NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE
(NAAC Accredited)
(Approved by AICTE, Affiliated to APJ Abdul Kalam Technological University, Kerala)

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

COURSE MATERIALS

BE 102 DESIGN AND ENGINEERING

VISION OF THE INSTITUTION

To mould true citizens who are millennium leaders and catalysts of change through excellence in education.

MISSION OF THE INSTITUTION

NCERC is committed to transform itself into a center of excellence in Learning and Research in Engineering and Frontier Technology and to impart quality education to mould technically competent citizens with moral integrity, social commitment and ethical values.

We intend to facilitate our students to assimilate the latest technological know-how and to imbibe discipline, culture and spiritually, and to mould them in to technological giants, dedicated research scientists and intellectual leaders of the country who can spread the beams of light and happiness among the poor and the underprivileged.

ABOUT DEPARTMENT

- Established in: 2002
- Course offered : B.Tech in Computer Science and Engineering

  M.Tech in Computer Science and Engineering

  M.Tech in Cyber Security
- Approved by AICTE New Delhi and Accredited by NAAC
- Affiliated to the University of . A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing Highly Competent, Innovative and Ethical Computer Science and Engineering Professionals to facilitate continuous technological advancement.

DEPARTMENT MISSION

1. To Impart Quality Education by creative Teaching Learning Process
2. To Promote cutting-edge Research and Development Process to solve real world problems with emerging technologies.
3. To Inculcate Entrepreneurship Skills among Students.
4. To cultivate Moral and Ethical Values in their Profession.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates will be able to Work and Contribute in the domains of Computer Science and Engineering through lifelong learning.

PEO2: Graduates will be able to Analyse, design and development of novel Software Packages, Web Services, System Tools and Components as per needs and specifications.

PEO3: Graduates will be able to demonstrate their ability to adapt to a rapidly changing environment by learning and applying new technologies.

PEO4: Graduates will be able to adopt ethical attitudes, exhibit effective communication skills, Team work and leadership qualities.

PROGRAM OUTCOMES (POS)

Engineering Graduates will be able to:

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO1: Ability to Formulate and Simulate Innovative Ideas to provide software solutions for Real-time Problems and to investigate for its future scope.

PSO2: Ability to learn and apply various methodologies for facilitating development of high quality System Software Tools and Efficient Web Design Models with a focus on performance optimization.

PSO3: Ability to inculcate the Knowledge for developing Codes and integrating hardware/software products in the domains of Big Data Analytics, Web Applications and Mobile Apps to create innovative career path and for the socially relevant issues.

COURSE OUTCOMES

CO1	Understand the different elements involved in good designs and practice them when called for.
CO2	Solve the different stages of Design and formulate detailed designs with solid modeling and visualization.
CO3	Acquire knowledge about prototype and propose various stages towards final product design.
CO4	Build a broader perspective of design covering the function, cost, environmental sensitivity, safety and factors other than from engineering analysis
CO5	Identify product oriented and user-oriented aspects that make the customer required design.
CO6	Utilize various modern engineering methods and build basic knowledge of Intellectual Property Rights.

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**
CO1	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
CO2	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
CO3	**2**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
CO4	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
CO5	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**
CO6	**3**	**-**	**3**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**

Note: H-Highly correlated=3, M-Medium correlated=2, L-Less correlated=1

MAPPING OF COURSE OUTCOMES WITH PROGRAM SPECIFIC OUTCOMES

	PSO1	PSO2	PSO3
CO1	2	2	
CO2		2	
CO3	2	2	
CO4		2	
CO5		3	2
CO6		3	2

SYLLABUS

Course No.	Course Name	L-T-P-Credits	Year of Introduction
BE102	DESIGN AND ENGINEERING	2-0-2-3	2016

Course Objectives

The purpose of this course is:-

1. To excite the student on creative design and its significance;
2. To make the student aware of the processes involved in design;
3. To make the student understand the interesting interaction of various segments of humanities, sciences and engineering in the evolution of a design;
4. To get an exposure as to how to engineer a design.

Syllabus

Design and its objectives; Role of science, engineering and technology in design; Engineering as a business proposition; Creative design and the Design Process; Design evaluation and communication of designs; Design for function and strength; Material selection and design detailing; Role of standards in design Engineering the design; Design for "X"; Product centered and user centered design; Aesthetics and ergonomics; Concepts of value engineering, concurrent engineering and reverse engineering in design; Culture based design; Modular design; Design optimization needs; User interface; Intelligent and autonomous products; Internet of things; Advanced products and human psychology; Life cycle design; Product and its environment; Design as a marketing tool; Products and IPR; Product liability.

Expected outcome
The student will be:-

- Able to appreciate the different elements involved in good designs and to apply them in practice when called for.
- Aware of the product oriented and user oriented aspects that make the design a success.
- Will be capable to think of innovative designs incorporating different segments of knowledge gained in the course;
- Students will have a broader perspective of design covering function, cost, environmental sensitivity, safety and other factors other than engineering analysis.

References Books:

- Balmer, R. T., Keat, W. D., Wise, G., and Kosky, P., Exploring Engineering, Third Edition: An Introduction to Engineering and Design - [Part 3 - Chapters 17 to 27], ISBN-13: 978-0124158917 ISBN-10: 0124158919
- Dym, C. L., Little, P. and Orwin, E. J., Engineering Design - A Project based introduction - Wiley, ISBN-978-1-118-32458-5
- Eastman, C. M. (Ed.), Design for X Concurrent engineering imperatives, 1996, XI, 489 p. ISBN 978-94-011-3985-4 Springer
- Haik, Y. And Shahin, M. T., Engineering Design Process, Cengage Learning, ISBN-13: 978-0-495-66816-9
- Pahl, G., Beitz, W., Feldhusen, J. and Grote, K. H., Engineering Design: A Systematic Approach, 3rd ed. 2007, XXI, 617p., ISBN 978-1-84628-319-2
- Dieter and Schmidt, Engineering Design, McGraw Hill Education(India) Edition 2013
- Voland, G., Engineering by Design, ISBN 978-93-325-3505-3, Pearson India

Web pages:

1. E-Book (Free download): http://opim.wharton.upenn.edu/~ulrich/designbook.html
2. http://www2.warwick.ac.uk/fac/sci/wmg/ftmsc/modules/modulelist/peuss/designforx/design_for_x_notes_section_5.pdf

Course Plan

Module	Contents	Hours	Sem. Exam Marks
I	Design and its objectives; Design constraints, Design functions, Design means and Design from; Role of Science, Engineering and Technology in design; Engineering as a business proposition; Functional and Strength Designs. Design form, function and strength;	L2	15%
	How to initiate creative designs? Initiating the thinking process for designing a product of daily use. Need identification; Problem Statement; Market survey-customer requirements; Design attributes and objectives; Ideation; Brain storming approaches; arriving at solutions; Closing on to the Design needs.	L3	
	An Exercise in the process of design initiation. A simple problem is to be taken up to examine different solutions-Ceiling fan? Group Presentation and discussion.	P4	

II	Design process- Different stages in design and their significance; Defining the design space; Analogies and "thinking outside of the box"; Quality function deployment-meeting what the customer wants; Evaluation and choosing of a design.	L2	15%
	Design Communication; Realization of the concept into a configuration, drawing and model. Concept of "Complex is Simple". Design for function and strength. Design detailing- Material selection, Design visualisation- Solid modelling; Detailed 2D drawings; Tolerancing; Use of standard items in design; Research needs in design; Energy needs of the design, both in its realization and in the applications.	L3	
	An exercise in the detailed design of two products (Stapler/ door/clock)	P4	
FIRST INTERNAL EXAM			
III	Prototyping- rapid prototyping; testing and evaluation of design; Design modifications; Freezing the design; Cost analysis.	L2	15%
	Engineering the design – From prototype to product. Planning; Scheduling; Supply chains; inventory; handling;	L3	

	manufacturing/construction operations; storage; packaging; shipping; marketing; feed-back on design.		
	List out the standards organizations. Prepare a list of standard items used in any engineering specialization. Develop any design with over 50% standard items as parts.	P4	
IV	Design for "X"; covering quality, reliability, safety, manufacturing/construction, assembly, maintenance, logistics, handling; disassembly; recycling; re-engineering etc. List out the design requirements(x) for designing a rocket shell of 3 meter diameter and 8 meter length.	L4	15%
	Design mineral water bottles that could be packed compactly for transportation.	P4	
SECOND INTERNAL EXAM			
V	Product centred and user centred design. Product centred attributes and user centred attributes. Bringing the two closer. Example: Smart phone. Aesthetics and ergonomics.	L2	20%
	Value engineering, Concurrent engineering, Reverse engineering in design; Culture based design; Architectural designs; Motifs and cultural background; Tradition and design; Study the evolution of Wet grinders; Printed motifs; Role of colours in design.	L4	
	Make sharp corners and change them to smooth curves- check the acceptance. Examine the possibility of value addition for an existing product.	P6	

VI	Modular design; Design optimization; Intelligent and autonomous products; User interfaces; communication between products; autonomous products; internet of things; human psychology and the advanced products. Design as a marketing tool; Intellectual Property rights – Trade secret; patent; copy-right; trademarks; product liability.	L3	20%
	Group presentation of any such products covering all aspects that could make or mar it.	P6	
END SEMESTER EXAM			

Evaluation Scheme:

First internal exam – closed book exam – 25 marks

Second internal exam – open book exam – 25 marks

Assignment/projects – 50 marks (iv) End semester exam – open book exam – 50 marks (2 hours duration – conducted by the University)

First Test: Marks: 25 Closed Book;

Questions may cover:-

Topics covered in the lectures.

How to arrive at the design details for a specific need gap given.

Sketching the design of a product that is to meet the given user requirements.

Second Test: Marks: 25 Open Book:

Students are permitted to bring in class notes, own notes, text books and other books (Maximum 3/4 books) for the test. Access to internet and mobile phones is NOT permitted.

Assignments: Marks: 20 Two assignments are to be given (10 marks each). These assignments are to cover specific design/s, sketching of the design, and a short but well written write-up on the design.

Projects: Marks: 30 Two mini projects are to be assigned. One is to be a group project and the other an individual one. A group of 3 or 4 students can take up the group project. Each project is to be evaluated for 15 marks.

The Group Project is to be done in the practical hours given for the course. Projects including the group projects are to be evaluated based on individual presentations and answers to the questions raised. These presentations could be done during the practical hours.

Question Paper Pattern for End Semester Examination (Open Book)

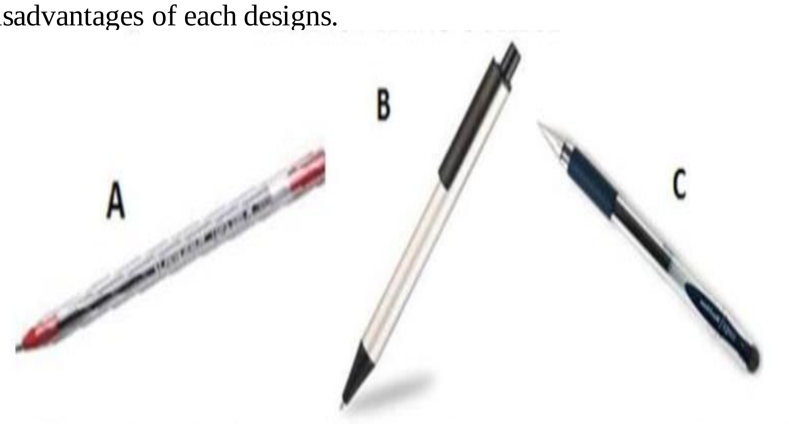
Part A – Eight questions of each 5 marks, out of which six questions are to be answered.

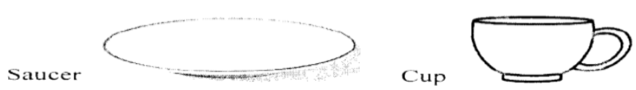
Part B – Three questions of each 10 marks, out of which two questions are to be answered.

