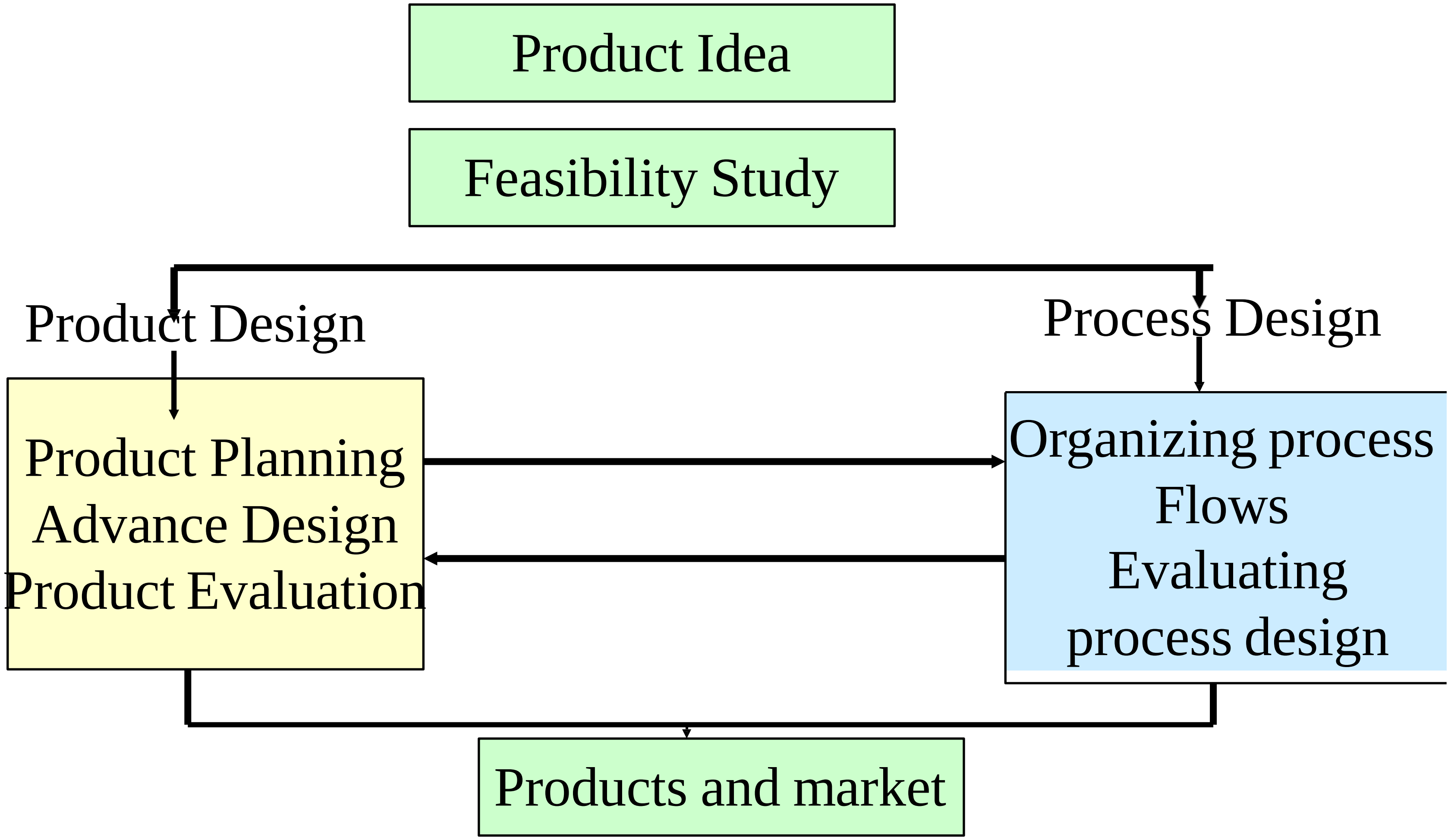
Interrelation between Product & Process Design



Key Decisions in Process Design

- Key decisions relating to Process design is related to organizing the process flows necessary to manufacture new products.
- **Organizing process flow**
  - Five types of Processes are distinguished
  - Project
  - Job Shop
  - Batch
  - Assembly line
  - Continuous

