & Process Selection

- **Organizational Decisions appropriate for different types of operations**

| Decision | Intermittent Operations | Repetitive Operations |
|---|---|---|
| Product design | Early stage of product life cycle | Later stage of product life cycle |
| Competitive priorities | Delivery, flexibility, and quality | Cost and quality |
| Facility layout | Resources grouped by function | Resources arranged in a line |
| Product strategy | Make-to-order/assemble-to-order | Make-to-stock |
| Vertical integration | Low | High |

# Linking Product Design & Process Selection con't

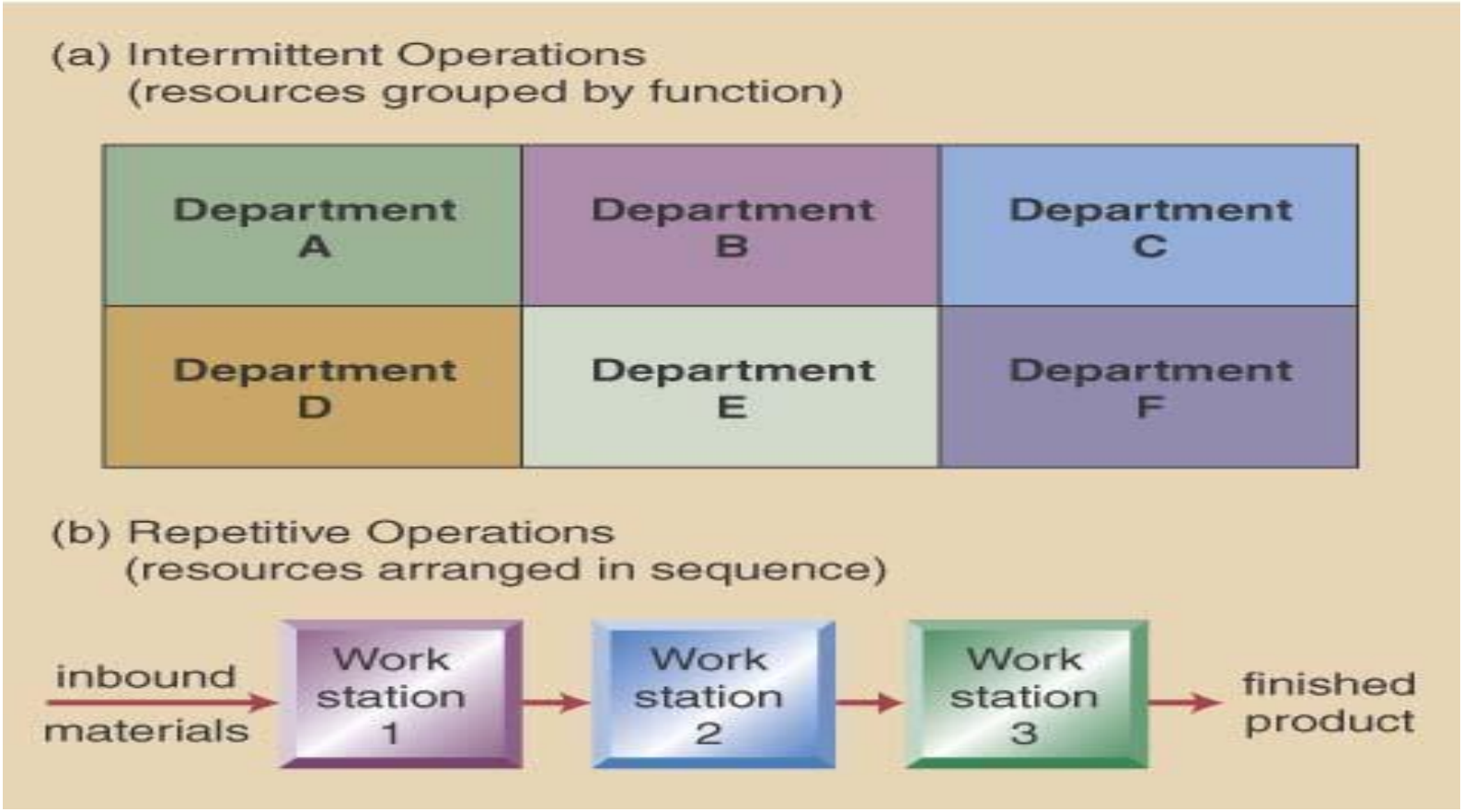
Product Design Decisions:

Intermittent and repetitive operations typically focus on producing products in different stages of the product life cycle. Intermittent is best for early in product life; repetitive is better for later when demand is more predicable.

# Linking Product Design & Process Selection, con't

- Competitive Priorities: decisions of how a company will compete in the marketplace. Intermittent operations are typically less competitive on cost than repetitive operations. (Think "off the rack" vs. custom tailored clothing.)

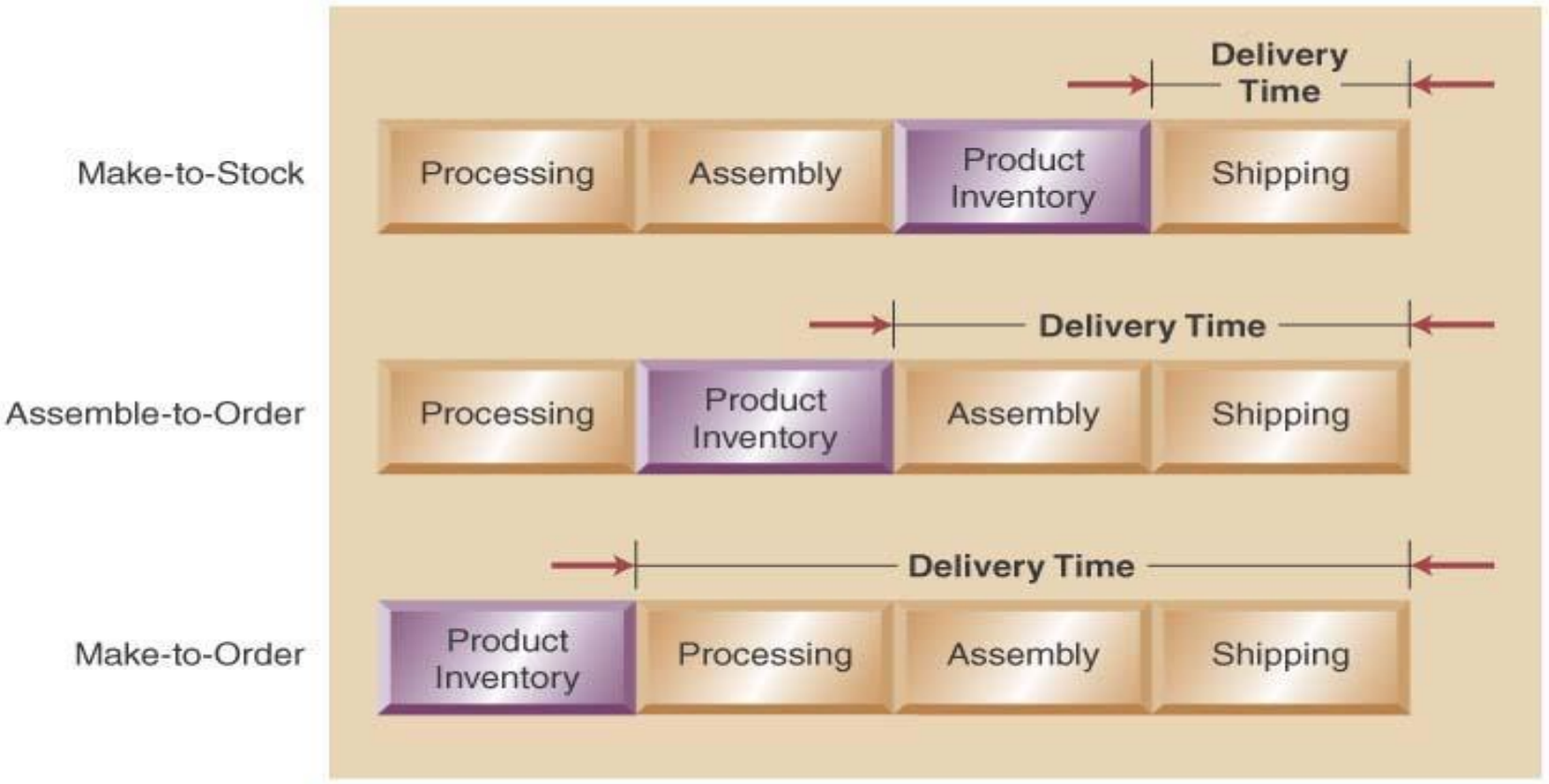
# Intermittent VS. Repetitive Facility Layouts