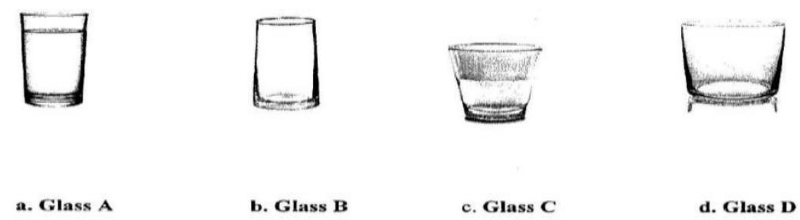
QUESTION BANK

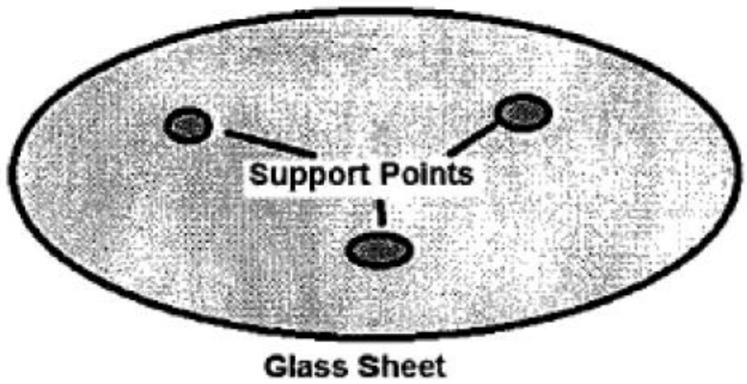
MODULE I			
Q:NO:	**QUESTIONS**	**CO**	**KL**
1	You were asked to design a coffee mug. As a designer, list out the possible limitations regarding its design.	CO1	K3
2	Explain Science & Engineering involved in any one of the following products. (i) Electric Fan (11) Radio (iii) Solar Panel	CO1	K3
3	Point out the three-step procedure for objective preparation.	CO1	K2
4	Analyze the objective tree for designing a super ladder	CO1	K4
5	List out the possible design objectives, constrains, functions and means of any one of the following products below. Also, construct its design objective tree. (i) Portable Dining Table (ii) Iron Box (iii) Navigation System for a car	CO1	K4
6	Suggest some design changes to the given coconut scraper that improve the efficiency and add value to it. 	CO1	K6
7	People experience difficulty in handling wired earphone as it gets twisted together (entangled) while taking it out from their pocket or bag. Suggest some possible design changes to overcome this difficulty.	CO1	K6
8	Write a short note on engineering design, design objectives and design constraints.	CO1	K2
9	Explain the elements of Science, Engineering, and Technology & Art with help of any one of the designs listed below. a) Ceiling Fan b) CFL c) GPS d) Camera	CO1	K3

10	A client requested you to design a baby chair that is to be used at dining room. List out some possible limitations of this design.	CO1	K6
11	Setting objectives is the primary stage of any designs. Why design objectives are so important? Substantiate your answer with suitable example.	CO1	K4
12	Justify the saying “form follows function” with an example.	CO1	K2
13	List out Objectives, Constrains, Functions & Means of any one of the designs listed below and construct an Objective tree for the design. a)Safety Helmet b) Iron box c) Portable Dining Table	CO1	K3
14	While you working in a design team to develop an automated car washing system, team leader assigned you to find out required functionality of the design. Draft a design proposal which explains the required functions and possible ways of achieving those functions.	CO1	K6
15	Justify the significance of Brain storming in decision making.	CO1	K2
	MODULE II		
1	Identify the various parts in a bicycle. Make a separate list of the parts that are not made up of metal. Sketch any two parts.	CO2	K2
2	Categorize all the possible customers of a washing machine and prepare questionnaires for each group in order to collect customer requirements.	CO2	K3
3	Design is a combination of art, architecture and engineering. Write a note to support this statement.	CO2	K4
4	Nowadays smart phones are integral part of modern life style. But a group of people found difficulty to carry smart phones while morning exercises. Suggest some optimal solutions for this problem.	CO2	K3
5	Demonstrate the four phases of Quality Function Deployment (QFD).	CO2	K2
6	Relate the basic characteristics of an engineering design.	CO2	K2
7	Outline the main objective and constraint for the design of ceiling fan.	CO2	K3
8	Suggest design changes for an ordinary tea cup (With sketch) that can add value to it. 	CO2	K6
9	Suggest design changes for a torch (With sketch) that can add value to it and improve its efficiency. How this modification reflects on market?	CO2	K6

			
10	While a designer developing an automated hair dying he was in need of identifying market requirements. Is it necessary that a designer researching about market? If it so suggest some method to collect information from market?	CO2	K6
11	Since design is a business proposition a designer should identify customer needs before designing a product. List out some possible customer needs to design a TV-remote.	CO2	K3
12	A group of engineering students gathered to develop a robot that can be used for cleaning class rooms. Suggest some scientific methods to initiate this new design.	CO2	K6
13	Explain the difference between strength design and functional design with suitable examples.	CO2	K4
14	Three differently designed pens are given below, tabulate the advantages and disadvantages of each designs. 	CO2	K5
15	30. While participating in a design competition two group of students assigned with different tasks. Group-1: Design a book shelf which should carry 100 kg Group-2: Design a camera that can be used to capture under water pictures Consider above scenario; suggest a design approach for above groups regarding the idea of “strength design” and “functional design”. Explain why?	CO2	K4c

MODULE III			
1	Analyze the Importance of supply chain management? What are the precautions required to provide continuous supply in the case of a cement company?	CO3	K4
2	Imagine you are the marketing manager of a company which sells bottled water. Design the bottle so that it as attractive and easy to carry.	CO3	K6
3	Suggest design changes for a torch (With sketch) that can add value to it and improve its efficiency. How these modifications reflect on market?	CO3	K6
4	Design a baby chair that is to be used at dining room. List out some limitations.	CO3	K6
5	In any good design, many standard parts are used. List at least 10 standard parts that are used in a completed residential house.	CO3	K3
6	Design of a chair with steel tube is shown in figure. The seat and the back rest are made of wood and are screwed on to the steel frame. Identify the interesting aspect of this design and list the number of different parts used for the chair. 	CO3	K6
7	7. The sketch below shows a plain saucer for placing the cup. What change can improve the saucer design? 	CO3	K3
MODULE IV			
1	Sketch a three-legged stool. Why three-legged chairs are not used in practice?	CO4	K3
2	Design a suitable product for easy cleaning of dust from windows, fans and lamp shades.	CO4	K6

3	What change can improve the saucer design?	CO4	K4
4	Four different design of drinking water glasses (i.e.; Glass A, B, C and D) are shown below. Discuss the merits and demerits of each of these four designs. 	CO4	K5
5	Discuss briefly any five "X" to be considered in the design for "X" of a bag to make it competitive in the market.	CO4	K2
6	4. Design a book shelf for „X", where (a) X is ease of assembly, (b) X is ease of disassembly. Justify your answer.	CO4	K6
	MODULE V		
1	Considering the principle of value engineering, design a suitable product for easy cleaning of dust from windows, fans and lamp shades.	CO5	K6
2	Design a handheld remote for household equipment's which is aesthetically and ergonomically feasible.	CO5	K6
3	Without using an air-conditioner, blower or exhaust fan, design a natural system of heat removal from the rooms of a building and simultaneous inflow of fresh air outside into the room. Prepare the necessary sketches.	CO5	K6
4	Develop and sketch anyone design concept of a mechanical system to drive a generator for energy harvesting by exploiting heavy traffic.	CO5	K5
5	A round glass of 600 mm diameter and 6 mm thick is available. This is to be designed as a table supported at three points by a steel tube bent in any convenient way. The height of the table is to be 300 mm and the total length of the tube used should not exceed 1.8 m. The tube should not be cut or joined. Design the bent tube for supporting the table.	CO5	K6

			
	MODULE VI		
1	How modular design is realized in i) Umbrella and ii) Ink Pen? Draw the different modules involved in each of these products.	CO6	K3
2	Modify the design of the conventional umbrella so that the below mentioned problems can be solved: a) The floor becomes wet once you close the umbrella and put it on the floor after a rain. b) Opening of umbrella in a crowd can hurt people.	CO6	K6
3	How modular design is realized in a bicycle? Draw the different modules involved in this product.	CO6	K4
4	Identify the different modules used in automobile.	CO6	K4
5	Public taps are now fitted with electronic sensors for hands free operation. Sketch the Design concepts of an automatic hands free flushing system for use in toilets. The system should be purely mechanical without any electronic circuits.	CO6	K5
6	Define IPR and explain the different things used for it.	CO6	K2
7	Design a water bottle with adequate trademark	CO6	K6

APPENDIX 1	
CONTENT BEYOND THE SYLLABUS	
S:NO;	TOPIC
1	Design Concept – Brute force search & Hill climbing

MODULE NOTES

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NEHRU COLLEGE OF ENGINEERING AND RESEARCH CENTRE

PAMPADY, THIRUVILWAMALA, THRISSUR (DT),680588

(ACCREDITED BY NAAC)

BE 102 DESIGN & ENGINEERING

COURSE MATERIAL

MODULE I

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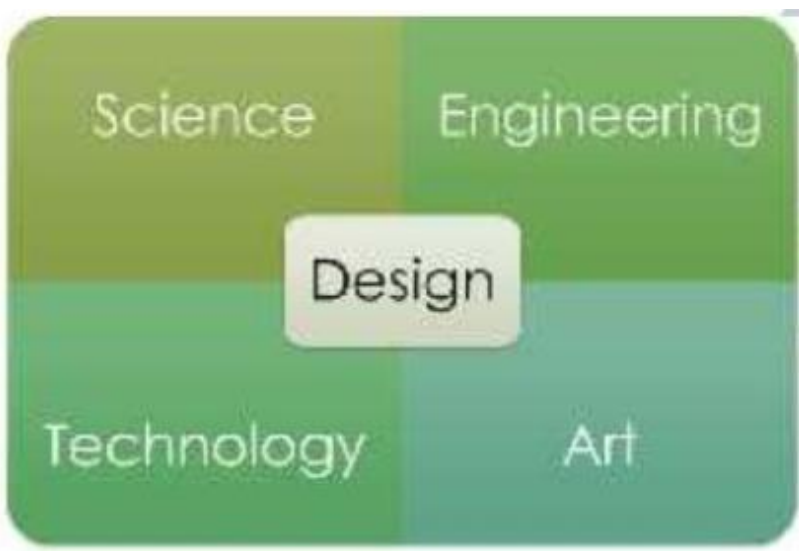
Introduction

Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and engineering sciences are applied to optimally convert resources to meet a stated objective. Among the fundamental elements of the design process is the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation.

Thus, although engineers are not the only people who design things, it is true that the professional practice of engineering is largely concerned with design; it is often said that design is the essence of engineering. To design is to pull together something new or to arrange existing things in a new way to satisfy a recognized need of society.

"Design establishes and defines solutions to and pertinent structures for problems not solved before, or new solutions to problems which have previously been solved in a different way." The ability to design is both a science and an art. The science can be learned through techniques and methods to be covered in this text, but the art is best learned by doing design. It is for this reason that your design experience must involve some realistic project experience.

Science, Technology, Engineering & Art



In a nutshell, a Scientist studies nature, a Technologist manipulates nature, and an Engineer exploits technology for human purposes. While Scientists may, at times, may conduct scientific studies for the sake of discovery, Engineers and Technologists always try to have in mind the ultimate benefit of humankind and results of their work are invariably beneficial for human purposes.

Engineering is the art of optimally using technology and is primarily concerned with how to direct to useful and economical ends the natural phenomena which scientists discover and formulate into acceptable. Engineering therefore requires the creative imagination to innovatively apply technology in order to obtain useful applications of natural phenomena.

It seeks newer, cheaper, better technologies of using natural sources of energy and materials.

Science Is very concerned with what is (exists) in the natural world. Whereas technology deals with how humans modify, change, alter, or control the natural world. And, Engineering attributes of design which let us develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

- Science is knowledge of the natural world put together, Engineering is creation based on the scientific knowledge put together, and Technology is the set of engineered creations put together.
- Science comes from observation of the world, Engineering comes from acquiring and applying knowledge, and Technology comes from repeated application and approval of the engineered tools.
- Science is about creating meaning of natural phenomenon, Engineering is about creating new devices, tools and processes, and Technology is about creating a collection of engineered and tested tools for the mankind.

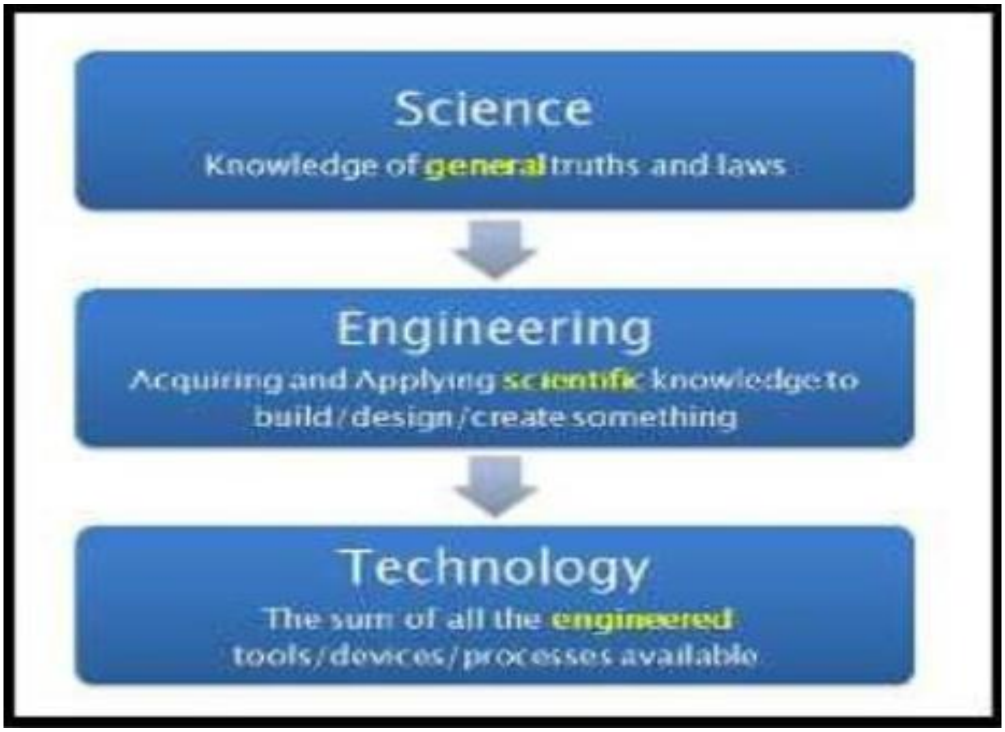
Eg-1:

Science is based on observation: The friction between a sphere and a flat surface is minimum, allowing the sphere to roll with the slightest deviation from the horizontal position of the surface. Given the weight of the sphere and the tilt angle, all parameters of the sphere motion can be calculated, including the rolling friction.

Technology: A wheel hub with ball bearings ensures long life and effortless wheel motion (e.g. cart wheel, etc.), by exploiting the minimum rolling friction principle.

Engineering: Modern vehicles wheel hubs are fitted with specially designed ball bearings which usually last well beyond the average life span of the vehicle.