Relations of process Design to types of process flow

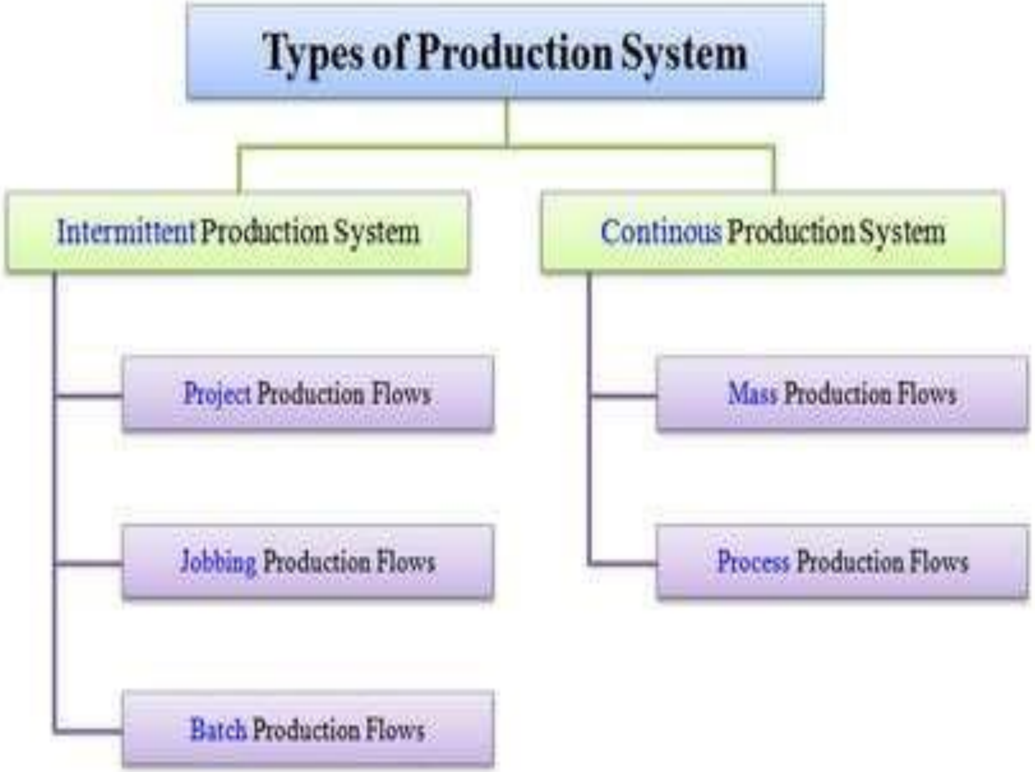
❖There is a definite relation between **Production** process and process flow.For continuous manufacturing the methods and processes are determined before the line set up.

