Department of Mechanical Engineering

DESIGN FOR MANUFACTURE- (R16)
(ELECTIVE – II)

UNIT - I

Introduction: Design philosophy-steps in design process-general design rules for manufacturability-basic principles of designing for economical production-creativity in design. Design for the life cycle total product life of consumer goods-design considerations.

Philosophy of design is the study of assumptions, foundations, and implications of design. The field is defined by an interest in a set of problems, or an interest in central or foundational concerns in design.

Design philosophy 1: Make your design instinctive

Designers should observe users' subconscious behavior and how they typically engage with digital products. Only then can they design solutions that users can interact with instinctively.
Designers should focus on creating experiences that accommodate users' interactions and responses, rather than trying to create new and different experiences that users can't relate to.

Design philosophy 2: Make things to last, don't replace them

'One should be in harmony with his or her environment, and things should be made to last rather than be replaced'.
The main purpose is to create design things that improve everyday life – efficient solutions that are built to last.

Design philosophy 3: Designers are not users

Essentially, designers shouldn't design for themselves but for the user. Sure, web and UX designers must have enthusiasm for what they are building. But this doesn't mean that they should take their own design assumptions.
'designers are not users' and they shouldn't rely on their assumptions of what the user wants or needs. To avoid designing with bias and really improve the user experience, designers need to get to know their users.

Design philosophy 4: Function over form

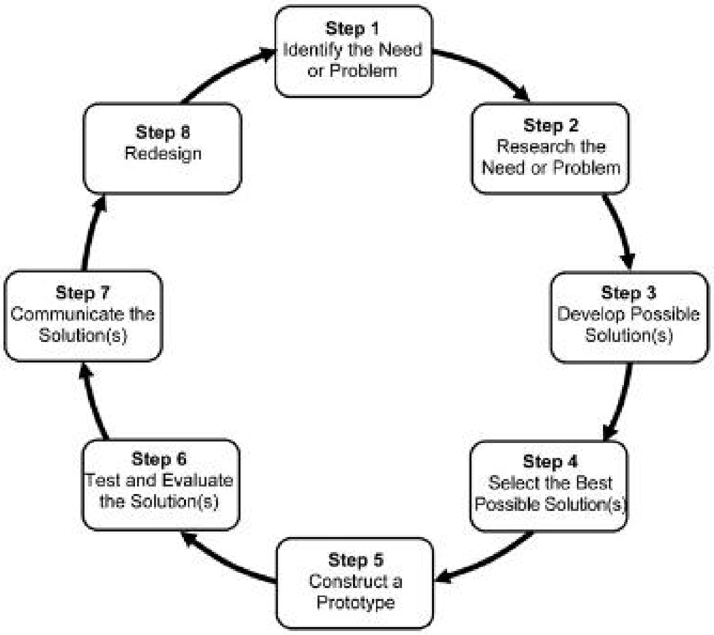
Designs are driven by the purpose of the object, rather than its aesthetics – seeking to achieve design purity through reduction and restraint.
To make something that people want to use, it needs to be useful, "good design emphasizes the usefulness of a product while disregarding anything that could possibly detract from it."

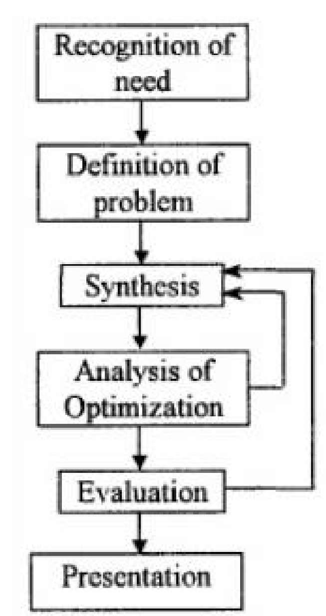
Design philosophy 5: Good design should be experienced and not seen