Note: The intriguing behaviour of a ball on a tilted flat surface triggers the curiosity of the scientist who derives the physical and mathematical laws underpinning that behaviour. The technologist finds (invents) the application(s) exploiting the laws governing the scientific phenomenon (whether he knows them or not). The engineer finds the most appropriate design for each specific technological application of the scientific principle.



Eg-2:

Science: Burning wood produces heat, water, and carbon dioxide. Heat denatures proteins in food.

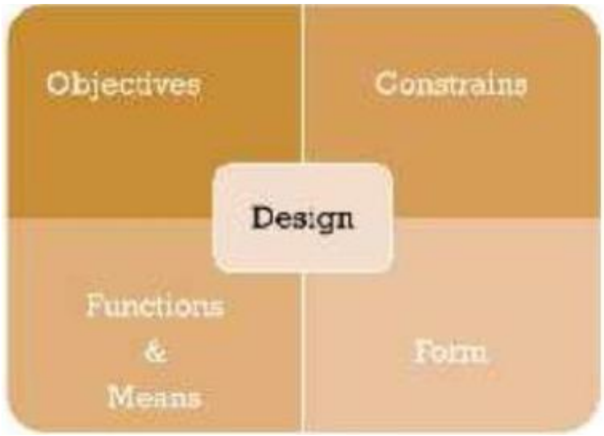
Technology: Fire can be used to cook food.

Engineering: Building a fireplace and chimney makes it easier to cook with fire without filling the room with smoke.

Hence it can be concluded that in every designs you can find the elements of science, engineering, technology and art.

Characteristics of Design or Aspects of Design

Having a defined engineering design and some vocabulary, we now define a process of design, that is, how we actually do a design. This may seem a bit abstract, because we will break down a complex process into smaller, more detailed design tasks. However, as we define those design tasks, we will identify specific design tools and methods that we use to implement a design process. Keep in mind that we are not presenting a recipe for doing design. Instead, we are outlining a framework within which we can articulate and think about what we are doing as we design something. Further, it is important to keep in mind that our overall focus will be on what we will identify as conceptual design, the early stage where different design ideas or concepts are developed and analysed.



It’s not a big surprise that a whole bunch of questions immediately come to mind. Typically, design projects start with a statement that talks about a client’s intentions or goals, the design’s form or shape, its purpose or function, and perhaps some things about legal requirements. That statement then leads to the designer’s first task: to clarify what the client wants in order to translate those wishes into meaningful objectives (goals), constraints (limits), and functions (what the design has to do). This clarification task proceeds as the designer asks the client to be more precise about what she really wants. Asking questions is an integral part of the design process. Aristotle noted long ago that knowledge resides in the questions that can be asked and the answers that can be provided. By looking at the kinds of questions that we can ask, we can articulate the design process as a Series of design tasks.

Thus the basic characteristics of any designs can be explained as follows:

Objective: a feature or behavior that the design should have or exhibit. Objectives are normally expressed as adjectives that capture what the design should be, as opposed to what the design should do. For example, saying that a ladder should be portable or lightweight expresses an attribute that the client wants the ladder to have. These features and behaviors, expressed in the natural languages of the client and of potential users, make the object “look good” in the eyes of the client or user.

Constraint: a limit or restriction on the design’s behaviors or attributes. Constraints are clearly defined limits whose satisfaction can be framed into a binary choice (e.g., a ladder material is a conductor or it is not). Any designs that violate these limits are unacceptable. For example, when we say a ladder must meet OSHA standards, we are stating a constraint.

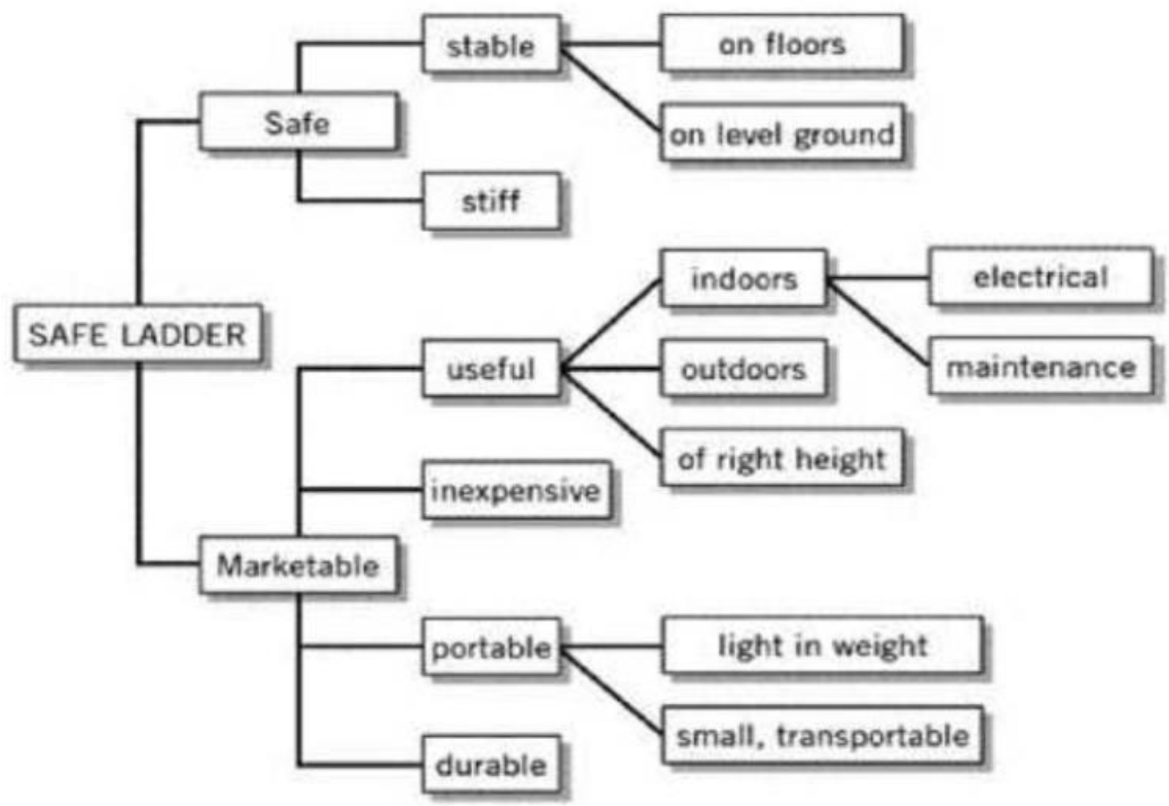
Function: a specific thing a designed device or system is expected to do. Functions are typically expressed as “doing” terms in a verb—noun pairing. Often they refer to engineering functions, such as the second function in Table 3.1: “Must not conduct electricity.” Note that this function is also a constraint.

Means: a way or method to make a function happen. Means or implementations are often expressed in very specific terms that, by their nature, are solution-specific. Means often come up because clients or others think of examples of things they’ve seen that they think are relevant. Because they are so strongly function-dependent, they should be pruned from our attribute list for the time being, but we will revisit them after we have looked at functions.

Form: It represents the shape of the design or otherwise how a design look like. Aesthetic and ergonomics of a design is depends upon the form of that design.

Objective Tree

Objectives trees are hierarchical lists of the client's objectives or goals for the design that branch out into tree-like structures. We build objectives trees in order to clarify and better understand a client's project statement. The objectives that designs must attain are clustered by sub-objectives and then ordered by degrees of further detail.



Objective Tree for Step Ladder Design

The graphical tree display is very useful for portraying design issues, and for highlighting things we need to measure, since these objectives will provide our basis for choosing between alternatives. The tree format also corresponds to the mechanics of the process that many designers follow: One of the most useful ways of "getting your mind around" a large list of objectives is to put them all together, and then move them around until the tree makes sense. Note, too, that process just outlined—from lists to refined lists to indented outlines to trees— has a lot in common with outlining, a fundamental skill of writing. A topical outline provides an indented list of topics to be covered, together with the details of the subtopics corresponding to each topic. Since each topic represents a goal for the material to be covered, the identification of an objectives tree with a topical (or an indented) outline seems logical.

In addition to their use in depicting design objectives, objectives trees are valuable in several other ways. First, and perhaps foremost, note that as we work down an objectives tree (or further in on the levels of indentation of an outline), we are not only getting more detail. We are also answering a generic how question for many aspects of the design.

"How are you going to do that?" Conversely, as we move up the tree, or further out toward fewer indentations, we are answering a generic why question about a specific objective: "Why do you want that?" This may be important if, when selecting a design, we find that one alternative is better with respect to one objective, but weaker with respect to another.

But if we're working downward as we construct and organize a tree, where do we stop? When do we end our list or tree of objectives? One simple answer is: We stop when we run out of objectives and implementations begin to appear. That is, within any given cluster, we could continue to parse or decompose our objectives until we are unable to express succeeding levels as further objectives. The argument for this approach is that it points the objectives tree toward a solution-independent statement of the design problem. We know what characteristics the design has to exhibit, without having to make any judgment about how it might get to be that way. In other words, we determine the features or behaviors of the designed object without specifying the way the objective is realized in concrete form. We can also limit the depth of an objectives tree by watching for verbs or "doing" words because they normally suggest functions. Functions do not generally appear on objectives trees or lists.

Obviously, it is important to take notes when we are generating our lists of objectives, because we are generating a lot of information, to ensure that all suggestions and ideas are captured, even those that seem silly or irrelevant at the moment. Then it becomes important to organize the information we're getting so we can use it effectively: It's always easier to prune and throw away things than to recapture spontaneous ideas and inspirations. Also, get the substance of the objectives down first: Once a rough outline of an objectives tree has emerged, it can be formalized and made to look presentable and pretty with any number of standard software packages for constructing organization charts, or similar graphical displays. Finally, do we build an objectives tree as soon as we start a design job, or after doing some homework and learning more about the design task we're undertaking? There's no hard and fast answer to these questions, in part because building an objectives list or tree is not a mathematical problem with an attendant set of initial conditions that must be met.

Also, building a tree is not a one-time, let's-get-it-done kind of activity. It's an iterative process, but one that a design team should start with at least some degree of understanding of the design domain. Thus, some of the questioning of clients, users, and experts should have begun, and some of the tree building can go on episodically while more information is being gathered.

Initiating Creative Designs

Our time appreciates rationality and logic. We think that these qualities are the only functions in science, and together with carefully gathered knowledge those are the most powerful tools in our technical, economic and social progress. But in the case of design work we realize that these tools are quite dull and we have got into a tight place with them. All remarkable creative inventions are rational and logical, when we look at them afterwards, but in order to find something new in front of us more powerful tools are needed. The tools are sensations and intuition. Because of their subconscious nature, we often do not take them seriously in our scientific work. All practical designers, however, are acquainted with those subconscious functions of the mind and they use them in those phases of work, when we have to go ahead of present knowledge. The rationality and logic of the new results are checked afterwards and, in a favorable case, a new piece of science is attained.

A despising attitude towards pictures remained a prominent attitude. Science was still based on logical thinking described by words, and by admiring it, the preceding ideas and images were ignored. During the present century and even earlier the technique in the form of concrete machines has revolutionized our everyday life, and still we consider that machine inventions are based barely on scientific mechanics and economical needs. According to this point of view we teach our future engineers and even engineering design we have described using strictly logical systematics. This way of teaching is producing successful engineering designers less frequently because the engineering design is essentially reading and producing pictures and images. The stressing of systematics and the lack of training in pictorial thinking have led to the fact that concrete design work especially drafting, is carried out by designers having a lower technical education. The enormous development of electronics and physics has further increased the appreciation of sharp logic. Because modern products based on this technology have brought the technical services nearer the man, these sciences have got admiration and value without criticism. At the same time there is a tendency to underestimate drafting and to think that engineering design has already reached its maturity and that its value is now in decline. The mechanical machines have been considered to represent the polluting chimney industry and they are attributed with all the disadvantages due to industry, whereas electronics and automation represent the new un-polluting communication society. It has not been realized that this is a false image without any basis.

Creative thinkers are distinguished by their ability to synthesize new combinations of ideas and concepts into meaningful and useful forms. A creative engineer is one who produces a lot of ideas. These can be completely original ideas inspired by a discovery. More often, creative ideas result from putting existing ideas together in novel ways. A creative person is adept at breaking an idea down to take a fresh look at its parts, or in making connections between the current problem and seemingly unrelated observations or facts.

We would all like to be called “creative,” yet most of us, in our ignorance of the subject, feel that creativity is reserved for only the gifted few. There is the popular myth that creative ideas arrive with flash-like spontaneity—the flash of lightning and clap of thunder routine. In keeping with the view of association, students of the creative process assure us that most ideas occur by a slow, deliberate process that can be cultivated and enhanced with study and practice.

A characteristic of the creative process is that initially the idea is only imperfectly understood. Usually the creative person senses the total structure of the idea but initially perceives only a limited number of its details. There ensues a slow process of clarification and exploration as the entire idea takes shape. The creative process can be viewed as moving from an amorphous idea to a well-structured idea, from the chaotic to the organized, from the implicit to the explicit. Engineers, by nature and training, usually value order and explicit detail and abhor chaos and vague generality. Thus, we need to train ourselves to be sensitive and sympathetic to these aspects of the creative process. We need also to recognize that the flow of creative ideas cannot be turned on upon command. Therefore, we need to recognize the conditions and situations that are most conducive to creative thought. We must also recognize that creative ideas are elusive, and we need to be alert to capture and record our creative thoughts.

Improving Creativity

Creative cognition is the use of regular cognitive operations to solve problems in novel ways. One way to increase the likelihood of positive outcomes is to apply methods found to be useful for others. Following are some positive steps you can take to enhance your creative thinking.