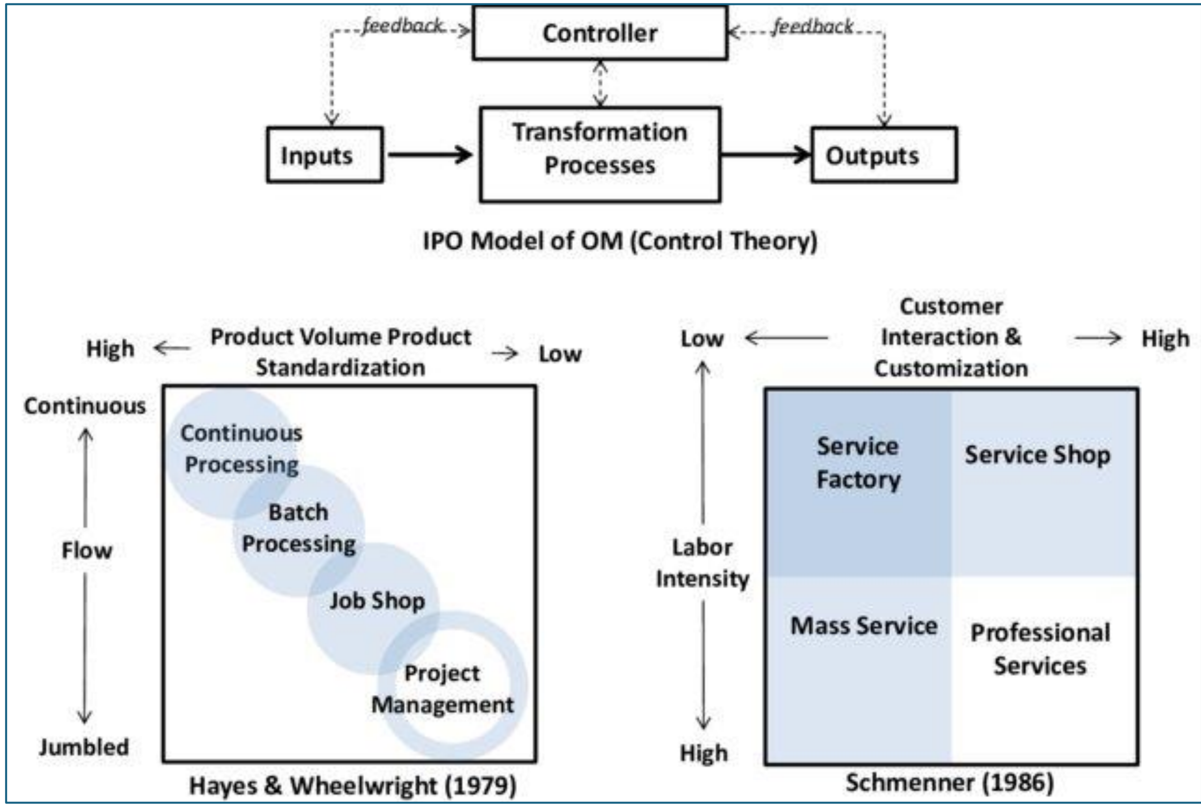
❖The process design is built into the line

❖Changes usually require that the line be shut down with consequent loss of production

❖For intermittent process no lines are set up.process engineer is usually adapt the methods to the types of equipment available.

Types of production process





For your reference: Table 6.1, page 234)

Intermittent production system

- Intermittent means something that starts (initiates) and stops (halts) at irregular (unfixed) intervals (time gaps).
- In the intermittent production system, goods are produced based on customer's orders.
- These goods are produced on a small scale.
- The design of these products goes on changing. It keeps changing according to the design and size of the product. Therefore, this system is very flexible.

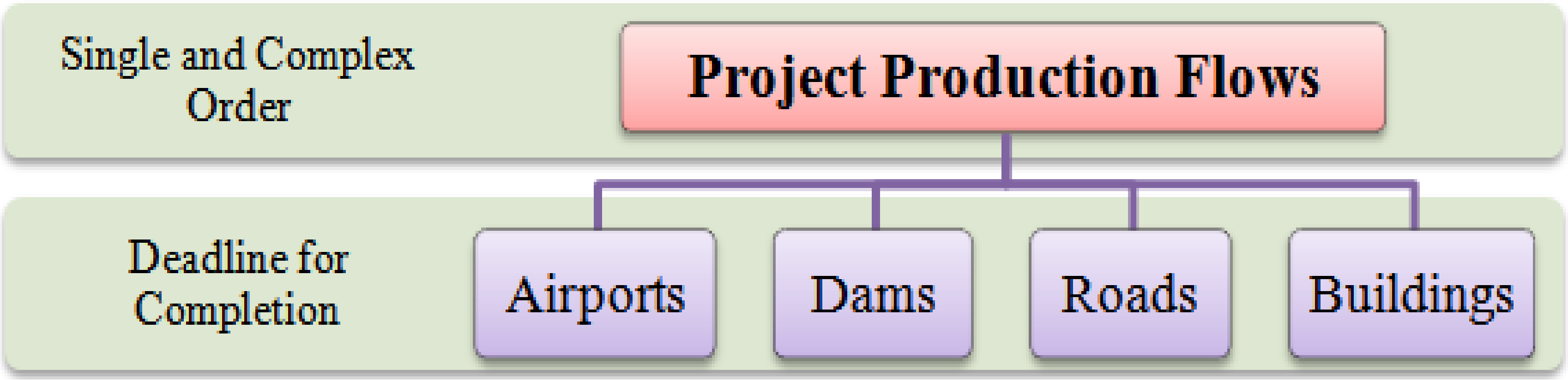
Features of an intermittent production system

Features of Intermittent Production System

1. Flow of Production is not Continous.
2. Variety of Products are Produced.
3. Volume of Production is Small.
4. General Purpose Machines are Used.
5. Sequence of Operation changes as per Design.
6. Production Depends on Customer's Orders.