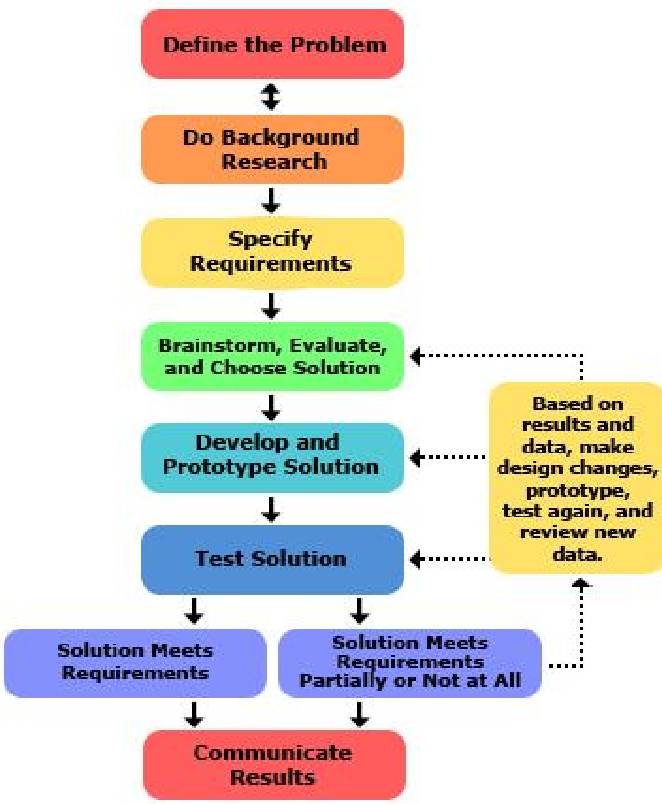
The better the design, the more subtle it becomes and the less we pay attention to it:

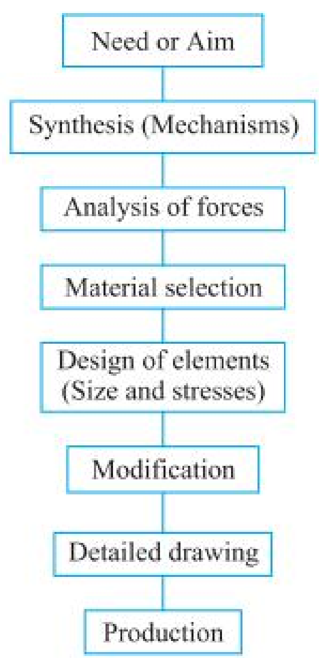
" It's like an air conditioner in a conference room. Nobody ever interrupts our meetings to tell us how comfortable the temperature is. They don't even notice."