- **Develop a creative attitude**: To be creative it is essential to develop confidence that you can provide a creative solution to a problem. Although you may not visualize the complete path through to the final solution at the time you first tackle a problem, you must have self-confidence; you must believe that a solution will develop before you are finished. Of course, confidence comes with success, so start small and build your confidence up with small successes.
- **Unlock your imagination:** You must rekindle the vivid imagination you had as a child. One way to do so is to begin to question again. Ask “why” and “what if,” even at the risk of displaying a bit of naiveté. Scholars of the creative process have developed thought games that are designed to provide practice in unlocking your imagination and sharpening creative ability.
- **Be persistent:** We already have dispelled the myth that creativity occurs with a lightning strike. On the contrary, it often requires hard work. Most problems will not succumb to the first attack. They must be pursued with persistence. After all, Edison tested over 6000 materials before he discovered the species of bamboo that acted as a successful filament for the incandescent light bulb. It was also Edison who made the famous comment, “Invention is 95 percent perspiration and 5 percent inspiration.”
- **Develop an open mind**: Having an open mind means being receptive to ideas from any and all sources. The solutions to problems are not the property of a particular discipline, nor is there any rule that solutions can come only from persons with college degrees. Ideally, problem solutions should not be concerned with company politics. Because of the NIH factor (not invented here), many creative ideas are not picked up and followed through.

- **Suspend your judgment:** We have seen that creative ideas develop slowly, but nothing inhibits the creative process more than critical judgment of an emerging idea. Engineers, by nature, tend toward critical attitudes, so special forbearance is required to avoid judgment at an early stage of conceptual design.
- **Set problem boundaries:** We place great emphasis on proper problem definition as a step toward problem solution. Establishing the boundaries of the problem is an essential part of problem definition. Experience shows that setting problem boundaries appropriately, not too tight or not too open, is critical to achieving a creative solution.

Brainstorming

Brainstorming is the most common method used by design teams for generating ideas. This method was developed by Alex Osborn 18 to stimulate creative magazine advertisements, but it has been widely adopted in other areas such as design. The word brainstorming has come into general usage in the language to denote any kind of idea generation.

Brainstorming is a carefully orchestrated process. It makes use of the broad experience and knowledge of groups of individuals. The brainstorming process is structured to overcome many of the mental blocks that curb individual creativity in team members who are left to generate ideas on their own. Active participation of different individuals in the idea generation process overcomes most perceptual, intellectual, and cultural mental blocks. It is likely that one person's mental block will be different from another's, so that by acting together, the team's combined idea generation process flows well.

A well-done brainstorming session is an enthusiastic session of rapid, free- flowing ideas. To achieve a good brainstorming session, it is important to carefully define the problem at the start. Time spent here can help us to avoid wasting time generating solutions to the wrong problem. It is also necessary to allow a short period for individuals to think through the problem quietly and on their own before starting the group process.

Participants in brainstorming sessions react to ideas they hear from others by recalling their own thoughts about the same concepts. This action of redirecting a stream of thought uncovers new possibilities in the affected team member. Some new ideas may come to mind by adding detail to a recently voiced idea or taking it in different, but related, directions. This building upon others' ideas is known as piggy-backing or scaffolding, and it is an indicator of a well- functioning brainstorming session. It has been found that the first 10 or so ideas will not be the most fresh and creative, so it is critical to get atleast 30 to 40 ideas from your session. An important attribute of this method is that brainstorming creates a large number of ideas, some of which will be creative.

The evaluation of your ideas should be done at a meeting on a day soon after the brainstorming session. This removes any fear that criticism or evaluation is coming soon and keeps the brainstorming meeting looser. Also, making the evaluation on the day after the idea generation session allows incubation time for more ideas to generate and time for reflection on what was proposed. The evaluation meeting should begin by adding to the original list any new ideas realized by the team members after the incubation period. Then the team evaluates each of the ideas. Hopefully, some of the wild ideas can be converted to realistic solutions.

Need Identification and Problem Statement

During the course of human development, different kinds of needs existed. For instance, there has always been and always will be a need for improving and making new designs. Lincoln Steffens wrote. "The world is yours, nothing is done and nothing is known. The greatest poem isn't written, the best railroad isn't built yet, the perfect state hasn't been thought of. Everything remains to be done right, everything." The engineer is a person who applies scientific knowledge to satisfy humankind's needs. It should be emphasized that the ability to design is a characteristic of an engineer.

One serious difficulty that engineers must overcome deals with the form in which problems are often presented to them. Even if some goals are given to the engineer, they often are not specifically stated. Problems may be presented vaguely: "The shaft is breaking." "The controls aren't producing the desired effect." "It costs too much to operate this engine." Thus, the first task of the engineer involves determining the real problems. Then, the engineer must determine the extent and confines of the goals. It is necessary to formulate a clear, exact statement of the problem in engineering words and symbols. It is also necessary to isolate the problem form the general situation and to delineate its form. This definition should clearly identify every aspect of the problem on which attention should be concentrated. The nonessential should be stripped away, and the individual characteristics of the problem should be differentiated. It should be determined whether or not the immediate problem is part of the larger problem. If it is, its relationship to the total part should be determined.

Consider the following examples.

- A designer is presented with a situation involving the waste of irrigation water in public parks. The park keepers forget to turn off the water. A general formulation of the problem would be "What can we do to minimize the possibility of workers forgetting to turn off the water before the end of their shit? Ah engineer could ask the following questions. "Why do workers continue to forget to turn off the water?" "What is the sequence of events that workers use during their daily activities?" "What will happen if a keeper does not show up for his/her shift?" "Do we need to manually turn on and off the water?" A more precise form of the problem statement would be "How do we prevent irrigation water waste in public parks?"

- A company has proposed to use the density gradient to isolate red blood cells from whole blood and thus to treat white blood cells with a light-activated drug. The designer should ask questions such as the following. "Is it necessary to use the density gradient if other methods of separation would be capable of isolating the red blood cells from the whole blood?" "If the white cells are being treated, why don't we isolate the white cells from the whole blood rather than isolate red blood cells?" "Why don't we impede the light into the blood and reduce the need for separation?"

- An engineer is presented with a problem caused by the formation of ice on roofs. The ice forms during certain types of weather, falls away from the roofs, and causes damage to vehicles and people below. A general formulation of this problem might be "How do we prevent ice from forming on roofs?" However, further questions may be asked. "What would happen if ice did form?" "What will cause the ice to fall?"

> "What harm would such formation do?" These questions determine that the first definition was much too narrow. A much broader definition was "How do we prevent ice that forms on roofs from doing harm or damage to people and equipment below?"

Designers need to abstract the need statement from its current state to a statement that they can base their design on. Vague statements from the customer usually result in a bad design.

Before an engineer can define the problem properly, he or she must recognize all of the problems that exist. Most of the failures in machines do not occur because we make mistakes in analysing the problem, but because we fail to recognize that there is a problem.

So, it is evident that the needs should be identified clearly, otherwise a vague statement of need will lead to a vague understanding of the product to be designed. A vague understanding cannot give a solution that addresses the specific problem. Asking the right question requires engineering knowledge, practice, and common sense.

Market Survey

Establishing who your customers are is one of the most important initial steps that a designer needs to take. One of the vital concepts to grasp is that customers are not only the end users. Customers of a product are everyone who will deal with the product at some stage during its lifetime. This includes the person who will manufacture the product, the person who will sell the product, the person who will service the product, the person who will maintain the product during its lifetime in operation, etc.

Consider an example: Discuss with your colleagues who the possible customers of a golf cart are. Here are a few ideas to start you off.

- The golf player
- The golf country club (Institution)
- The transportation company that will transport-the cart
- The golf club (Equipment) manufacturers for storage of their clubs in the cart

Once all possible customers have been identified, their needs should be considered, and more often than not, their needs can conflict with each other. It is the responsibility of the designer to recognize all of these needs in a prioritized manner and later arrive at a feasible solution that is an optimal combination of all these 'desires'. One good way to identify the needs in a prioritized manner is to conduct a market survey. There are a number ways in which this can be carried out.

1. Focus group meetings
2. Telephone interviews
3. One-on-one interviews
4. Questionnaires

Each method cited has its advantages and disadvantages. In a focus group meeting, a group of 6 to 12 potential 'customers' meet and discuss their needs and other aspects of the product. If the product already exists, the discussion usually focuses on a 'satisfaction' based feedback in terms of what they liked, what they disliked, and what they would like to see improved. However, for a new product, the discussion usually focuses on their wishes and desires in a particular market segment, what they would like to see introduced to improve their lives, or what current problems exist in the similar products on the market. It is important to ensure that any potential solutions are filtered out at this stage and converted into a neutral need. However, this method is an expensive process, and the sample size is relatively small. It is however a good starting point and is frequently used as a precursor to sending out a larger survey in the form of questionnaires. Telephone and one-on-one interviews can eliminate some of the ambiguities that arise for questionnaires. However, they are very expensive to run and also have a potential disadvantage of the interviewer 'leading' the interview and causing bias. For example, a question can be asked: "Would you really walk a long distance in the cold, rainy weather, in the middle of rush hour to get to your office early in the morning, or would you prefer taking the cheap, fast, and comfortable public transport?" An unbiased question could be "What is your preferred mode of transport to your office in the morning?"

The questionnaire format is one of the most popular survey methods, as it involves taking the opinion of a large number of people (sample) at a relatively low cost. It is important to construct a questionnaire carefully in order to provide meaningful, useful, and unbiased feedback. Here are some points to follow when creating a questionnaire:

- ✓ Develop a standard set of questions. The main goal of a questionnaire is to ascertain potential needs, problems, likes, and dislikes. It is useful at this stage to also identify which (if any) market segment would be most interested in the product as well as to gain an estimate of how much they would be willing to spend.
- ✓ Ensure that the questionnaire is easy to read and complete. Use simple language and simple formatting. Try to keep the writing to a minimum, and offer multiple choice questions or yes/no answers where possible. Leave an opportunity for writing for those who wish to do so.
- ✓ Identify the demographic you want to target. Mailing lists can be purchased from market research companies. KY Wee.com
- ✓ Test the questionnaire initially on a pilot sample (friends, family, or small group of people) before sending it out to the entire sample. This is an opportunity to iron out any ambiguous questions and to observe whether or not you are obtaining the desired information.
- ✓ Introduce only one issue per question.
- ✓ Similar to interviews, you do not want to give your questions a bias. Ensure all questions are unbiased.
- ✓ Avoid negative questions, which cause confusion. For example, a question such as "Do you not like to travel in the morning" may result in the answer "No, I do not like

to travel in the morning". Reading this carefully reveals a double-negative answer which means "I do like to travel in the morning."

- ✓ Ask a few conflicting questions and compare the answers to ensure that the person who has completed the questionnaire actually read the questions. For example ask "Do you ALWAYS switch off the electricity from the mains?" Later on ask "Do you forget to switch off the electricity from the mains?" If the person completing the questionnaire replied the same yes or no to both questions, then this particular feedback is not reliable.

Preliminary Research on Customer Needs

In a large company, the research on customer needs for a particular product or for the development of a new product is done using a number of formal methods and by different business units. The initial work may be done by a marketing department specialist or a team made up of marketing and design professionals. The natural focus of marketing specialists is the buyer of the product and similar products. Designers focus on needs that are unmet in the marketplace, products that are similar to the proposed product, historical ways of meeting the need and technological approaches to engineering similar products of the type under consideration. Clearly, information gathering is critical for this stage of design.

Design teams will also need to gather information directly from potential customers. One way to begin to understand needs of the targeted customers is for the development team to use their own experience and research to date. The team can begin to identify the needs that current products in their area of interest do not meet and those that an ideal new product should meet. In fact, there's no better group of people to start articulating unmet needs than members of a product development team who also happen to be end users of what they are designing.

Design attributes and customer requirements

Not all customer requirements are equal. This essentially means that customer requirements have different values for different people. The design team must identify those requirements that are most important to the success of the product in its target market and must ensure that those requirements and the needs they meet for the customers are satisfied by the product. This is a difficult distinction for some design team members to make because the pure engineering viewpoint is to deliver the best possible performance in all product aspects. A Kano diagram is a good tool to visually partition customer requirements into categories that will allow for their prioritization.

Kano recognized that there are four levels of customer requirements: **(1) expecters, (2) spokens, (3) unspokens, and (4) exciters.**

Expecters: These are the basic attributes that one would expect to see in the product, i.e., standard features. Expecters are frequently easy to measure and are used often in benchmarking.

Spokens: These are the specific features that customers say they want in the product.

Because the customer defines the product in terms of these attributes, the designer must be willing to provide them to satisfy the customer.

Unspokens: These are product attributes the customer does not generally talk about, but they remain important to him or her. They cannot be ignored. They may be attributes the customer simply forgot to mention or was unwilling to talk about or simply does not realize he or she wants. It takes great skill on the part of the design team to identify the unspoken requirements.

Exciters: Often called delighters, these are product features that make the product unique and distinguish it from the competition. Note that the absence of an exciter will not make customers unhappy, since they do not know what is missing.

BE-102 DESIGN & ENGINEERING

QUESTION BANK

Module I & II

1. You were asked to design a coffee mug. As a designer, list out the possible limitations regarding its design.

2. Explain Science & Engineering involved in any one of the following products.

(i) Electric Fan (11) Radio (iii) Solar Panel

3. Point out the three step procedure for objective preparation.

4. Analyze the objective tree for designing a super ladder

5. List out the possible design objectives, constrains, functions and means of any one of the following product below. Also, construct its design objective tree.