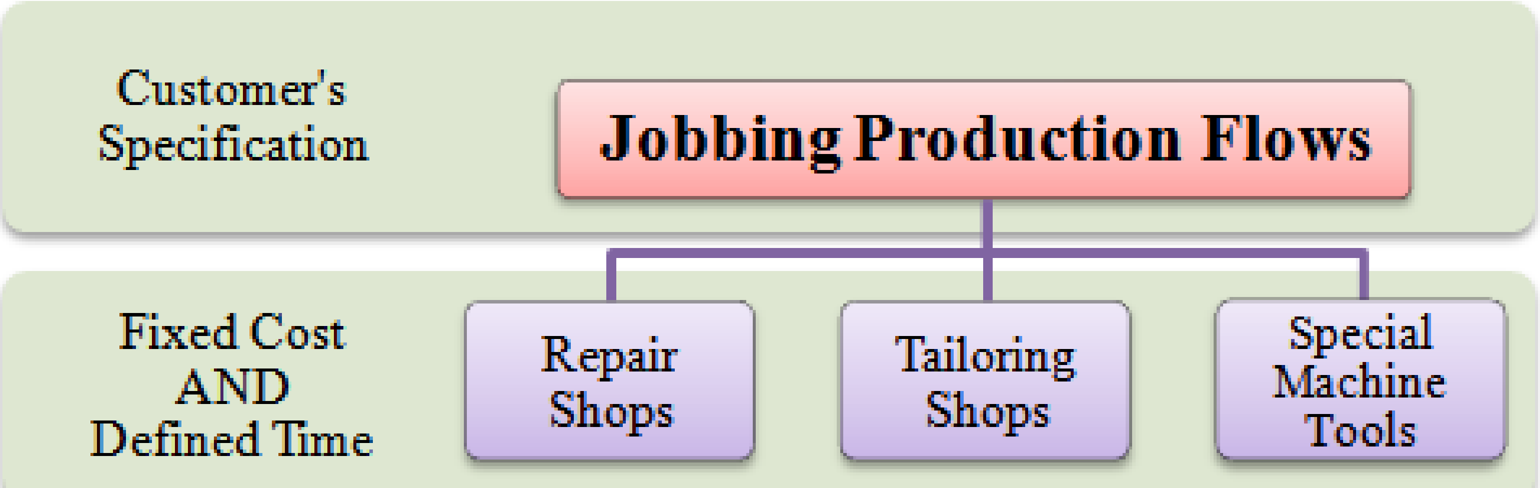
Project production flows

- Here, in project production flows, company accepts a single, complex order or contract. The order must be completed within a given period of time and at an estimated cost.
- Examples of project production flows mainly include, construction of airports, dams, roads, buildings, shipbuilding, etc.