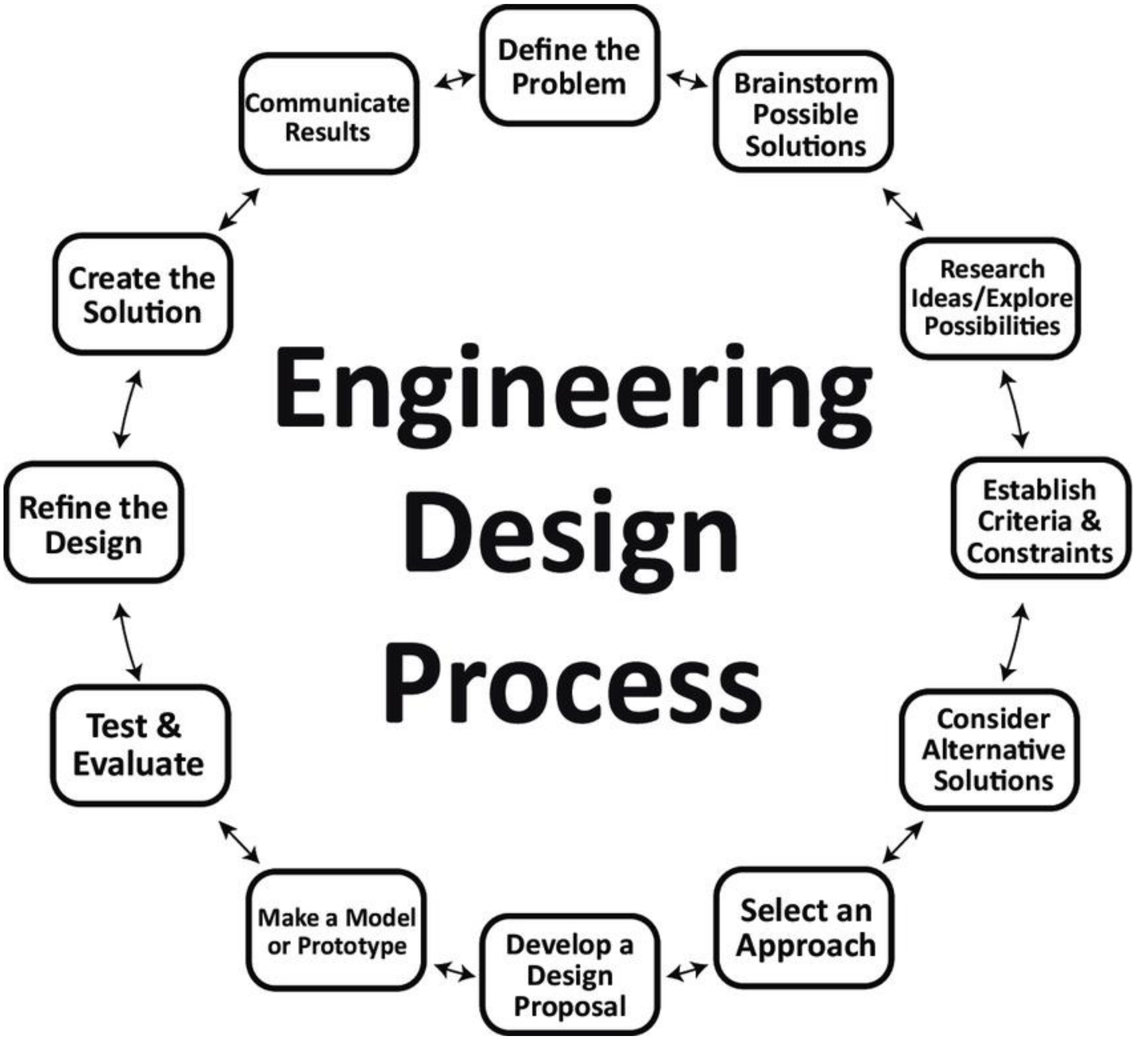
Steps in design process











DESIGN CONSIDERATIONS

- Strength
- Rigidity
- Reliability
- Safety
- Cost
- Weight
- Ergonomics
- Aesthetics
- Manufacturing considerations
- Assembly considerations
- Conformance to standards
- Friction and wear
- Life
- Vibrations
- Thermal considerations
- Lubrication
- Maintenance
- Flexibility
- Size and shape
- Stiffness
- Corrosion
- Noise
- Environmental considerations

Design considerations

- Type of Load and Stresses caused by the Load

The load on the Machine Component may act in several ways due to which the Internal Stresses are set up

- Motion of Parts

The successful operation of any Machine depends largely upon the simplest arrangements of the Parts, which will give the required motion. Hence the Motion of the Part may be,
A) Rectilinear Motion, which includes Unidirectional and Reciprocating Motion
B) Curvilinear Motion, which includes Rotary, Oscillatory Simple Harmonic
C) Constant Velocity
D) Constant or Variable Acceleration

- Selection of Material

Every Machine Design Engineer should have a thorough knowledge of the Properties of Material and their behaviour under working conditions.

- Form and Size of the Parts

In order to Design any Machine Part for form and size, it is necessary to know the Forces which the Part must sustain.
So, any suddenly applied or impact load must be taken into consideration, which may cause failure.

- Frictional Resistance and Lubrication

There is always a Loss of Power due to Frictional Resistance.
Hence, Careful attention must be given to the matter of Lubrication of all surfaces which moves in contact with others.

- Safety of Operator

A Machine Designer should always provide a safety device for the safety of the operator.
Also, The Safety Appliances should in no way interfere with the operation of the Machine.

- Use of Standard Parts

The uses of Standard Parts are closely related to the Cost of Machine.
Because the Cost of Standard Parts is only a fraction of the cost of similar parts made to order.

- Convenient and Economical Features

The operating feature of the machine should be carefully studied.
The Starting, Controlling and Stopping Levers should be located on the basis of convenient handling.

- Workshop Facilities

A Design Engineer should be familiar with the limitation of his Employer's Workshop.
So, we can avoid the necessity of having work done in some other Workshop.

- Assembling

Every Machine must be assembled as a unit before it can function.
The final Location of any Machine is important.
Hence, The Design Engineer must anticipate the exact location and the local facilities for erection.

The development of a complete plant design requires consideration of many different factors such as: a. Plant location b. Site and plant layout c. Plant operation and control d. Utilities e. Storage f. Waste disposal g. Health and safety h. Materials handling

General Design Considerations

a- Plant Location and Site Selection The geographical location of the final plant can have strong influence on the success of an industrial venture. Considerable care must be exercised in selecting the plant site, and many different factors must be considered. Primarily, the plant should be located where the minimum cost of production and distribution can be obtained, but other factors, such as room for expansion and safe living conditions for plant operation as well as the surrounding community, are also important.

The major factors in the selection of most plant sites are:

Marketing Area For materials that are produced in bulk quantities, such as cement, mineral acids, and fertilizers, where the cost of the product per metric ton is relatively low and the cost of transport is a significant fraction of the sales price, the plant should be located close to the primary market. This consideration is much less important for low-volume production and high-priced products, such as pharmaceuticals.