   (i) Portable Dining Table (ii) Iron Box (iii) Navigation System for a car

6. Suggest some design changes to the given coconut scraper that improve the efficiency and add value to it.

7. People experience difficulty in handling wired earphone as it gets twisted together (entangled) while taking it out from their pocket or bag. Suggest some possible design changes to overcome this difficulty.

8. Demonstrate the four phases of Quality Function Deployment (QFD).

9. Write a short note on engineering design, design objectives and design constraints.

10. Explain the elements of Science, Engineering, and Technology & Art with help of any one of the designs listed below.

a) Ceiling Fan b) CFL c) GPS d) Camera

11. A client requested you to design a baby chair that is to be used at dining room. List out some possible limitations of this design.
12. Setting objectives is the primary stage of any designs. Why design objectives are so important? Substantiate your answer with suitable example.
13. Justify the saying “form follows function” with an example.
14. List out Objectives, Constrains, Functions & Means of any one of the design listed below and construct an Objective tree for the design.

a) Safety Helmet b) Iron box c) Portable Dining Table

15. While you working in a design team to develop an automated car washing system, team leader assigned you to find out required functionality of the design. Draft a design proposal which explains the required functions and possible ways of achieving those functions.
16. Justify the significance of Brain storming in decision making.
17. Identify the various parts in a bicycle. Make a separate list of the parts that are not made up of metal. Sketch any two parts.
18. Categorize all the possible customers of a washing machine and prepare questionnaires for each group in order to collect customer requirements.
19. Design is a combination of art, architecture and engineering. Write a note to support this statement.
20. Nowadays smart phones are integral part of modern life style. But a group of people found difficulty to carry smart phones while morning exercises. Suggest some optimal solutions for this problem.
21. Relate the basic characteristics of an engineering design.
22. Outline the main objective and constraint for the design of ceiling fan.
23. Suggest design changes for an ordinary tea cup (With sketch) that can add value to it.

24. Suggest design changes for a torch (With sketch) that can add value to it and improve its efficiency. How this modification reflects on market?

25. While a designer developing an automated hair dying he was in need of identifying market requirements. Is it necessary that a designer researching about market? If it so suggest some method to collect information from market?

26. Since design is a business proposition a designer should identify customer needs before designing a product. List out some possible customer needs to design a TV-remote.

27. A group of engineering students gathered to develop a robot that can be used for cleaning class rooms. Suggest some scientific methods to initiate this new design.

28. Explain the difference between strength design and functional design with suitable examples.

29. Three differently designed pens are given below, tabulate the advantages and disadvantages of each designs.

30. While participating in a design competition two group of students assigned with different tasks.

Group-1: Design a book shelf which should carry 100 kg

Group-2: Design a camera that can be used to capture under water pictures

Consider above scenario; suggest a design approach for above groups regarding the idea of "strength design" and "functional design". Explain why?

THE DESIGN PROCESS

The basic five-step process usually used in a problem-solving works for design problems as well. Since design problems are usually defined more vaguely and have a multitude of correct answers, the process may require backtracking and iteration. Solving a design problem is a contingent process and the solution is subject to unforeseen complications and changes as it develops. Until the Wright brothers actually built and tested their early gliders, they did not know the problems and difficulties they would face controlling a powered plane.

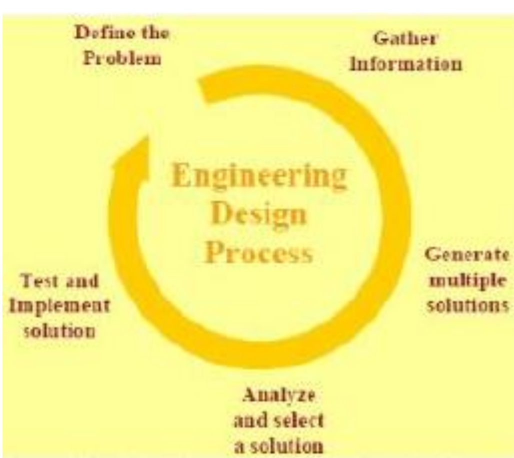
The five steps used for solving design problems are:

1. Define the problem
2. Generate concepts and gather pertinent information
3. Develop the solutions
4. Construct and test prototype
5. Evaluate and implement the solution
6. Present the solution

1. Define Problem

The first step in the design process is the problem definition. This definition usually contains a listing of the product or customer requirements and specially information about product functions and features among other things. In the next step, relevant information for the design of the product and its functional specifications is obtained. A survey regarding the availability of similar products in the market should be performed at this stage. Once the details of the design are clearly identified, the design team with inputs from tests, manufacturing, and marketing teams generates multiple alternatives to achieve the goals and the requirements of the design. Considering cost, safety, and other criteria for selection, the more promising alternatives are selected for further analysis.

Detail design and analysis step enables a complete study of the solutions and result in identification of the final design that best fits the product requirements. Following this step, a prototype of the design is constructed and functional tests are performed to verify and possibly modify the design. When solving a design problem, you may find at any point in the process that you need to go back to a previous step. The solution you chose may prove unworkable for any number of reasons and may require redefining the problem, collecting more information, or generating different solutions. This continuous iterative process is represented in the Figure.



This document intends to clarify some of the details involved in implementing the design process. Therefore a description of the details involved in each step of the design process is listed below. Although the descriptions of the activities within each step may give the impression that the steps are sequential and independent from each other, the iterative nature of the application of the process should be kept in mind throughout the document.

You need to begin the solution to a design problem with a clear, unambiguous definition of the problem. Unlike an analysis problem, a design problem often begins as a vague, abstract idea in the mind of the designer. Creating a clear definition of a design problem is more difficult than, defining an analysis problem. The definition of a design problem may evolve through a series of steps or processes as you develop a more complete understanding of the problem. Identify and Establish the Need Engineering design activity always occurs in response to a human need. Before you can develop a problem definition statement for a design problem, you need to recognize the need for a new product, system, or machine. Thomas Newcomen saw the need for a machine to pump the water from the bottom of coal mines in England. Recognizing this human need provided him the stimulus for designing the first steam engine in 1712. Before engineers can clearly define a design problem, they must see and understand this need.

Although engineers are generally involved in defining the problem, they may not be the ones who initially recognize the need. In private industry, market forces generally establish the need for a new design. A company's survival depends on producing a product that people will buy and can be manufactured and sold at a profit. Ultimately, consumers establish a need, because they will purchase and use a product that they perceive as meeting a need for comfort, health, recreation, transportation, shelter, and so on. Likewise, the citizens of a government decide whether they need safe drinking water, roads and highways, libraries, schools, fire protection, and so on. The perceived need, however, may not be the real need. Before you delve into the details of producing a solution, you need to make sure you have enough information to generate a clear, unambiguous problem definition that addresses the real need. The following example illustrates the importance of understanding the need before attempting a solution.

Example: Automobile Airbag Inflation - How Not to Solve a Problem

A company that manufactures automobile airbags has a problem with an unacceptably high rate of failure in the inflation of the bag. During testing, 10 percent of the bags do not fully inflate. An engineer is assigned the job of solving the problem. At first the engineer defines the problem as a failure in the materials and construction of the inflation device. The engineer begins to solve this problem by producing a more robust inflation device. The engineer begins to solve this problem by producing more robust inflation device does not change the failure rate in the bags. Eventually, this engineer re-examines the initial problem further and discovers that a high degree of variability in the tightness of folds is responsible for the failure of some bags to inflate. At the time the bags were folded and packed by people on an assembly line. With a more complete understanding of the need, the engineer redefined the problem as one of increasing the consistency in tightness of the folds in the bags. The final solution to this problem is a machine that automatically folds the bags. Often the apparent need is not the real need. A common tendency is to begin generating a solution to an apparent problem without understanding the problem. This approach is exactly the wrong way to begin solving a problem such as this. You would be generating solutions to a problem that has never been defined.

People have a natural tendency to attack the current solution to a problem rather than the problem itself. Attacking a current solution may eliminate inadequacies but will not produce a creative and innovative solution. For example, the engineer at the airbag company could have only looked at the current method for folding airbags-using humans on an assembly line. The engineer might have solved the problem with inconsistent tightness by modifying the assembly line procedure. However, the final solution to the problem proved to be more cost effective and reliable, in addition to producing a superior consistency in the tightness of the folds.

Develop a Problem Statement

The first step in the problem-solving process, therefore, is to formulate the problem in clear and unambiguous terms. Defining the problem is not the same as recognizing a need. The problem definition statement results from first identifying a need. The engineer at the airbag company responded to a need to reduce the number of airbag inflation failures. He made a mistake, however, in not formulating a clear definition of the problem before generating a solution. Once a need has been established, engineers define that need in terms of an engineering design problem statement. To reach a clear definition, they collect data, run experiments, and perform computations that allow that need to be expressed as part of an engineering problem-solving process.

Consider for example the statement "Design a better mousetrap." This statement is not an adequate problem definition for an engineering design problem. It expresses a vague dissatisfaction with existing mousetraps and therefore establishes a need. An engineer would take this statement of need and conduct further research to identify what was lacking in existing mousetrap designs.

After further investigation the engineer may discover that existing mousetraps are inadequate because they don't provide protection from the deadly Hantavirus carried by mice. Therefore, a better mousetrap maybe one that is sanitary and does not expose human beings to the Hantavirus. From this need, the problem definition is modified to read, "Design a mousetrap that allows for the sanitary disposal of the trapped mouse, minimizing human exposure to the Hantavirus."

The problem statement should specifically address the real need yet be broad enough not to preclude certain solutions. A broad definition of the problem allows you to look at a wide range of alternative solutions before you focus on a specific solution. The temptation at this point in the design process is to develop a preconceived mental "picture" of the problem solution. For example, you could define the better mousetrap problem as "Design a mousetrap that sprays the trapped mouse with disinfectant." This statement is clear and specific, but it is also too narrow. It excludes many potentially innovative solutions. If you focus on a specific picture or idea for solving the problem at this stage of the design process, you may never discover the truly innovative solutions to the problem. A problem statement should be concise and flexible enough to allow for creative solutions.

Here is one possible problem definition statement for our better mousetrap problem:

A Better Mousetrap: Certain rodents such as the common mouse are carriers and transmitters of an often fatal virus, the Hantavirus. Conventional mousetraps expose people to this virus as they handle the trap and dispose of the mouse. Design a mousetrap that allows a person to trap and dispose of a mouse without being exposed to any bacterial or viral agents being carried on the mouse.

2. Generate concepts

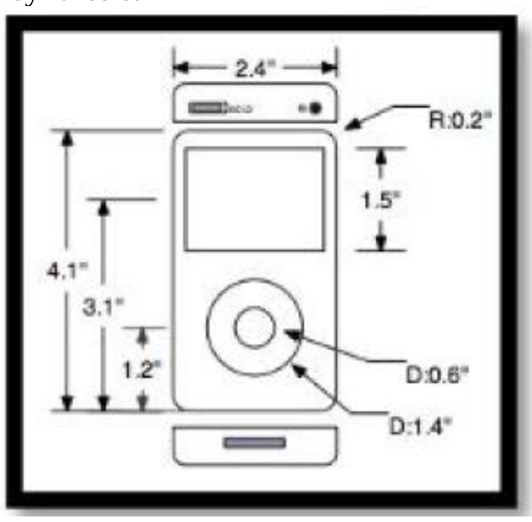
Before you can go further in the design process, you need to collect all the information available that relates to the problem. Novice designers will quickly skip over this step and proceed to the generation of alternative solutions. You will find, however, that effort spent searching for information about your problem will pay big dividends later in the design process. Gathering pertinent information can reveal facts about the problem that result in a redefinition of the problem. You may discover mistakes and false starts made by other designers. Information gathering for most design problems begins with asking the following questions. If the problem addresses a need that is new, then there are no existing solutions to the problems, so obviously some of the questions would not be asked.

- Is the problem real and its statement accurate?
- Is there really a need for a new solution or has the problem already been solved?
- What are the existing solutions to the problem?
- What is wrong with the way the problem is currently being solved?
- What is right about the way the problem is currently being solved?
- What companies manufacture the existing solution to the problem?
- What are the economic factors governing the solution?
- How much will people pay for a solution to the problem?
- What other factors are important to the problem solution (such as safety, aesthetics and environmental issues)?

By answering above questions designer can develop new idea to solve any design problems. Designer may use scientific methodologies such as brain storming, decision matrix etc.
Solutions to engineering design problems do not magically appear. Ideas are generated when people are free to take risks and make mistakes. Brainstorming at this stage is often a team effort in which people from different disciplines are involved in generating multiple solutions to the problem.

3. Develop the solution

The next step in the design process begins with creativity in generating new ideas that may solve the problem. Creativity is much more than just a systematic application of rules and theory to solve a technical problem. You start with existing solutions to the problem and then tear them apart-find out what's wrong with those solutions and focus on how to improve their weaknesses. Consciously Combine new ideas, tools, and methods to produce totally unique solution to the problem. This process is called synthesis.



Detailed designs should be generated in this step by representing designs through technical drawings which consisting of relevant information's to manufacture the product. If a solution is found to be invalid or cannot be justified, the designer must return to a previous step in the design process.

Analyse and select suitable solution:

Once you've conceived alternative solutions, to your design problem, you need to analyze those a and then decide which solution best suited for implementation. Analysis is the evaluation of the proposed designs. You apply your technical knowledge to the proposed solutions and use the results to decide which solution to carry out. You will cover design analysis in more depth when you get into upper-level engineering courses.

At this step in the design process, you must consider the results of your design analysis. This is a highly subjective step and should be made by a group of experienced people. This section introduces a systematic methodology you can use to evaluate alternative designs and assist in making a decision.