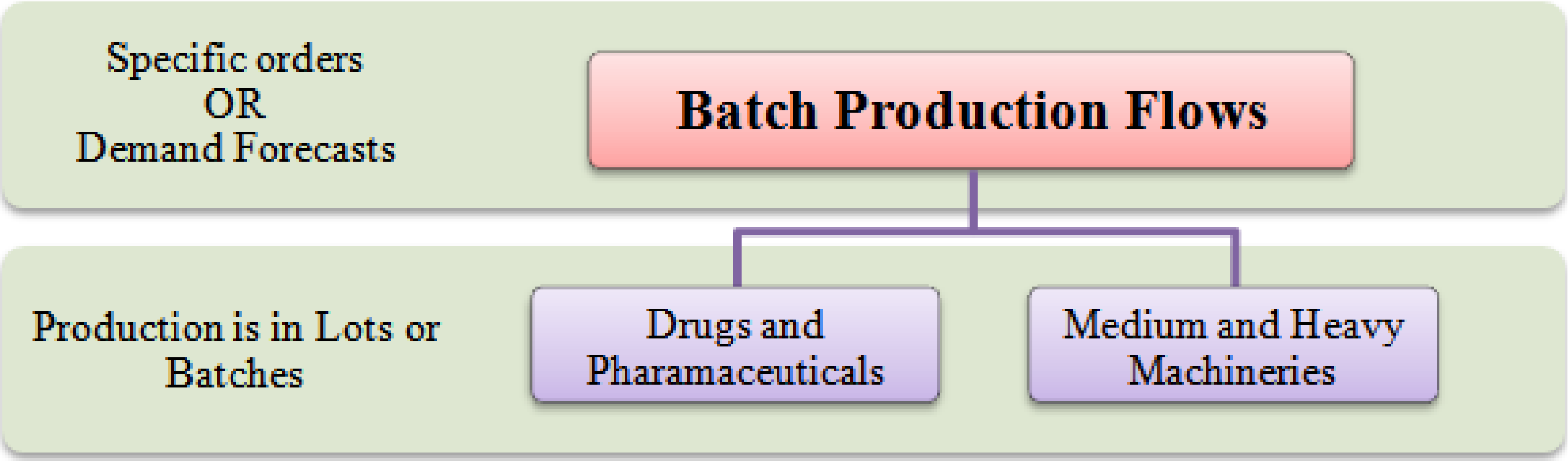
Job production

- Here, in jobbing production flows, company accepts a contract to produce either one or few units of a product strictly as per specifications given by the customer.
- The product is produced within a given period and at a fixed cost. This cost is fixed at the time of signing the contract.
- Examples of such jobbing production flows include, services given by repair shops, tailoring shops, manufacturer of special machine tools, etc.



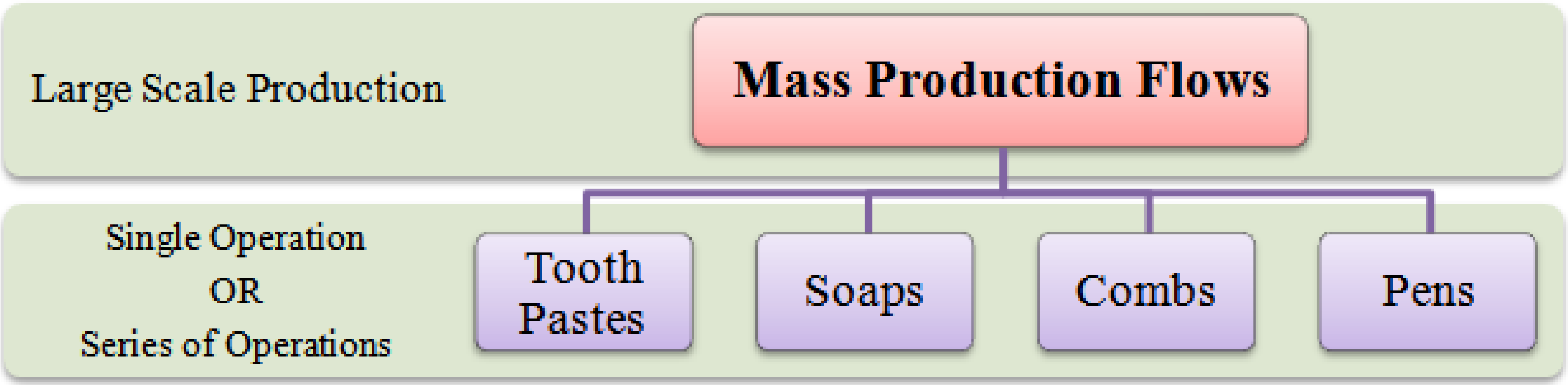
Batch production

- In batch production flows, the production schedule is decided according to specific orders or are based on the demand forecasts.
- Here, the production of items takes place in lots or batches. A product is divided into different jobs.
- All jobs of one batch of production must be completed before starting the next batch of production.
- Examples of batch production flows include, manufacturing of drugs and pharmaceuticals, medium and heavy machineries, etc.