Raw Materials The availability and price of suitable raw materials will often determine the site location. Plants that produce bulk chemicals are best located close to the source of the major raw material, as long as the costs of shipping product are not greater than the cost of shipping feed. For example, at the time of writing much of the new ethylene capacity that is being added worldwide is being built in the Middle East, close to supplies of cheap ethane from natural gas. Oil refineries, on the other hand, tend to be located close to major population centers, as an oil refinery produces many grades of fuel, which are expensive to ship separately.

Transportation Facilities The transport of materials and products to and from the plant can be an overriding consideration in site selection. If practicable, a site should be selected that is close to at least two major forms of transport: road, rail, waterway (canal or river), or a sea port. Road transport is increasingly used and is suitable for local distribution from a central warehouse. Rail transport is usually cheaper for the long-distance transport of bulk chemicals. Air transport is 2 convenient and efficient for the movement of personnel and essential equipment and supplies, and the proximity of the site to a major airport should be considered.

Availability of Labors Labor will be needed for construction of the plant and its operation. Skilled construction workers are usually brought in from outside the site area, but there should be an adequate pool of unskilled labor available locally, and labor suitable for training to operate the plant. Skilled craft workers such as electricians, welders, and pipe fitters will be needed for plant maintenance. Local labor laws, trade union customs, and restrictive practices must be considered when assessing the availability and suitability of the local labor for recruitment and training.

Water supply Chemical processes invariably require large quantities of water for cooling, washing, steam generation, and as a raw material, and the plant must be located near a source of water of suitable quality. Process water may be drawn from a river, from wells, or purchased from a local authority.

Energy Availability (power and fuel) Power and steam requirements are high in most industrial plants, and fuel is ordinarily required to supply these utilities. Consequently, power and fuel can be combined as one major factor in the choice of a plant site. If the plant requires large quantities of coal or oil, location near a source of fuel supply may be essential for economic operation. The local cost of power can help determine whether power should be purchased or self-generated. Electrical power is needed at all sites. Electrochemical processes (for example, chlorine manufacture or aluminum smelting) require large quantities of power and must be located close to a cheap source of power. A competitively priced fuel must be available on site for steam and power generation.

Climate Adverse climatic conditions at a site will increase costs. Abnormally low temperatures require the provision of additional insulation and special heating for equipment and pipe runs. Stronger structures are needed at locations subject to high winds (cyclone/ hurricane areas) or earthquakes. Corrosive environments will need strong protection for the plant equipment.

b- Site layout and plant layout

Site layout The process units and ancillary buildings should be laid out to give the most economical flow of materials and personnel around the site. Hazardous processes must be located at a safe distance from other buildings. Consideration must also be given to the future expansion of the site. The ancillary buildings and services required on a site, in addition to the main processing units (buildings), include

1. Storage for raw materials and products: tank farms and warehouses; 2. Maintenance workshops; 3. Stores, for maintenance and operating supplies; 4. Laboratories for process quality control; 5. Fire stations and other emergency services; 6. Utilities; 7. Effluent disposal plant: waste water treatment, solid and or liquid waste collection; 8. Offices for general administration; 9. Canteens and other amenity buildings, such as medical centers; 10. Parking lots.

When the preliminary site layout is roughed out, the process units are normally sited first and arranged to give a smooth flow of materials through the various processing steps, from raw material to final product storage. Process units are normally spaced at least 30 m apart; greater spacing may be needed for hazardous processes.

The location of the principal ancillary buildings should then be decided. They should be arranged so as to minimize the time spent by personnel in traveling between buildings. Administration offices and laboratories, in which a relatively large number of people will be working, should be located well away from potentially hazardous processes. Control rooms are normally located adjacent to the processing units, but those with potentially hazardous processes may have to be sited at a safer distance.

The sitting of the main process units determines the layout of the plant roads, pipe alleys, and drains. Access roads to each building are needed for construction and for operation and maintenance.

Some rules (notes) about the site layout Utility buildings should be sited to give the most economical run of pipes to and from the process units. Cooling towers should be sited so that, under the prevailing wind, the plume of condensate spray drifts away from the plant area and adjacent properties. 4 The main storage areas should be placed between the loading and unloading facilities and the process units they serve. Storage tanks containing hazardous materials should be sited at least 70 m (200 ft) from the site boundary.