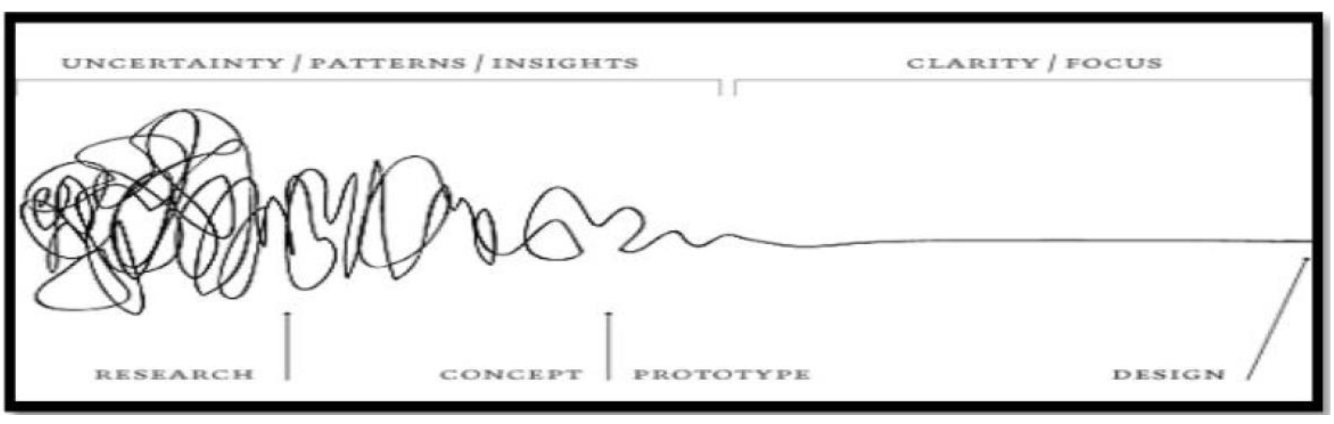
Analysis of Design Solutions:

Before deciding which design solution to implement, you need to analyze each alternative solution against the selection criteria defined in step 1. You should perform several types of analysis on each design. Every design problem is unique and requires different types of analysis. The following is a list of analysis that may need to be considered; bear in mind that the importance of each varies depending on the nature of the problem and the solution.

- Functional analysis
- Industrial design/Ergonomics
- Mechanical/Strength analysis
- Electrical/Electromagnetic
- Manufacturability/Testability
- Product safety and liability
- Economic and market analysis
- Regulatory and Compliance

4. Construct and test prototype

The final phase of the design process is implementation, which refers to the testing, construction, and manufacturing of the solution to the design problem. You must consider several methods of implementation, such as prototyping and concurrent engineering, as well as distinct activities that occur during implementation, such as documenting the design solution and applying for patents.



Prototyping:

The first stage of testing and implementation of a new product, called prototyping, consists of building a prototype of the product-the first fully operational production of the complete design solution. A prototype is not fully tested and may not work or operate as intended. The purpose of the prototype is to test the design solution under real conditions. For example, a new aircraft design would first be tested as a scale model in a wind tunnel. Wind tunnel tests would generate information to be used in constructing a full-size prototype of the aircraft. Test pilots then fly the prototype extensively under real conditions. Only after testing under all expected and unusual operating conditions are the prototypes brought into full production.

5. Evaluate and implement solution

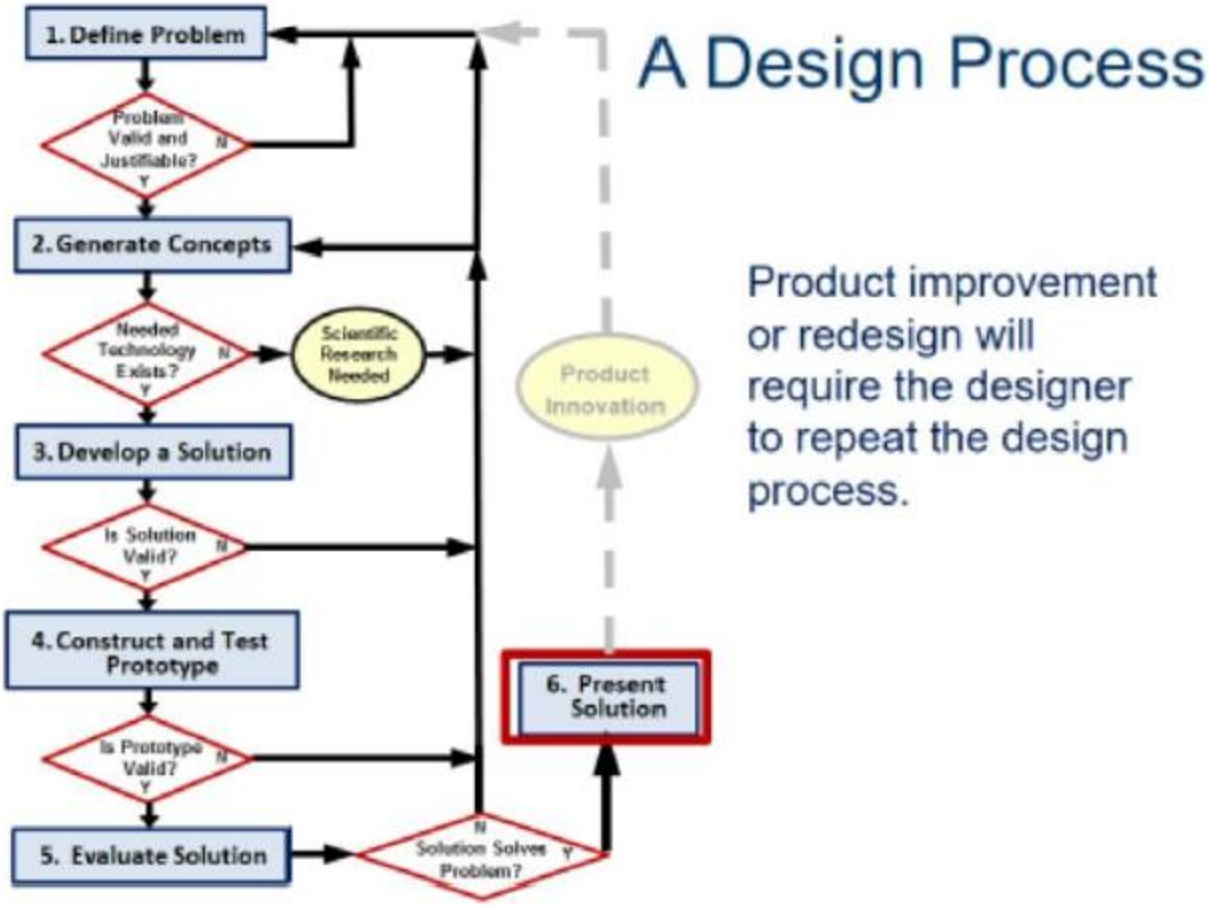
Testing and verification are important parts of the design process. Atall steps in the process, you may find that your potential solution is flawed and have to back up to a previous step to get a workable solution. Without proper testing at all stages in the process, you may find yourself making costly mistakes later.

6. Present solutions

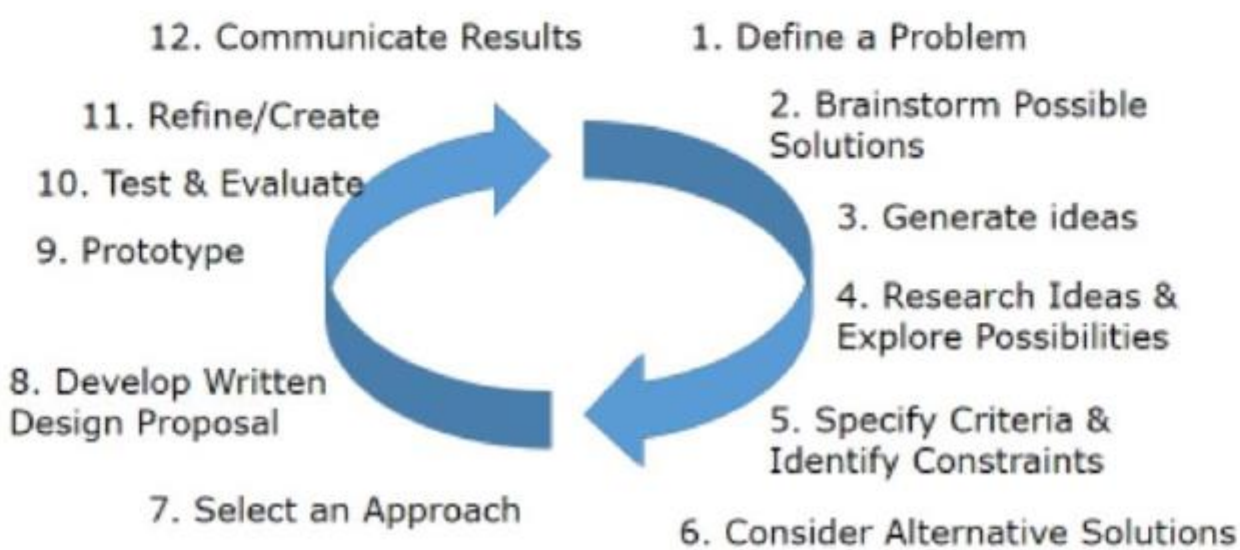
Communicating the solution to a design problem through language, both written and oral, is a vital part of the implementation phase. Many people you will be communicating with do not have technical training and competence. They may be the general public, government officials, or business leaders. Successful engineers must possess more than just technical skills. The ability to communicate and sell a design solution to others is also a critical skill.You can use graphs, charts, and other visual materials to summarize the solution process and present your work to others. Multimedia techniques, including Power Point presentations, slides, sounds, videos, and computer-generated animations, are often used to clearly communicate the solution to a design problem.

Documentation: One of the most important activities in design is documenting your work, clearly communicating the solution to your design problem so someone else can understand what you have created. Usually this consists of a design or technical report.

Schematic representations of design process

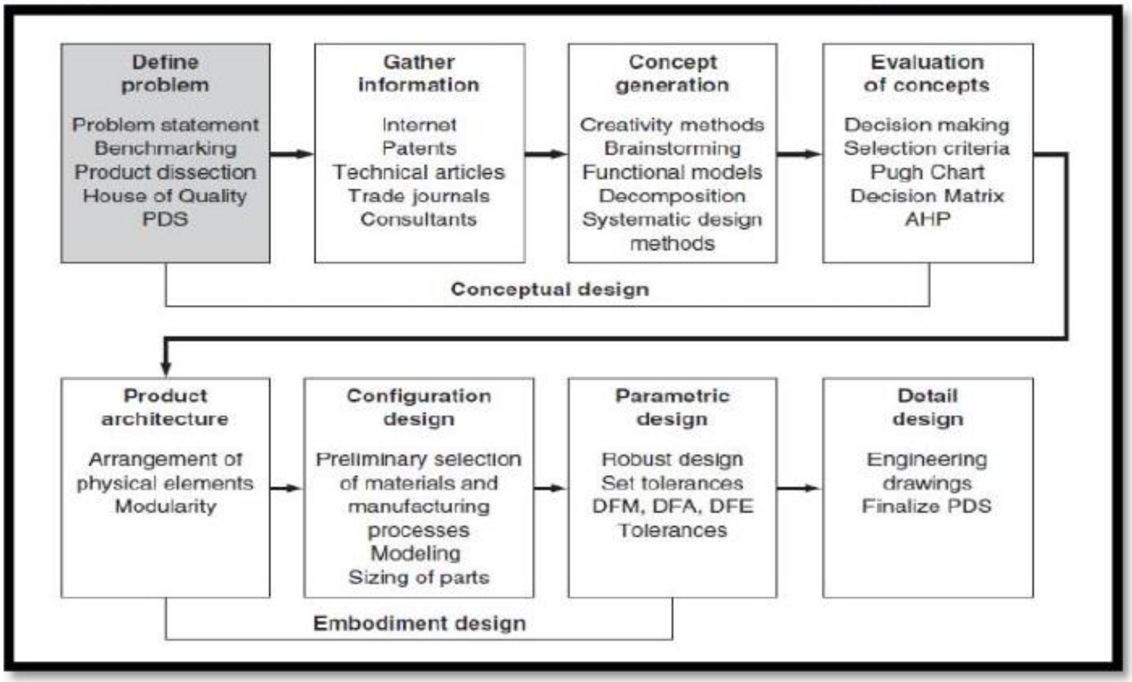


Detailed Design Process



Conceptual Design & Embodiment Design

The total design process can be divided in to three as shown in the figure:



1. **Conceptual design**

Conceptual design is the process by which the design is initiated, carried to the point of creating a number of possible solutions, and narrowed down to a single best concept. It is sometimes called the feasibility study. Conceptual design is the phase that requires the greatest creativity, involves the most uncertainty, and requires coordination among many functions in the business organization.

The following are the discrete activities that we consider under conceptual design Identification of customer needs: The goal of this activity is to completely understand the customers' needs andto communicate them to the design team.

- Problem definition: The goal of this activity is to create a statement that describes whathas to be accomplished to satisfy the needs of the customer. This involves analysis of competitive products, the establishment of target specifications, and the listing of constraints and trade-offs.
- Gathering information: Engineering design presents special requirements over engineering research in the need to acquire a broad spectrum of information.
- Conceptualization: Concept generation involves creating a broad set of concepts that potentially satisfy the problem statement. Team-based creativity methods, combined with effi cient information gathering, are the key activities.
- Concept selection: Evaluation of the design concepts, modifying and evolving into a single preferred concept, are the activities in this step. The process usually requires several iterations.
- Refinement of the PDS: The product design specification is revisited after the concept has been selected. The design team must commit to achieving certain critical values of design parameters, usually called critical-to-quality (CTQ) parameters, and to living with

trade-offs between cost and performance.