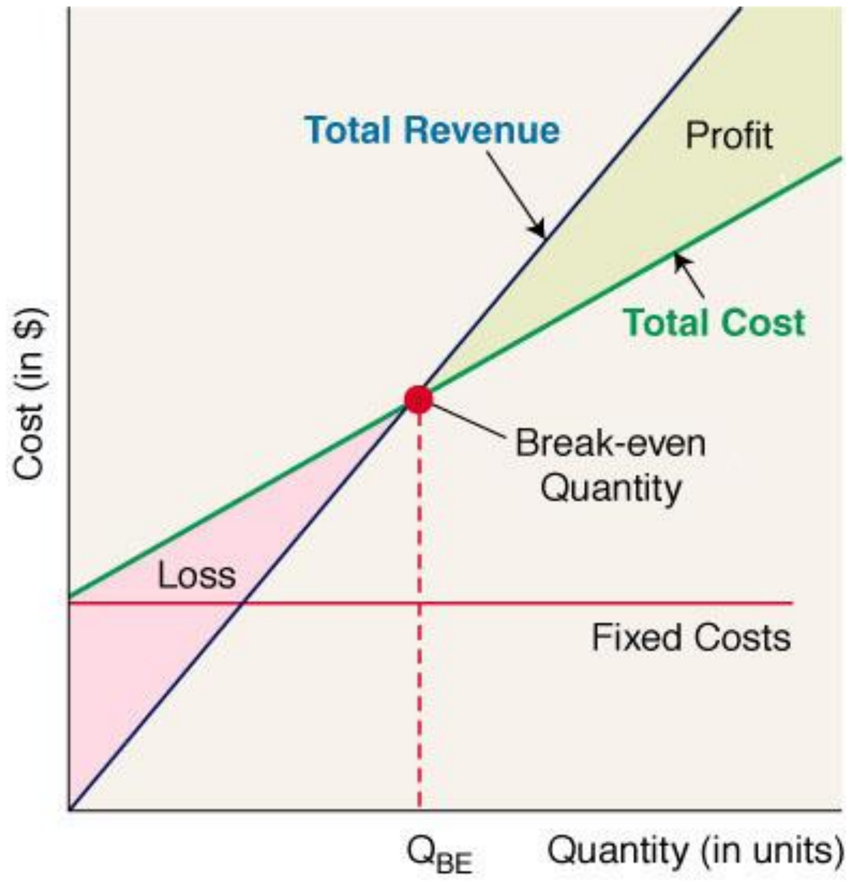


Mass production flows

- Here, company produces different types of products on a large-scale and stock them in warehouses until they are demanded in the market.
- The goods are produced either with the help of a single operation or uses a series of operations.
- E.g. of mass production is the production of toothpastes, soaps, pens, etc.



Break-Even Analysis



Break-Even Analysis

- Total cost = fixed costs + variable costs (quantity):

$$TC = F + (VC)Q$$

- Revenue = selling price (quantity)

$$R = (SP)Q$$

- Profit=Revenue-total cost

- Break-even point is where total costs = revenue:

$$TC = R \quad or \quad F + (VC)Q = (SP)Q$$

$$or \quad Q = \frac{F}{SP - VC}$$

BEA Example

- A firm estimates that the fixed cost of producing a line of footwear is $52,000 with a $9 variable cost for each pair produced. They want to know:
  - If each pair sells for $25, how many pairs must they sell to break-even?
  - If they sell 4000 pairs at $25 each, how much money will they make?

Solution

- Break-even point: $$Q = \frac{F}{SP - VC} = \frac{\$52{,}000}{\$25 - \$9} = 3250 \ pairs$$

- Profit = total revenue – total costs

$$P = (SP)Q - (F + (VC)Q)$$
$$= (\$25)4000 - (\$52{,}000 + (\$9)4000)$$
$$= \$12{,}000$$

Class exercise

Breakeven Analysis

Travis and Jeff own Up Right Paddlers, a start-up company with the goal of designing, making, and marketing stand-up paddle boards for streams and rivers. A new fitness craze, stand-up paddle boards are similar to surfboards in appearance, but are used by individuals to navigate down rivers in an upright position with a single long pole (or paddle), instead of sitting in tubes or rafts and floating down. River boards are constructed from heavy-duty raft material that is inflatable, rather than fiberglass used in ocean boards. Unlike ocean boards that market for $500 to $1000 each, river boards are typically sold for between $100 and $400. Since Travis and Jeff are just starting out and the demand for paddle boards on the East Coast has not been firmly established, they anticipate selling their product for $100 each. Travis estimates the fixed cost for equipment and space will be $2000, and the material and labor costs will run $50 per unit. What volume of demand will be necessary for Travis and Jeff to break even on their new venture?