Plant layout The economic construction and efficient operation of a process unit will depend on how well the plant and equipment specified on the process flow sheet is laid out. The arrangement of the major items of equipment often follows the sequence given on the process flow sheet: with the columns and vessels arranged in rows and the ancillary equipment, such as heat exchangers and pumps, positioned along the outside. The principal factors to be considered in making plant layout are: 1. Economic considerations: construction and operating costs; 2. The process requirements; 3. Convenience of operation; 4. Convenience of maintenance; 5. Safety; 6. Future expansion

1. Economic considerations: construction and operating costs The cost of construction can be minimized by adopting a layout that gives the shortest run of connecting pipe between equipment and the least amount of structural steel work; however, this will not necessarily be the best arrangement for operation and maintenance.

2. Process Requirements An example of the need to take into account process considerations is the need to elevate the base of columns to provide the necessary net positive suction head to a pump or the operating head for a thermosiphon reboiler.

3. Operation Equipment that needs to have frequent operator attention should be located convenient to the control room. Valves, sample points, and instruments should be located at convenient positions and heights. Sufficient working space and headroom must be provided to allow easy access to equipment. If it is anticipated that equipment will need replacement, then sufficient space must be allowed to permit access for lifting equipment.

4. Maintenance Heat exchangers need to be sited so that the tube bundles can be easily withdrawn for cleaning and tube replacement. Vessels that require frequent replacement of catalyst or packing should be located on the outside of buildings.

Equipment that requires dismantling for maintenance, such as compressors and large pumps, should be placed under cover.

5. Safety Blast walls may be needed to isolate potentially hazardous equipment and confine the effects of an explosion. At least two escape routes for operators must be provided from each level in process buildings.

6. Plant Expansion Equipment should be located so that it can be conveniently tied in with any future expansion of the process. Space should be left on pipe racks for future needs, and service pipes should be oversized to allow for future requirements.

Steps in design process

Recognition of need: The problems in the existing products (or) Potential for new products in market has to be identified.

Definition of problem:
The problem in the existing product or specification of the new product is specified as “Design Brief” to the designers. It includes the specification of physical and functional characteristics, cost, quality, performance requirements etc.

Synthesis: In this stage, the designer develops number of designs to meet the requirement of design brief.

Analysis & Optimization:
•Each design from the synthesis stages are analysed and optimum one is selected.
•It should be noted that synthesis and analysis are highly iterative. A certain component or subsystem of the overall system conceived by the designer in the synthesis stage is subjected to analysis.
•Based on the analysis, improvements are made and redesigned. The process is repeated until the design optimized within all the constraints imposed by designer

Evaluation:
•In this stage optimized design from the previous stage is checked for all the specification mentioned in the “Design Brief”.
•A prototype of the product is developed and experimentally checked for its performance, quality, reliability and other aspects of product.
•The discrepancies/problems are faced, it is recommend to redesign the product which should be fed back to the designer in the synthesis stage.

Presentation: After the product design passing through the evaluation stage, drawings. diagrams, material specification, assembly lists, bill of materials etc. which are required for product manufacturing are prepared and given to process planning department and production department.

General Procedure in Machine Design
1. Recognition of need. First of all, make a complete statement of the problem, indicating the need, aim or purpose for which the machine is to be designed.
2. Synthesis (Mechanisms). Select the possible mechanism or group of mechanisms which will give the desired motion.
3. Analysis of forces. Find the forces acting on each member of the machine and the energy transmitted by each member.
4. Material selection. Select the material best suited for each member of the machine.
5. Design of elements (Size and Stresses). Find the size of each member of the machine by considering the force acting on the member and the permissible stresses for the material used. It should be kept in mind that each member should not deflect or deform than the permissible limit.

6. Modification. Modify the size of the member to agree with the past experience and judgment to facilitate manufacture. The modification may also be necessary by consideration of manufacturing to reduce overall cost.
7. Detailed drawing. Draw the detailed drawing of each component and the assembly of the machine with complete specification for the manufacturing processes suggested.
8. Production. The component, as per the drawing, is manufactured in the workshop.

General Design rules for manufacturability

1. Reduce the total number of parts. The reduction of the number of parts in a product is probably the best opportunity for reducing manufacturing costs. Less parts implies less purchases, inventory, handling, processing time, development time, equipment, engineering time, assembly difficulty, service inspection, testing, etc. In general, it reduces the level of intensity of all activities related to the product during its entire life.

2. Develop a modular design. The use of modules in product design simplifies manufacturing activities such as inspection, testing, assembly, purchasing, redesign, maintenance, service, and so on. One reason is that modules add versatility to product update in the redesign process, help run tests before the final assembly is put together, and allow the use of standard components to minimize product variations.

3. Use of standard components. Standard components are less expensive than custom-made items. The high availability of these components reduces product lead times. Also, their reliability factors are well ascertained.