- Design review: Before committing funds to move to the next design phase, a design review will be held. The design review will assure that the design is physically realizable and that it is economically worthwhile. It will also look at a detailed product development schedule. This is needed to devise a strategy to minimize product cycle time and to identify the resources in people, equipment, and money needed to complete the project.

2. Embodiment Design

Structured development of the design concept occurs in this engineering design phase. It is the place where flesh is placed on the skeleton of the design concept. An embodiment of all the main functions that must be performed by the product must be undertaken. It is in this design phase that decisions are made on strength, material selection, size, shape, and spatial compatibility. Beyond this design phase, major changes become very expensive. This design phase is sometimes called preliminary design. Embodiment design is concerned with three major tasks—product architecture, configuration design, and parametric design.

- Product architecture:

Product architecture is concerned with dividing the overall design system into subsystems or modules. In this step we decide how the physical components of the design are to be arranged and combined to carry out the functional duties of the design.

- Configuration design of parts and components:

Parts are made up of features like holes, ribs, splines, and curves. Configuring a part means to determine what features will be present and how those features are to be arranged in space relative to each other. While modeling and simulation may be performed in this stage to check out function and spatial constraints, only approximate sizes are determined to assure that the part satisfies the PDS. Also, more specificity about materials and manufacturing is given here. The generation of a physical model of the part with rapid prototyping processes may be appropriate.

- Parametric design of parts:

Parametric design starts with information of the configuration of the part and aims to establish its exact dimensions and tolerances. Final decisions on the material and manufacturing processes are also established if this has not been done previously. An important aspect of parametric design is to examine the part, assembly, and system for design robustness. Robustness refers to how consistently a component performs under variable conditions in its service environment.

3. Detailed Design

In this phase the design is brought to the stage of a complete engineering description of a tested and producible product. Missing information is added on the arrangement, form, dimensions, and tolerances, surface properties, materials, and manufacturing processes of each part. This results in a specification for each special-purpose part and for each standard part to be purchased from suppliers. In the detail design phase the following activities are completed and documents are prepared:

- Detailed engineering drawings suitable for manufacturing. Routinely these are computer-generated drawings, and they often include three-dimensional CAD models.
- Verification testing of prototypes is successfully completed and verification data is submitted. All critical-to-quality parameters are confirmed to be under control. Usually the building and testing of several preproduction versions of the product will be accomplished.
- Assembly drawings and assembly instructions also will be completed. The bill of

materials for all assemblies will be completed.

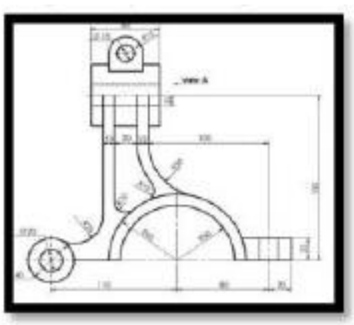
- A detailed product specification, updated with all the changes made since the conceptual design phase, will be prepared.
- Decisions on whether to make each part internally or to buy from an external supplier will be made.
- With the preceding information, a detailed cost estimate for the product will be carried out.
- Finally, detail design concludes with a design review before the decision is made to pass the design information on to manufacturing.

Phases I, II, and III take the design from the realm of possibility to the real world of practicality. However, the design process is not finished with the delivery of a set of detailed engineering drawings and specifications to the manufacturing organization. Many other technical and business decisions must be made that are really part of the design process. A great deal of thought and planning must go into how the design will be manufactured, how it will be marketed, how it will be maintained during use, and finally, how it will be retired from service and replaced by a new, improved design.

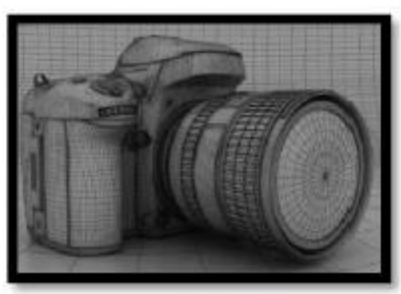
Generally these phases of design are carried out elsewhere in the organization than in the engineering department or product development department. As the project proceeds into the new phases, the expenditure of money and personnel time increases greatly.

Design Communication

It must always be kept in mind that the purpose of the design is to satisfy the needs of a customer or client. Therefore, the finalized design must be properly communicated, or it may lose much of its impact or significance. The communication is usually by oral presentation to the sponsor as well as by a written design report. Surveys typically show that the design engineers spend 60 percent of their time in discussing designs and preparing written documentation of designs, while only 40 percent of the time is spent in analyzing and testing designs and doing designing. Detailed engineering drawings, computer programs. 3-D computer models, and working models are frequently among the ‘deliverables’ to the customer.



2D Drawings



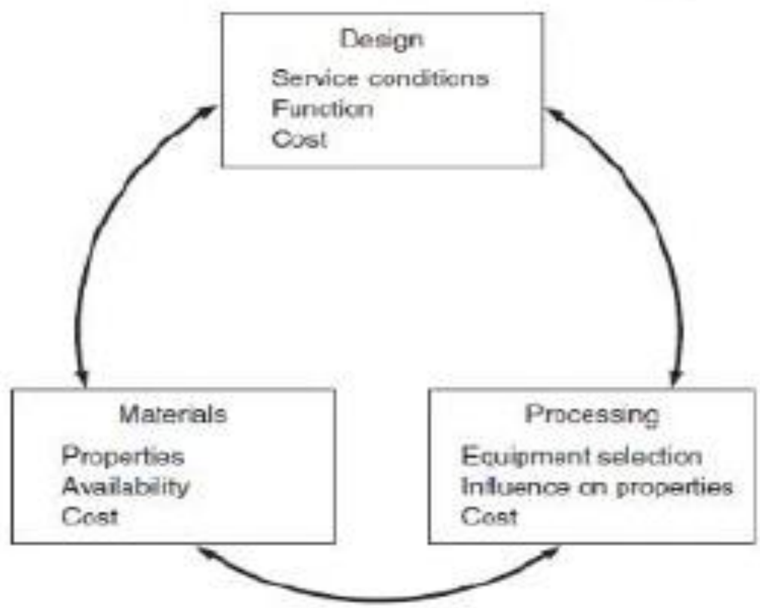
3D Drawings

3D Printed Models2D

It hardly needs to be emphasized that communication is not a one-time occurrence to be carried out at the end of the project. In a well-run design project there is continual oral and written dialog between the project manager and the customer. Note that the problem-solving methodology does not necessarily proceed in the order just listed. While it is important to define the problem early on, the understanding of the problem improves as the team moves into solution generation and evaluation. In fact, design is characterized by its iterative nature, moving back and forth between partial solutions and problem definition. This is in marked contrast with engineering analysis, which usually moves in a steady progression from problem setup to solution.

Material Selection

Materials and the manufacturing processes that convert them into useful parts underlie all of engineering design. There are over 100,000 engineering materials to choose from. The typical design engineer should have ready access to information on 30 to 60 materials, depending on the range of applications he or she deals with. The recognition of the importance of materials selection in design has increased in recent years. Concurrent engineering practices have brought materials specialists into the design process at an earlier stage. The importance given to quality and cost aspects of manufacturing in present-day product design has emphasized the fact that materials and manufacturing are closely linked in determining final product performance.

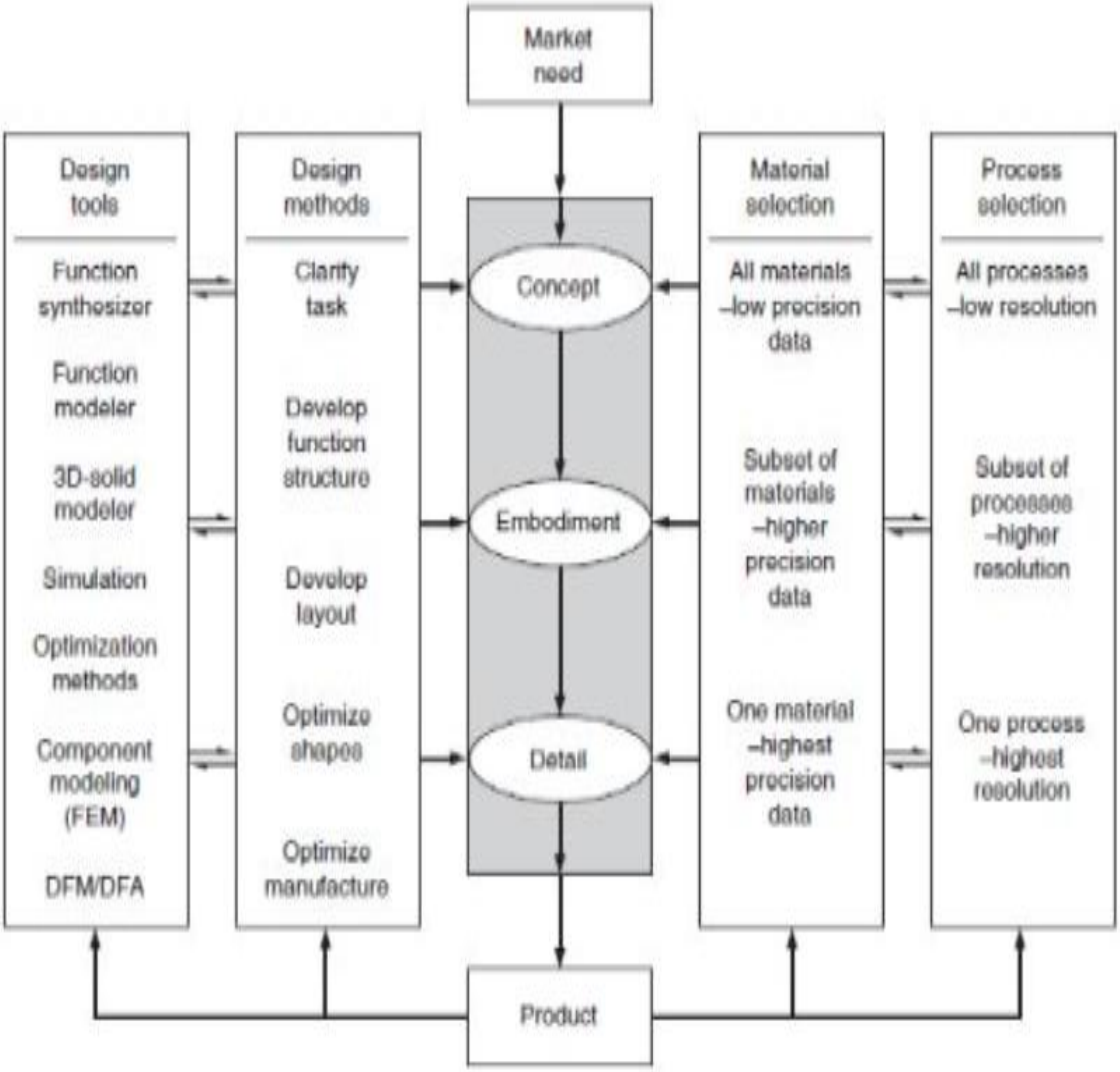


Moreover, the pressures of worldwide competition have increased level of automation in manufacturing to the point where material costs comprise 60 percent or more of the cost for most products. Finally, the extensive activity in materials science worldwide has created a variety of new materials and focused our attention on the Competition between six broad classes of materials: metals, polymers, elastomers, ceramics, glasses and composites. Thus the range of materials available to the engineer is much broader than ever before. This presents the opportunity for innovation in design by utilizing these materials to provide greater performance at lower cost. Achieving these benefits requires a rational process for materials selection.

Material Selection & Design

An incorrectly chosen material can lead not only to failure of the part but also to excessive life- cycle cost. Selecting the best material for a part involves more than choosing both a material that has the properties to provide the necessary performance. In service and the

processing methods used to create the finished part. .
A poorly chosen material can add to manufacturing cost. Properties of the material can be enhanced or diminished by processing, and that may affect the service performance of the part. Faced with the large number of combinations of materials and processes from which to choose, the materials selection task can only be done effectively by applying simplification and systemization. As design proceeds from concept design, to configuration and parametric design (embodiment design), and to detail design, the material and process selection becomes more detailed. Figure below compares the design methods and tools used at each design stage with materials and processes selection.



At the concept level of design, essentially all materials and processes are considered in broad detail. The task is to determine whether each design concept will be made from metal, plastics, ceramic, composite, or wood, and to narrow it to a group of materials within that material family. The required precision of property data is rather low. Note that if an innovative choice of material is to be made it must be done at the conceptual design phase because later in the design process too many decisions have been made to allow for a radical change. The emphasis at the embodiment phase of design is on determining the shape and size of a part using engineering analysis. The designer will have decided on a class of materials and processes, such as a range of aluminum alloys, wrought and cast. The material properties must be known to a greater level of precision. At the parametric design step the alternatives will have narrowed to a single material and only a few manufacturing processes. Here the emphasis will be on deciding on critical tolerances, optimizing for robust design, and selecting the best manufacturing process using quality engineering and cost modeling methodologies. Depending on the importance of the part, materials properties may need to be known to a high level of precision. This may require the development of a detailed database based on an extensive materials testing program. Thus, material and process selection is a progressive process of narrowing from a large universe of possibilities to a specific material and process.

