PRODUCT DESIGN AND PROCESS SELECTION

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Product design

- The process of defining features and characteristics of the product
- Product design defines a product's characteristics such as:
  - Appearance
  - Material it is made of
  - Its dimensions and tolerances
  - Its performance standards

Product design

- A company's product designs must also support the company's business strategy.
- Product design is a major factor in a company's ability to keep and build its customer base.
- A company's product design must match the needs and preferences of the customer group targeted by the company's business strategy. Otherwise, the company will lose its customer base and erode its market position.

Product Design Process

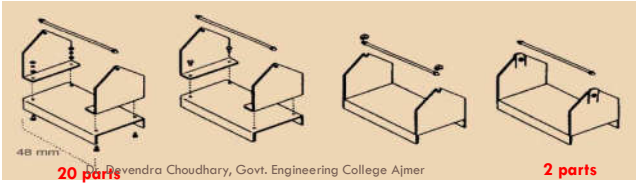
- Step 1 - Idea Development - Someone thinks of a need and a product/service design to satisfy it: customers, marketing, engineering, competitors, benchmarking, reverse engineering
- Step 2 - Product Screening - Every business needs a formal/structured evaluation process: fit with facility and labor 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

Factors to consider in product design

- **Idea development:** all products begin with an idea whether from:
  - customers,
  - competitors using benchmarking (best-in-class) or
  - suppliers
- **Reverse engineering:** buying a competitor's product
  - The process of disassembling a product to analyze its design features.

Factors to consider in product design

- **Design for manufacture (DFM):** at the product design stage, we must think
  - how to please the customer
  - how easy or difficult it is to manufacture
- We may have a great product design that is difficult or too costly to manufacture

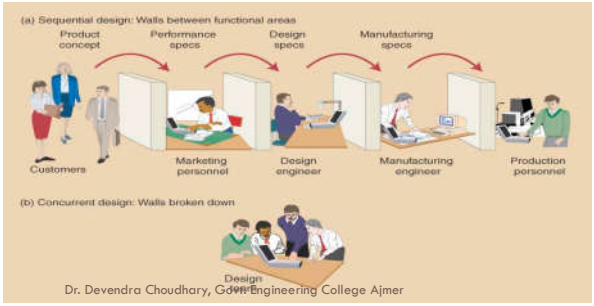


Factors to consider in product design

- Following DFM guidelines result into fewer chances for error, better quality, greater variety and flexibility and lower costs:
- Design simplification: means reducing the number of parts and features of the product whenever possible.
- Design standardization: refers to the use of common and interchangeable parts.
- Use modular design
- Avoid tools
- Simplify operations

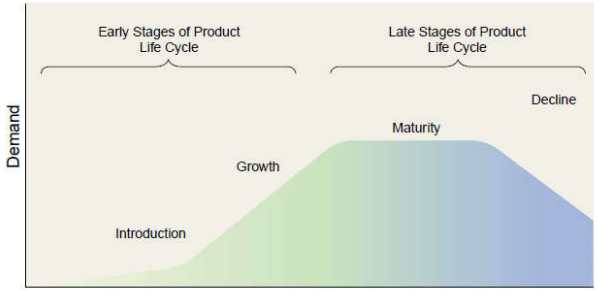
Factors to consider in product design

- Concurrent Engineering : An approach that brings together multifunction teams in the early phase of product design in order to simultaneously design the product and the process.



Factors to consider in product design

- **Product life cycle:** A series of stages that products pass through in their lifetime, characterized by changing product demands.



Factors to consider in product design

- **Product life cycle:** A series of stages that products pass through in their lifetime, characterized by changing product demands.

What is process?

- The sequence of activities intended to create added value (in product or service form) for the customers.

What is process planning?