4. Design parts to be multi-functional. Multi-functional parts reduce the total number of parts in a design, thus, obtaining the benefits given in rule 1. Some examples are a part to act as both an electric conductor and as a structural member, or as a heat dissipating element and as a structural member.

5. Design parts for multi-use. In a manufacturing firm, different products can share parts that have been designed for multi-use. These parts can have the same or different functions when used in different products. In order to do this, it is necessary to identify the parts that are suitable for multi-use. For example, all the parts used in the firm (purchased or made) can be sorted into two groups: the first containing all the parts that are used commonly in all products. Then, part families are created by defining categories of similar parts in each group. The goal is to minimize the number of categories, the variations within the categories, and the number of design features within each variation.

6. Design for ease of fabrication. Select the optimum combination between the material and fabrication process to minimize the overall manufacturing cost. In general, final operations such as painting, polishing, finish machining, etc. should be avoided. Excessive tolerance, surface-finish requirement, and so on are commonly found problems that result in higher than necessary production cost.

7. Avoid separate fasteners. The use of fasteners increases the cost of manufacturing a part due to the handling and feeding operations that have to be performed. In general, fasteners should be avoided and replaced, for example, by using tabs or snap fits

8. Minimize assembly directions. All parts should be assembled from one direction. If possible, the best way to add parts is from above, in a vertical direction, parallel to the gravitational direction (downward). In this way, the effects of gravity help the assembly process, contrary to having to compensate for its effect when other directions are chosen.

9. Maximize compliance. Errors can occur during insertion operations due to variations in part dimensions or on the accuracy of the positioning device used. This faulty behavior can cause damage to the part and/or to the equipment. For this reason, it is necessary to include compliance in the part design and in the assembly process. Examples of part built-in compliance features include tapers or chamfers and moderate radius sizes to facilitate insertion, and nonfunctional external elements to help detect hidden features.

10. Minimize handling. Handling consists of positioning, orienting, and fixing a part or component. To facilitate orientation, symmetrical parts should be used when ever possible. If it is not possible, then the asymmetry must be exaggerated to avoid failures. Use external guiding features to help the orientation of a part.

Basic principles of designing for economical production-creativity in design.

1. Simplicity
2. Standard materials and components
3. Standardized design of the product itself
4. Liberal tolerances
5. Use of the most processible materials
6. Teamwork with manufacturing personnel
7. Avoidance of secondary operations
8. Design appropriate to the expected level of production
9. Utilizing special process characteristics
10. Avoiding process restrictiveness

Simplicity

- Description: minimize the number of parts, intricate shapes, and manufacturing operations
- Motivation: generally provides reduced cost, improved reliability, easier servicing, and improved robustness
- Example: Braun Lift

Standard materials and components

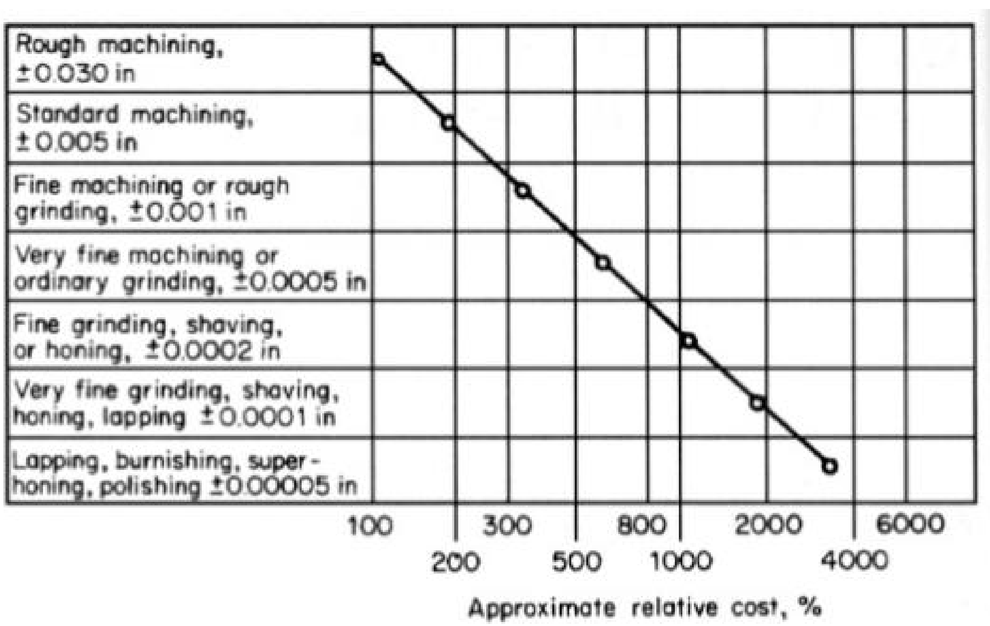
- Description: Use standard off-the-shelf parts and widely available materials
- Motivation: eases purchasing, simplifies inventory management, and avoids tooling investments
- Example: Screws