# Product and Service Strategy

- Type of operation is directly related to product and service strategy
- Three basic strategies include
  1. Make-to-stock; in anticipation of demand
  2. Assemble-to-order; built from standard components on order
  3. Make-to-order; produce to customer specification at time of order

# Product and Service Strategy Options



# Degrees of Vertical Integration & Make or Buy

- ***Vertical integration*** **refers to the degree a firm chooses to do processes itself- raw material to sales**
  - Backward Integration means moving closer to primary operations
  - Forward Integration means moving closer to customers

- **A firm's *Make-or-Buy* choices should be based on the following considerations:**
  - Strategic impact
  - Available capacity
  - Expertise
  - Quality considerations
  - Speed
  - Cost (fixed cost + variable cost)$_{make}$ = Cost (fixed cost + Variable cost)$_{buy}$

# Technology Decisions

## Information Technology

- Simplify first then apply appropriate technology
  - ERP, GPS, RFID
  - Automation
  - Automated Material Handling: Automated guided vehicles (AGV), Automated storage & retrieval systems (AS/RS)
  - Flexible Manufacturing Systems (FMS)
  - Robotics & Numerically-Controlled (NC) equipment

# E-manufacturing

- Web-based environment creates numerous business opportunities to include;
  - Product design collaboration
  - Process design collaboration
- Computer-aided design – uses computer graphics to design new products
- Computer-integrated manufacturing – integration of product design, process planning, and manufacturing using an integrated computer system

# Capacity planning

- Capacity is the maximum output rate of an operating unit.

  Refers to an upper limit or ceiling on the load that an operating unit can handle.

- Capacity planning is the process of establishing the output rate that can be achieved at a facility:
  - Capacity is usually purchased in "chunks"
  - Strategic issues: how much and when to spend capital for additional facility & equipment
  - Tactical issues: workforce & inventory levels, & day-to-day use of equipment

# Measuring Capacity Examples

- **There is no one best way to measure capacity**
- **Output measures like kegs per day are easier to understand**
- **With multiple products, inputs measures work better**

| Type of Business | Input Measures of Capacity | Output Measures of Capacity |
|---|---|---|
| Car manufacturer | Labor hours | Cars per shift |
| Hospital | Available beds | Patients per month |
| Pizza parlor | Labor hours | Pizzas per day |
| Retail store | Floor space in square feet | Revenue per foot |

# Measuring Available Capacity

- Design capacity:
  - Maximum output rate under ideal conditions
  - A bakery can make 30 custom cakes per day when pushed at holiday time
- Effective capacity:
  - Maximum output rate under normal (realistic) conditions
  - On the average this bakery can make 20 custom cakes per day

Design capacity>Effective Capacity>=Actual Capacity

# Measuring Effectiveness of Capacity Use

- Efficiency measures the performance relative to a standard performance
- Utilization ratio measures how much of the available capacity is actually being used