- The planning for conversion process of raw materials in finished products
- It consists of two parts:
  - Process Design
  - Operations Design

Process design

- It is concerned with the overall sequence of operations required to achieve the product specifications.
- The sequence of operations are determined by
  - Nature of the product
  - Materials to be used
  - Quantity to be produced
  - Existing physical layout of the plant

Process design

- Steps of Process Design:
  - Determine the method of manufacturing
  - Establish the sequence & type of operations involved
  - Select the tools and equipment required and
  - Analyze how the manufacturing of the product will fit into the facilities

Framework for process design

- Characteristics of product and services offered to the customer
- Expected volume of output
- Equipment & machines available in the plant
- Cost of the equipment & machineries
- Labour-skills and their wage rates
- Expenditure to be incurred for the manufacturing process
- Make or buy decision
- Method of handling material economically

Operation Design

- It is concerned with the design of the individual manufacturing operations

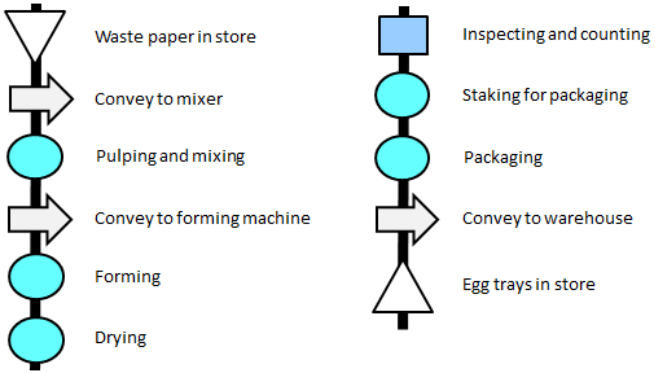
Process flow analysis

- A tool for evaluating an operation in terms of the sequence of steps from inputs to outputs
- Goal is to improve process design
- Most important tool in process flow analysis is a process flowchart
- A process flowchart shows the flow of all the process steps involved in producing the product or service

Process flow chart symbols

	Inspection	Giving an admission ticket to a customer, installing an engine in a car, etc.
	Decision point	How much change should be given to a customer, which wrench should be used, etc.
	Storage areas or queues	WIP, Finished goods, lines of people waiting for a service, etc.
	Flows of materials or customers	Customers moving to a seat, mechanic getting a tool, etc.

Process flow chart examples



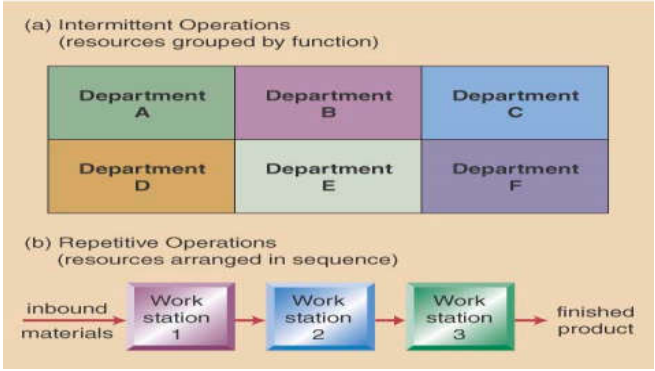
Types of processes

- Intermittent processes: Processes used to produce many different products with varying processing requirements in lower volumes.
- Continuous processes: Processes used to produce one or a few standardized products in high volume.

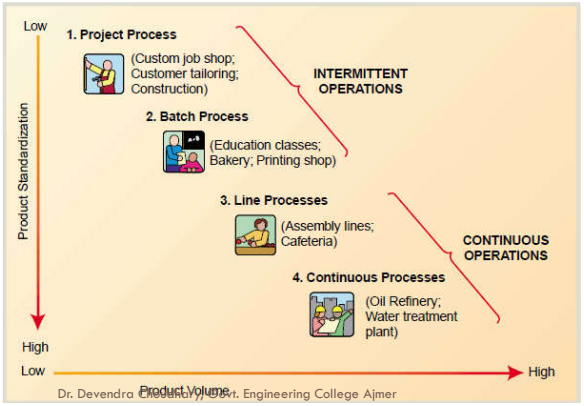
Types of processes

Decision	Intermittent Operations	Continuous 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 import)
Type of equipment	General purpose	Specialized
Degree of automation	Low	High
Throughput time	Longer	Shorter
Work-in-process inventory	More	Less

Intermittent VS. Repetitive Facility Layouts



Types of processes



Project/Job-shop process

- Making a one-at-a-time product exactly to customer specifications.
- There is high customization and low product volume.
- Examples:
  - in construction, shipbuilding, medical procedures, creation of artwork, custom tailoring, and interior design.