Standardized design of the product itself

- Description: For similar products, specify the same materials, parts, and subassemblies as much as possible.
- Motivation: provides economies of scale, simplifies operations, and simplifies inventory management
- Example: Braun Lift

Liberal tolerances

- Description: make tolerances as forgiving as possible
- Motivation: tight tolerances are expensive (in a non-linear fashion)



Use Easily Processed Materials

- Description: take advantage of materials that have been developed for easy processibility
- Motivation: while material may cost more, it will often provide lower overall cost
- Example: "Free-Machining" Grades, Many polymer grades are tuned to a process

Teamwork with Manufacturing Personnel

- Description: collaborate with the people who will be producing your product (the earlier the better)
- Motivation: they provide a unique body of knowledge and useful insights

Avoidance of Secondary Operations

- Description: minimize the need for secondary operations
- Motivation: secondary operations (e.g. deburring, inspection, painting, and heat treating) can be as expensive as the primary manufacturing operation
- Example: Pre-painted steel, investment casting, MIM in firearms

Understand and Utilize Manufacturing Process Characteristics

- Description: understand and take advantage of the special capabilities of various manufacturing processes
- Motivation: can often eliminate manufacturing operations and reduce the number of parts
- Example: injection molding snap fits and living hinges

Avoiding process restrictiveness

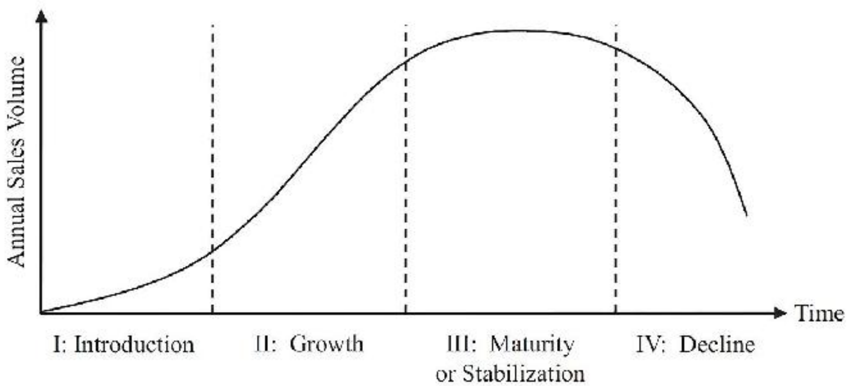
- Description: on part drawings, specify only the final characteristics needed; do not specify the process to be used
- Motivation: potential cost savings

Product life-cycle management (PLM) is the succession of strategies by business management as a product goes through its life-cycle. The conditions in which a product is sold (advertising, saturation) changes over time and must be managed as it moves through its succession of stages.

Product Life Cycle

Product life cycle is a representation of the cycle through which each product goes through from introduction to decline and eventual demise of the product. The Product Life Cycle helps us recognize which stage the products are in. Accordingly, the company can adjust their marketing strategy to make most of the conditions.

There are four distinct stages in a product's lifecycle. Right from the introduction of the product in the market to its end. Every stage has its own distinct features. And the company should change its marketing strategy every time the product makes its move from one stage to another. Let us take a look at the four stages.



1. Introduction

As the name suggests this is the stage of introduction of the product to the market. At this stage, the demand for the product is only a proved demand and not effective demand. This stage is categorized by the following features

- The product's sale is at its lowest and is increasing but very slowly
- During the introduction, the promotion expense is very high. Extensive promotions have to be undertaken to create awareness and demand for the product.
- The products are put in limited outlets. The distribution is also kept limited to a few channels. The point is to try out the product before expanding distribution.