Fixed cost (FC)= $2000
Variable cost (VC)=$50 per board
Selling Price (SP)= $100 per board

$$Q = \frac{F}{SP - VC} = \frac{\$2,000}{\$100 - \$50} = 40 board$$

Process Selection

Jeff, the more optimistic of the two owners of UpRight Paddlers, believes that demand for paddle boards will exceed the breakeven point of 40 units calculated in Example 6.1. He proposes spending $10,000 in fixed costs to buy more automated equipment that would reduce material and labor costs to $30 per board. The boards would sell for $100, regardless of which manufacturing process is chosen. Compare the two processes and determine for what level of demand each process would be preferred. Label Travis's proposal as Process A and Jeff's proposal as Process B.

Point of indifference = modules of (FC2-FC1)/VC1-Vc2)
Process A cost equation= 2000+$50Q
Process B cost equation= 10000+30 Q
Q=400 boards

Class exercise

6.11. Creative Designs makes intricate jewelry out of precious metal. The company is introducing a new line and needs to select a manufacturing process. Three options are available. The first involves using a mold to mass produce the design for pendants, earrings, and bracelets. The second option laser cuts the design from a block of metal using a pattern directed by the software. The third option builds the design out of metal powder (gold, silver, and bronze) via a 3D printer. The company is uncertain about demand for the new design.

Option	Fixed Cost	Variable Cost
1	$10,000	$10
2	$ 5,000	$30
3	$ 3,000	$50

a. If Creative Designs expects to sell 200 pieces of the new design, which process should it use?

b. If Creative Designs expects to sell 1000 pieces of the new design, which process should it use?

c. Create a decision rule that specifies which process to select for different levels of demand.

Process Analysis, Assembly Operations, Little’s Law

Process Analysis Terms

Throughput: the output of a production process per unit time (in aircraft/month, patients/hour, $/year). Sometimes also called flow or 'l'.

Stock: the inventory between the start and end of the process (in aircraft, patients, dollars). Sometimes also called number in system or work in process (WIP) or 'L'.

Lead time: time from entry into the system until exit from the system (in months, hours, years). Sometimes also called time in system or flow time or cycle time or 'W'.

Raw process time: time necessary to complete actual work. Or, time for one unit of the product to traverse an otherwise empty system

Process Analysis
A Fundamental Relationship

John D.C. Little at MIT gave the first mathematical proof of the ‘law’ in 1961.

Little’s Law:

(average stock) = (average throughput)*(average lead time)

Warning: Little’s Law will apply to any process as long as:

- consistent units are used.
- long-term averages are used (during the observation period we take a large ‘sample’ and most of what has come in has also gone out).
- consistent flows are measured.

Process Analysis: Little's Law Example

(*Average stock*) = (*Average throughput*)*(*Average lead time*)

At a/c case,

avg. throughput = 5 aircraft/month,
avg. lead time = 2 months

avg. stock = 10 aircraft

Process Performance Metrics

- Operation time = $\frac{\text{Setup time}}{\text{Run time}}$
- Throughput time = Average time for a unit to move through the system
- Velocity = $\frac{\text{Throughput time}}{\text{Value-added time}}$
- Cycle time = Average time between completion of units
- Throughput rate = $\frac{1}{\text{Cycle time}}$
- Efficiency = $\frac{\text{Actual output}}{\text{Standard Output}}$
- Productivity = Output/Input
- Utilization = Time Activated/ Time Available

Cycle Time Example

- Suppose you had to produce 600 units in 80 hours to meet the demand requirements of a product. What is the cycle time (in minutes) to meet this demand requirement?
- Answer: There are 4,800 minutes (60 minutes/hour x 80 hours) in 80 hours. So the average time between completions would have to be: Cycle time = 4,800/600 units = 8 minutes.

Process Throughput Time Reduction

- Perform activities in parallel.
- Change the sequence of activities.
- Reduce interruptions.