Batch process

- Producing small quantities of products in groups or batches based on customer orders or product specifications.
- The volumes of each product produced are still small.
- There can still be a high degree of customization.
- Examples
  - in bakeries, education, and printing shops.
  - Taking classes in university/college

Line process

- Producing a large volume of a standardized product for mass production.
- Product that is produced is made in high volume with little or no customization.
- Examples:
  - typical assembly line that produces everything from cars, computers, television sets, shoes, candy bars, even food items.

Continuous process

- Operates continually to produce a very high volume of a fully standardized product.
- Examples:
  - include oil refineries, water treatment plants, and certain paint facilities.
- The products produced by continuous processes are usually in continual rather than discrete units, such as liquid or gas.
- Facilities are usually highly capital intensive and automated.

Process selection

- The development of the process necessary to produce the designed product.
- Product design and process selection decisions are typically made together.
- Product design and process selection affect product quality, product cost, and customer satisfaction.
- A company can have a highly innovative design for its product, but if it has not figured out how to make the product cost effectively, the product will stay a design forever.

Factors to consider in process selection

- Product-Process matrix
- Degree of vertical integration
- Flexibility of resources
- Mix between capital & human resources
- Degree of customer contact

Product – Process matrix

- The product-process matrix is a tool for analyzing the relationship between the **product life cycle** and the **process life cycle**.
- There is a strong interaction between the evolution of the product through its life cycle, and the evolution of the manufacturing process used to produce the product.

Product life cycle

- The product life cycle model describes the evolution over time of a product.

	Introduction	Growth	Maturation	Decline
Variety	High	Declines		Low
Volume	Low	Increases		High
Competitive strategy	Product characteristics	Quality and availability	Price and dependability	Price

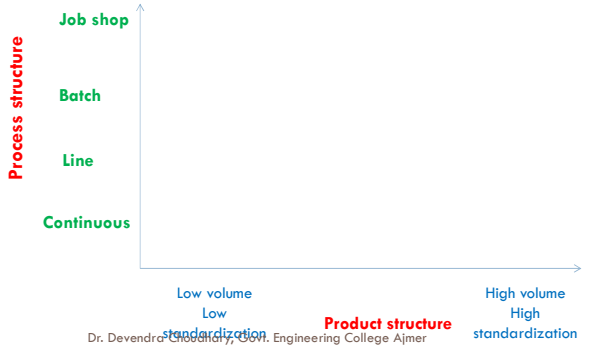
Process life cycle

- The process life cycle model suggests that a production process evolves from
  - uncoordinated process (a **job shop process**),
  - towards increasing standardization, mechanization and automation (a **batch process or assembly line**),
  - until it eventually becomes very efficient, capital-intensive, interrelated and less flexible (**a continuous flow line**).

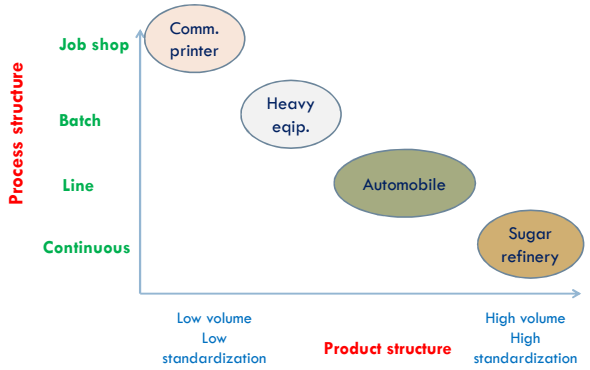
Process life cycle

	Job shop	Batch	Assembly Line	Continuous
Flexibility	High	Decreases →		Low
Customization	High	Decreases →		Low
Efficiency	Not cost efficient	Increases →		Very cost efficient
Standardization, mechanization, and automation	Increases →			
Work content	Different			Same
Equipment	General purpose			Special purpose
Equipment utilization	Less			100%
Workers Skill	Wide range			limited

Product – Process matrix

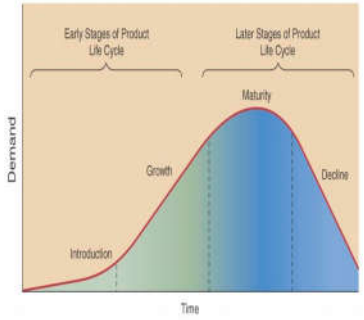


Product – Process matrix



Product – Process matrix

- 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.



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)$_{buy}$
- **Business are trending toward less *backward integration*, more *outsourcing***

Linking product and process

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

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.