2. Growth Stage

This is the second stage of the product lifecycle. Now the sales begin to take off and the product becomes well known. Some other characteristics are

- The promotion expenses still remain high. Now the focus will be on brand recognition and brand image. This helps the product maintain and extend its selective demand.
- With a rise in sales, the profits also rise sharply
- This is the stage where new competitors may enter the market with better research and better products. To keep up with their products, the company may make improvement and modifications to their products

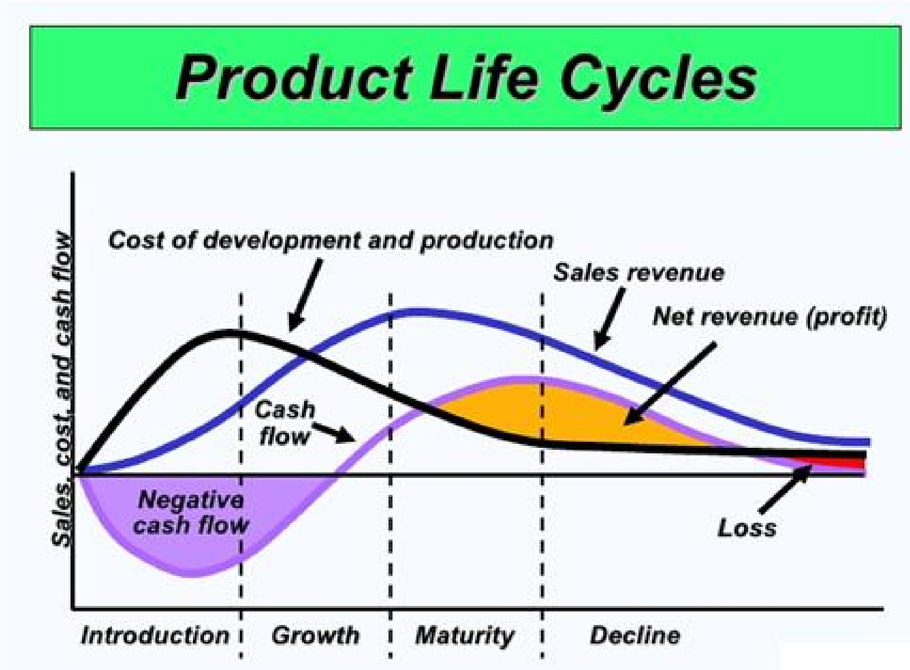
3. Maturity Stage

- This is the stage where the market saturates and sales growth of the firm slow down and finally stabilizes at a stage.
- Competition in the market will intensify in this stage. All competitors will want to maintain a production level to enjoy economies of scale
- This stage may also see a price war in order to keep their market share. Reducing prices may affect the profit margin of the company.

4. Decline Stage

This the terminal stage of the products, they are no longer relevant in the market. So the end of this stage is the eventual demise of the product in the market.

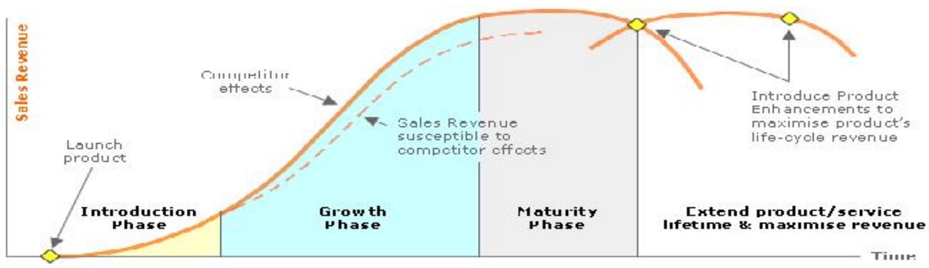
Identifying features	Stages			
	Introduction	Growth	Maturity	Decline
Sales	Low	High	High	Low
Investment cost	Very high	High (lower than introduction stage)	Low	Low
Competition	Low or no competition	High	Very high	Very High
Profit	Low	High	High	Low



Extending the product life cycle

Extending the product life cycle by improving sales, this can be done through

- Advertising: Its purpose is to get additional audience and potential customers.
- Exploring and expanding to new markets: By conducting market research and offering the product (or some adapted form of it) to new markets, it is possible to get more customers.
- Price reduction: Many customers are attracted by price cuts and discount tags.
- Adding new features: Adding value to the product to enhance its usability or to attract the attention of a wider customer base.
- Packaging: New, attractive, useful or eco-friendly packaging influence the target customers.
- Changing customer consumption habits: Promoting new trends of consumption can increase the number of customers.
- Special promotions: Raising interest by offering Jackpot and other offers.



SHORT & LONG ANSWER QUESTIONS

1. a) Explain the principles which are to be followed while designing a product considering the economical aspects.
   b) What is design philosophy?
2. a) Draw the schematic diagram of the basic elements of a design process and explain them briefly.
   b) Briefly explain the design considerations.
3. a) Discuss the general design rules for manufacturability.
   b) Explain the design for the life cycle total product life of consumer goods.