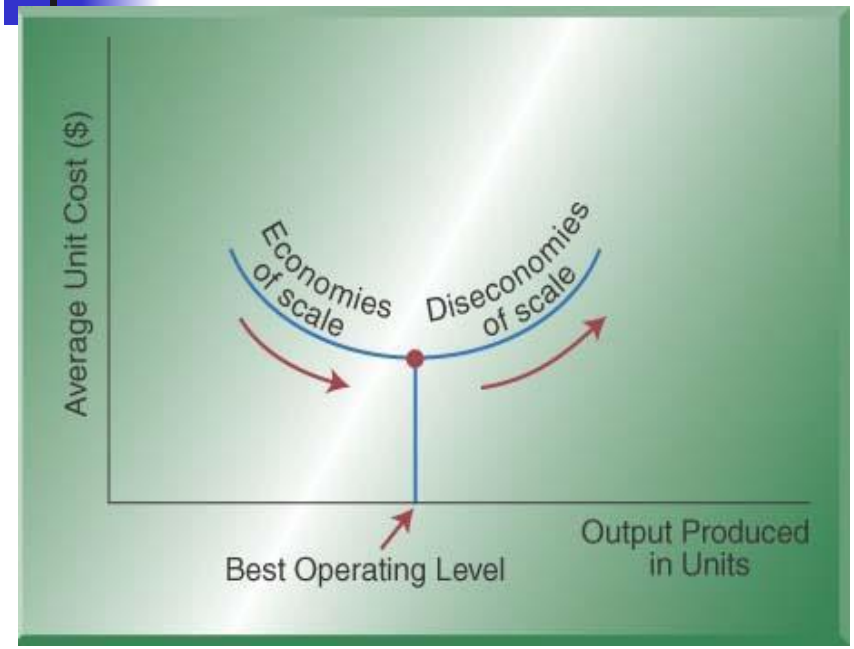
$$\text{Efficiency} = \frac{\text{actual output}}{\text{effective capacity}}(100\%)$$

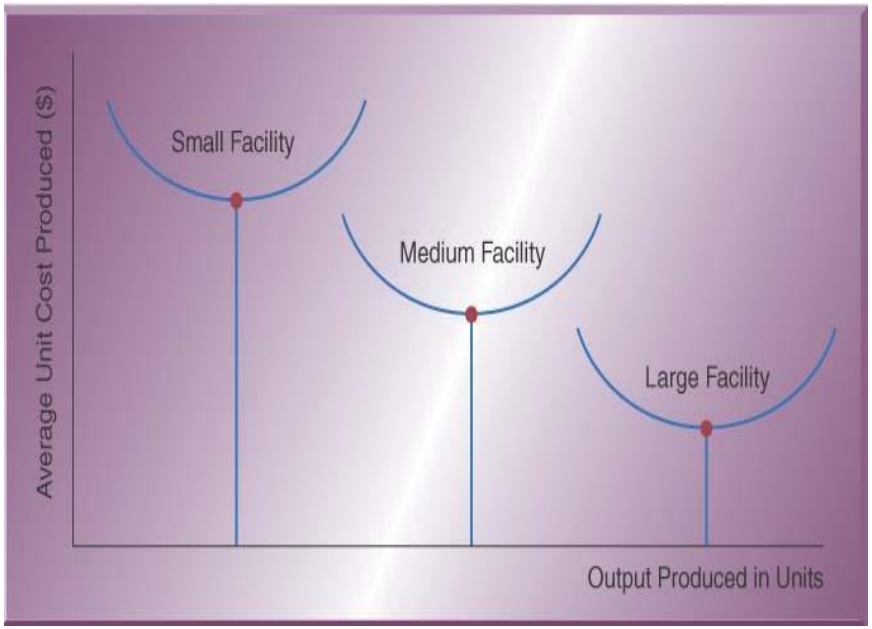
$$\text{Utilization} = \frac{\text{actual output}}{\text{design capacity}}(100\%)$$