Metrics Example: At Zelle's Dry Cleaning, it takes an average of 3 ½ hours to dry clean & press a shirt, with value-added time estimated at 110 min. Workers are paid for a 7-hour workday but work 5 ½ hr/day, accounting for breaks and lunch. Zelle's completes 25 shirts per day, while the industry standard is 28 for a comparable facility.

Process Velocity = (Throughput Time)/(Value-added time)

= (210 minutes/shirt)/(110 minutes/shirt) = **1.90**

Labor Utilization = (Time in Use)/(Time Available)

= (5 ½ hr)/(7 hr) = .786 or **78.6%**

Efficiency = (Actual Output)/(Standard Output)

= (25 shirts/day)/(28 shirts/day) = .89 or **89%**

Break-even-point (BEP) analysis

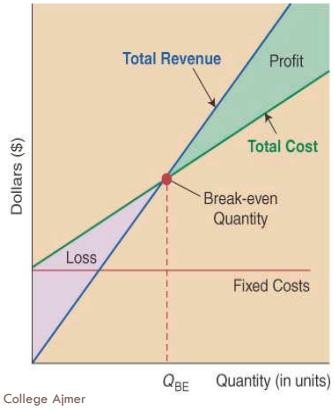
Total cost = fixed cost + variable cost

Total cost = *FC* + *(VC) Q*

Revenue = *(SP) Q*

Profit = total revenue -total cost

Profit = *(SP)Q – [FC+(VC)Q]*



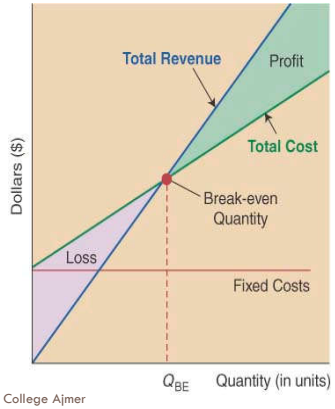
Break-even-point (BEP) analysis

At BEP

total revenue = total cost

*SP*Q = FC + VC*Q*

Q_{BE} = *FC/(SP – VC)*



Break-Even Analysis (example)

- Sale Price = $300
- Option 1:
  - Purchase = $200 * Demand
- Option 2:
  - Lathe = $80,000 + $75 * Demand
- Option 3:
  - Machine center = $200,000 + $15 * Demand

Purchase vs. Lathe? Lathe vs. Machining Center?

Break-Even Analysis (example)

- Purchase versus Lathe:

  $200 * Demand = $80,000 + $75 * Demand

  ($200 * Demand) - ($75 * Demand) = $80,000

  $125 * Demand = $80,000

  Demand = $80,000/$125 = 640 units

  so – less than 640 units, purchase; 640 of greater, use Lathe

- Lathe versus Machine Center:

  $80,000 + $75 *Demand = $200,000 + $15 * Demand

  Demand = $120,000/$60 = 2,000 units

  so – less that 2000 units use the Lathe; 2000 or more use the machining center

Break-Even Analysis (example 2)

- You are starting a new business and your fixed costs are estimated to be $500,000. Your product sells for $100 and costs you $50 to manufacture. What is the breakeven point? If you sell 15,000 units, what will be your profit?

Break-Even Analysis (example 2)

- You are starting a new business and your fixed costs are estimated to be $500,000. Your product sells for $100 and costs you $50 to manufacture. What is the breakeven point? If you sell 15,000 units, what will be your profit?
  - Answer: Break Even Value is 10,000 and Profit is $250,000

Break-Even Analysis (example 3)

- In your business you are considering two machines. Machine 1 costs $500,000 and has a variable per unit cost of $50 per item. Machine 2 has a fixed cost of $200,000 and has a variable per unit cost of $80 per item. What is the break-even volume for the two machines. If a friend tells you to use Machine 2 if the volume is 5,000 items, is she right or wrong?

Break-Even Analysis (example 3)

- In your business you are considering two machines. Machine 1 costs $500,000 and has a variable per unit cost of $50 per item. Machine 2 has a fixed cost of $200,000 and has a variable per unit cost of $80 per item. What is the break-even volume for the two machines. If a friend tells you to use Machine 2 if the volume is 5,000 items, is she right or wrong?
  - Answer: Break Even Value is 10,000