Product/Production relationships

Product parameters that are influential in determining how the products are manufactured;

- Prod. Quantity
- Prod. Variety------hard product variety and soft product variety
- Complexity of assembles products
- Complexity of individual parts

Contd…

- Q= production quantity
- P= product variety
- QP= product variety and product relationships
- q= the number of units of a given part or product that and produced annually by a plant
- Q_j= annual quantity of style j
- Q_f= total quantity of all parts or products made by the factory
- P= total number of different part or product styles
- Where j=1,2,3……..P

$$Q_f = \sum_{j=1}^{P} Q_j$$

Contd..

- Number of component n_p represents the product complexity
- The number of processing steps required to produce it n_o

Type of Plant	Np-no	Description
Parts producer	$n_p=1, n_o>1$	Produce individual component and requires multiple processing
Assembly plant	$n_p>1; n_o=1$	A pure assembly plant produces no parts
Vertically integrated plant	$n_p>1, n_o>1$	The pure plant of this type makes all its parts and assemblies them into final product

Designing factory process

$n_{pf} = total$ number of parts made in the factory (pcs/year)

$Q_j = annual$ quantity of product style j

$\mathrm{n}_{pj} = number$ of parts in product j (pcs/product)

$$\mathrm{n}_{pf} = \sum_{j=1}^{P} Q_j.\mathrm{n}_{pj}$$

n_{of} = total number of operations cycles performed in factory (ops/year0

n_{ojk} = number of processing ops for each part k, summed over the number of parts in product j, n_{pj}

$$n_{of} = \sum_{j=1}^{P} Q_j.\sum_{k=1}^{n_{pj}} n_{ojk}$$

Contd..

- If we assume the number of product design P are produced in equal quantities Q, all products have the same number of the components n_p, and all components require an equal number of processing steps n_o
- Then, total number of product units $Q_f = P.Q$
- Total number of the parts produced by the factory $n_{pf} = P.Q.n_p$
- Total number of manufacturing operations cycles $n_{of} = P.Q.n_p.n_o$

Plant capabilities

- The plant capabilities is based on
- Technological processing capability
- Production capacity

Example

- A company has designed a new product line. It will build a new plant to manufacture this product line. The new line consists of 100 different product types. Annual production of the company is 10,000 units each product. Every product has an average of 1000 parts. The average number of operations required for each part is 10. All parts will be made in the plant. Each operations takes an average of 1 minutes.

Compute

- How many products will the company produce?
- How many parts will the plant process?
- How many operations will the plant perform?
- How many workers will be needed for the plant, if it operates one shift for 250 days/yr?

Answer

The number of products P=100

Number of parts: P.Q.n_p

100*10000*1000= 10^9

The number of operations P.Q.n_p.n_o

100*10000*1000*10= 10^10

Workforce required

Number of operations =10^10

T=1 min/cycle D=250days/year

S=1 shift/day H=8hrs/shift

$$\text{workers}=\frac{n_{of}.T_c}{D.S.H.60}=83333\,person$$

Production Process planning

- Production capacity is defined as the maximum rate of output that a production facility able to produce under set of assumed operating conditions.

$$\text{Plantcapacity} = n.S.H.R_p$$

n=no of work center

S= number of shift per week

H= number of hours per shift

R_p=hourly production rate (pc/hours)

if each work unit is routed through n_o and

each operation requires a new setup or processing on different m/c then

$$PC = \frac{n.S.H.R_p}{n_o}$$

Example

A Pizza baking shop having six baking oven, all devoted to the production of the same type of the pizza. The shop operates 10shifts/week. The number of hours per shift averages 8.0. Average production rate of each oven is 17 pc/hour. Determine the weekly production capacity.

PC= 6*10*8*17= 8160 pizza/week

Utilization

- Utilization refers to the amount of output of a production facility relative to its capacity
- U= Q/PC
- If all ovens are able to produce only 6000 units per week and was idle remaining time then
- U= 6000/8160=73.50 %

Process availability

- Availability is a common measure of reliability for equipment.
- Mean time between failure (MTBF)- is the average time during equipment is running
- Mean time to repair (MTTR) is the average time required for servicing a equipment
- %A= (MTBF-MTTR)/MTBF
- With the previous data, if a oven is availability is 90% and utilisation of oven 80% then final quantity produced
- PC.U.A= 8160*.8*.9= 5875