# Capacity Considerations

- The **Best Operating Level** is the output that results in the lowest average unit cost
- **Economies of Scale:**
  - Where the cost per unit of output drops as volume of output increases
  - Spread the fixed costs of buildings & equipment over multiple units, allow bulk purchasing & handling of material
- **Diseconomies of Scale:**
  - Where the cost per unit rises as volume increases
  - Often caused by congestion (overwhelming the process with too much work-in-process) and scheduling complexity

# Best Operating Level and Size




- Alternative 1: Purchase one large facility, requiring one large initial investment
- Alternative 2: Add capacity incrementally in smaller chunks as needed

# Other Capacity Considerations

- Focused factories:
  - Small, specialized facilities with limited objectives
- Plant within a plant (PWP):
  - Segmenting larger operations into smaller operating units with focused objectives
- Subcontractor networks:
  - Outsource non-core items to free up capacity for what you do well

# Importance of Capacity Decisions

- Impacts on the ability to meet future demands for products and services
- Affects operating costs (forecasted demand ≠ actual demand)
- Acts as a major determinant of initial costs
- Involves long-term commitment of resources – decisions are hard to reverse

# Importance of Capacity Decisions

- Affects **competitiveness** – variable capacity or excess capacity might increase barrier to entry
- Affects **ease of management** – easy to manage appropriate capacity vs. mismatched capacity
- Globalization adds complexity
- Impacts **long range planning** – huge resources involvement

# Making Capacity Planning Decisions

**The three-step procedure for making capacity planning decisions is as follows:**

1. Identify Capacity Requirements
2. Develop Capacity Alternatives
3. Evaluate Capacity Alternatives

# Capacity Considerations

- Forecasting Capacity:
  - Long-term capacity requirements based on future demand
  - Identifying future demand based on forecasting
  - Forecasting, at this level, relies on qualitative forecast models
    - Executive opinion
    - Delphi method – expert's opinion
  - Forecast and capacity decision must include strategic implications
- Capacity cushions
  - Plan to underutilize capacity to provide flexibility
- Strategic Implications
  - How much capacity a competitor might have
  - Potential for overcapacity in industry a possible hazard

# Developing & Evaluating Capacity Alternatives

- Capacity alternatives include
  - do nothing now – reevaluate later,
  - expand large now (may included capacity cushion), or
  - expand small now with option to add later (build for change)
- Use decision support aids to evaluate decisions (decision tree most popular)

# Product Design and Process Selection Across the Organization

- Strategic and financial of product design and process selection mandates operations work closely across the organization
  - Marketing is impacted by product that is produced
  - Finance is integral to the product design and process selection issues due to frequent large financial outlays
  - Information services has to be developed to match the needs of the production process
  - Human resources provides important input to the process selection decisions for staffing needs

# Product Screening Tool – Break-Even Analysis

- Breakeven point is the point at which its sales revenue matches with the total expenses. (Revenue = Total Cost)
- Break-even Quantity can be calculated as:

**$Q_{BE}$ = F/ (SP - VC)**

- $Q_{BE}$ – Break even quantity
- F – Fixed costs
- SP – selling price/unit
- VC – Variable cost

# Product Screening Tool – Break-Even Analysis con't

- Other important formulas:

  Total cost = F + (VC)*Q

  Revenue = (SP) * Q

Where

F = Fixed Cost

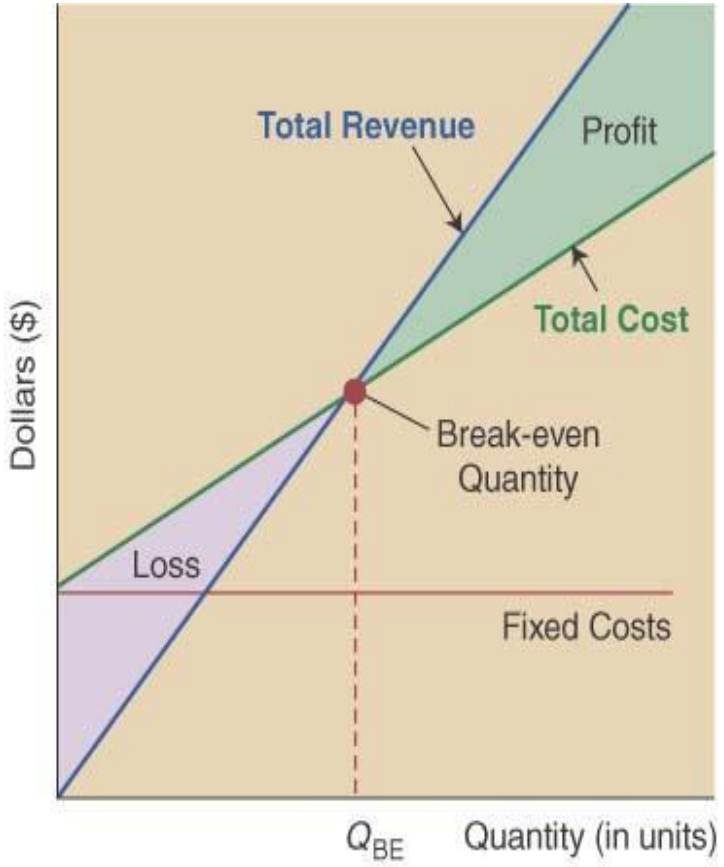
VC = Variable Cost

SP = Selling Price

Q = number of units produced/sold

# Break-Even Analysis: Graphical Approach

- Compute quantity of goods that must be sold to break-even
- Compute total revenue at an assumed selling price
- Compute fixed cost and variable cost for several quantities
- Plot the total revenue line and the total cost line
- Intersection is break-even
- Sensitivity analysis can be done to examine changes in all of the assumptions made



# Break-Even Exercise (5 mins)

A company is planning to establish a chain of movie theaters. It estimates that each new theater will cost approximately $1 Million. The theaters will hold 500 people and will have 4 showings each day with average ticket prices at $8. They estimate that concession sales will average $2 per patron. The variable costs in labor and material are estimated to be $6 per patron. They will be open 300 days each year.

- What must the average occupancy be to break-even?
- What is the gross profit if they sell 300,000 tickets?
- If concessions only average $.50/patron, what is break-even Q now? (sensitivity analysis)

# Break-Even Example Calculations

- **Break-Even Point**

  Total revenues = Total costs @ break-even point Q

  Selling price*Q = Fixed cost + variable cost*Q

  ($8+$2)Q= $1,000,000 + $6*Q

  Q = **250,000 patrons (42% occupancy)**

- **What is the gross profit if they sell 300,000 tickets**

  Profit = Total Revenue – Total Costs

  P = $10*300,000 – (1,000,000 + $6*300,000)

  P = **$200,000**

- **If concessions only average $.50/patron, what is break-even Q now? (sensitivity analysis)**

  ($8.50)Q = 1,000,000 + $6*Q

  Q = **400,000 patrons (67% occupancy)**

# Chapter 3 Highlights

- Product design is the process of deciding on the unique characteristics and features of a company's product Process selection is the development of the process necessary to produce the product being designed.
- Steps in product include idea generation, product screening, preliminary design and testing, and final design
- Break-even analysis is a tool used to compute the amount of goods that have to be sold just to cover costs.
- Production processes can be divided into two broad categories: intermittent and repetitive operation project to batch to line to continuous

# Chapter 3 Highlights con't

- Product design and process selection decisions are linked
- Process flow charts is used for viewing the flow of the processes involved in producing the
- Different types of technologies can significantly enhance product and process design. These include automation, automated material handling devices, CAD, NC, FMS, and CIM
- Designing services have more complexities than manufacturing, because service produce an intangible product and typically have a high degree of customer contact.