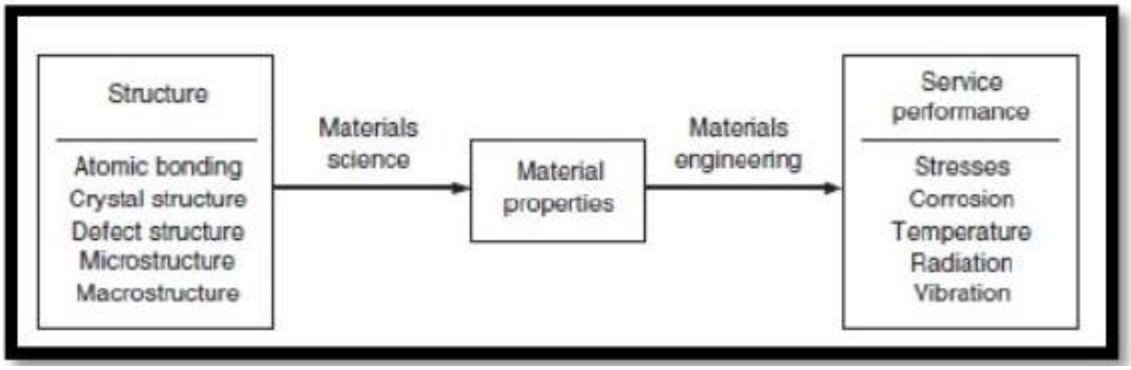
Criteria for Material Selection

Materials are selected on the basis of four general criteria:

- Performance characteristics (properties)
-
- Processing (manufacturing) characteristics
- Environmental profile
- Business considerations

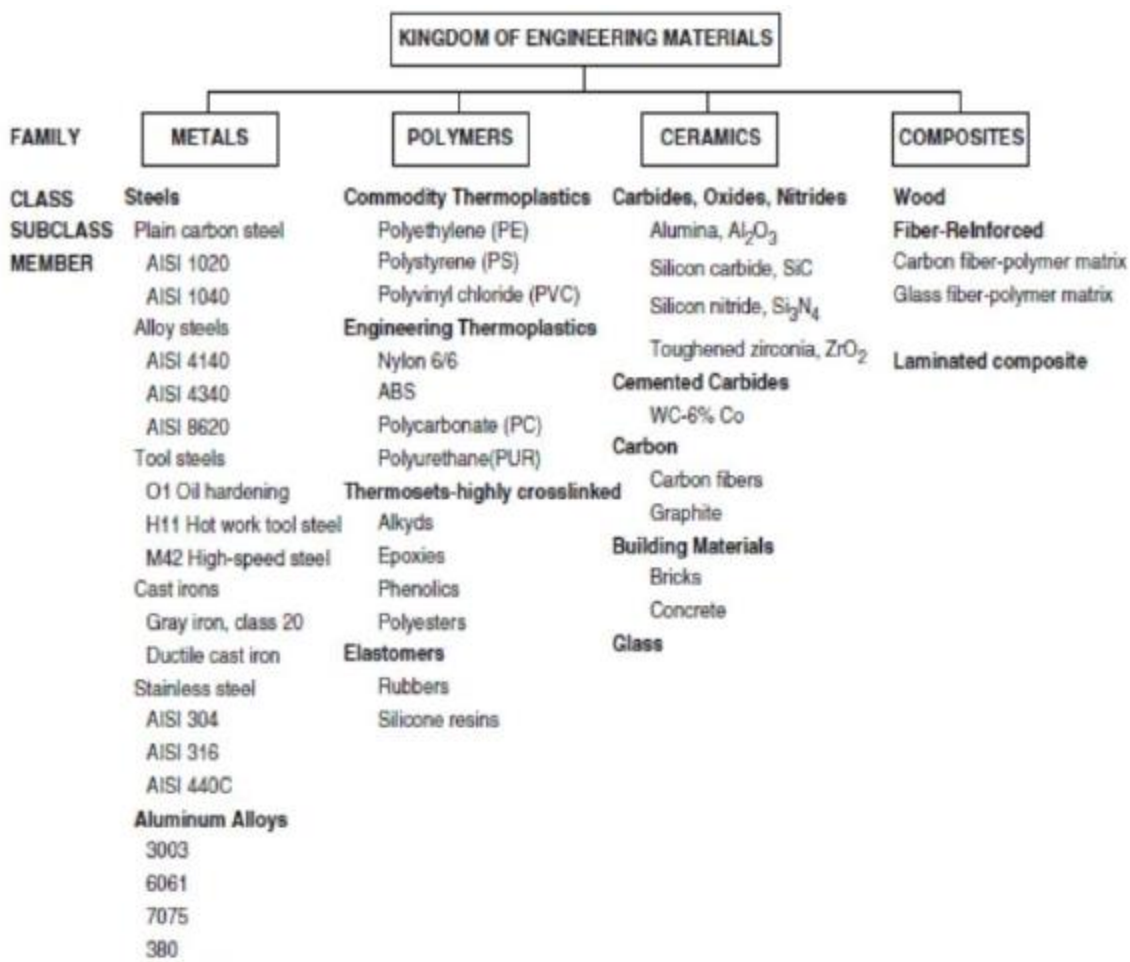
Materials selection, like other aspects engineering design, is a decision-making process. The steps in the process are as follows:

1. Analysis of the materials requirements. Determine the conditions of service and environment that the product must withstand. Translate them into material properties.
2. Screening for candidate materials. Compare the needed properties with a large materials property database to select a few materials that look promising for the application. Usually, steps 1 and 2 are performed in the conceptual phase of design.
3. Analysis of candidate materials in terms of trade-offs of product performance, cost, manufacturability, and availability to select the best material for the application. This is done in the embodiment phase of design.
4. Development of design data for critical systems or components. Determine experimentally the key material properties for the selected material to obtain statistically reliable measures of the material performance under the specific conditions expected to be encountered in service. It is not always necessary to carry out this step, but when it is, it is usually part of the detail design phase.



Classification of Materials

We can divide materials into metals, ceramics, and polymers. Further division leads to the categories of elastomers, glasses, and composites. Finally, there are the technologically important classes of optical, magnetic, and semiconductor materials. An engineering material is a material that is used to fulfill some technical functional requirement, as opposed to being just used for decoration. Those materials that are typically used to resist forces or deformations in engineering structures are called structural materials.



Copper Alloys
ETP copper-C1100
Yellow brass-C36000
High-Performance Nonferrous Alloys
Inconel 600 - Ni-Cr alloy
Stellite - Co-Cr-W alloy
Ti-6Al-4V

Properties of Materials

The performance or functional requirements of a material are usually given by a definable and measurable set of material properties. The first task in materials selection is to determine which material properties are relevant to the application. We look for material properties that are easy and inexpensive to measure, are reproducible, and are associated with a material behavior that is well defined and related to the way the material performs in service. For reasons of technological convenience we often measure something other than the most fundamental material property. For example, the elastic limit measures the first significant deviation from elastic behavior, but it is tedious to measure, so we substitute the easier and more reproducible 0.2 % offset yield strength. That, however, requires a carefully machined test specimen, so the yield stress may be approximated by the exceedingly inexpensive and rapid hardness test.
.

A Short List of Material Properties

Structure-Insensitive Properties	Structure-Sensitive Properties
Melting point, T_m	Strength, σ_f, where f denotes a failure mode
Glass transition temperature, for polymers, T_g	Ductility
Density, ρ	Fracture toughness, K_{Ic}
Porosity	Fatigue properties
Modulus of elasticity, E	Damping capacity, η
Coefficient of linear thermal expansion, α	Creep
Thermal conductivity, k	Impact or shock loading resistance
Specific heat, c_p	Hardness
Corrosion rate	Wear rate or corrosion rate

first step in classifying material properties into structure insensitive properties and structure-sensitive properties, in above table Both types of properties depend on the atomic binding energy and arrangement and packing of the atoms in the solid, but the structure-sensitive properties also depend strongly on the number, size, and distribution of the imperfections (dislocations, solute atoms, grain boundaries, inclusions, etc.) in the solid. Except for modulus of elasticity and corrosion in this table, all of the structure-insensitive properties are classified as physical properties.

The Material Selection Process

In design we considered the important issue in materials selection of identifying the appropriate material properties that allow the prediction of failure-free functioning of the component. The equally important task of identifying a process to manufacture the part with the material is discussed in Chap. 13. While these are important considerations, they are not the only issues in materials selection. The following business issues must also be considered. Failure to get a positive response in any of these areas can disqualify a material from selection.

1. Availability
   Are there multiple sources of supply?
   What is the likelihood of availability in the future?
   Is the material available in the forms needed (tubes, wide sheet, etc.)?
2. Size limitations and tolerances on available material shapes and forms, e.g., sheet thickness or tube wall concentricity
3. Excessive variability in properties
4. Environmental impact, including ability to recycle the material
5. Cost. Materials selection comes down to buying properties at the best available price.

A Material Selection Example

Consider the question of materials selection for an automotive exhaust system. The product design specification states that it must provide the following functions:

- Conduct engine exhaust gases away from the engine.
- Prevent noxious fumes from entering the car
- Cool the exhaust gases
- Reduce the engine noise
- Reduce the exposure of automobile body parts to exhaust gases
- Affect the engine performance as little as possible
- Help control unwanted exhaust emissions
- Have an acceptably long service life

Have a reasonable cost, both as original equipment and as a replacement part. The basic system configuration is a series of tubes that collect the gases at the engine and convey them to the rear of the automobile. The size of the tubes is determined by the volume of gases to be carried away and the extent to which the exhaust system can be permitted to impede the flow of gases from the engine (back pressure). In addition, a muffler is required for noise reduction and a catalytic converter to change polluting gases to less harmful emissions.

Material Requirements for an Automotive Exhaust system

- Mechanical property requirements overly severe.
- Suitable rigidity to prevent excessive vibration
- Moderate fatigue resistance
- Good creep resistance in hot parts

Limiting property: corrosion resistance, especially in the cold end where gases condense to form corrosive liquids.
Properties of unique interest: The requirements are so special that only a few materials meet them regardless of cost.

- Pt-base catalysts in catalytic converter
- Special ceramic carrier that supports the catalyst

Previous materials used: Low-carbon steel with corrosion-resistant coatings.
Material is relatively inexpensive, readily formed and welded. Life of tailpipe and muffler is limited
.
Newer materials used: With greater emphasis on automotive quality, many producers have moved to specially developed stainless steels with improved corrosion and creep properties. Ferritic 11%Cr alloys are used in the cold end components and 17 to 20%Cr ferritic alloys and austenitic Cr-Ni alloys in the hot end of the system.

Tolerance

A tolerance is the permissible variation from the specified dimension. The designer must decide how much variation is allowable from the basic dimension of the component to accomplish the desired function. The design objective is to make the tolerance no tighter than necessary, since smaller tolerances increase manufacturing cost and make assembly more difficult.

1. Bilateral tolerance

The variation occurs in both directions from the basic dimension. That is, the upper limit exceeds the

basic value and the lower limit falls below it.

2.500 ± 0.005 (This is the most common way of specifying tolerances)

2. Unilateral tolerance:

The basic dimension is taken as one of the limits, and variation is in only one direction $2.500^{+0.000}_{-0.010}$

Each manufacturing process has an inherent ability to maintain a certain range of tolerances, and to produce a certain surface roughness (finish).To achieve tolerances outside of the normal range requires special processing that typically results in an exponential increase in the manufacturing cost. Thus, the establishment of the needed tolerances in embodiment design has an important influence on the choice of manufacturing processes and the cost. Fortunately, not all dimensions of a part require tight tolerances. Typically those related to critical-to quality functions require tight tolerances. The tolerances for the noncritical dimensions should be set at values typical for the process used to make the part.

Design Standards and Codes

While we have often talked about design being a creative process, the fact is that much of design is not very different from what has been done in the past. There are obvious benefits in cost and time saved if the best practices are captured and made available for all to use. Designing with codes and standards has two chief aspects:

- It makes the best practice available to everyone, thereby ensuring efficiency and safety, and
- It promotes interchangeability and compatibility. With respect to the second point, anyone who has traveled widely in other countries will understand the compatibility problems with connecting plugs and electrical voltage and frequency when trying to use small appliances.

A code is a collection of laws and rules that assists a government agency in meeting its obligation to protect the general welfare by preventing damage to property or injury or loss of life to persons. A standard is a generally agreed-upon set of procedures, criteria, dimensions, materials, or parts. Engineering standards may describe the dimensions and sizes of small parts like screws and bearings, the minimum properties of materials, or an agreed-upon procedure to measure a property like fracture toughness. The terms standards and specifications are sometimes used interchangeably. The distinction is that standards refer to generalized situations, while specifications refer to specialized situations. Codes tell the engineer what to do and when and under what circumstances to do it. Codes usually are legal requirements, as in the building code. Standards tell the engineer how to do it and are usually regarded as recommendations that do not have the force of law. Codes often incorporate national standards into them by reference, and in this way standards become legally enforceable.

Standards are often prepared by individual companies for their own proprietary use. They address such things as dimensions, tolerances, forms, manufacturing processes, and finishes. In-house standards are often used by the company purchasing department when outsourcing. The next level of standard preparation involves groups of companies in the same industry arriving at industry consensus standards. Often these are sponsored through an industry trade association, such as the American Institute of Steel Construction (AISC) or the Door and Hardware Institute. Industry standards of this type are usually submitted to the American National Standards Institute (ANSI) for a formal review process, approval, and publication. A similar function is played by the International Organization for Standardization (ISO) in Geneva, Switzerland.

Applications and benefits of design standards

- Standards are a “COMMUNICATION” tool that allows all users to speak the same language when reacting to products or processes
- They provide a “Legal,” or at least enforceable, means to evaluate acceptability and sale-ability of products and/or services
- They can be taught and applied globally!
- They, ultimately, are designed to protect the public from questionable designs, products and practices
- They teach us, as engineers, how we can best meet environmental, health, safety and societal responsibilities

Quality Function Deployment

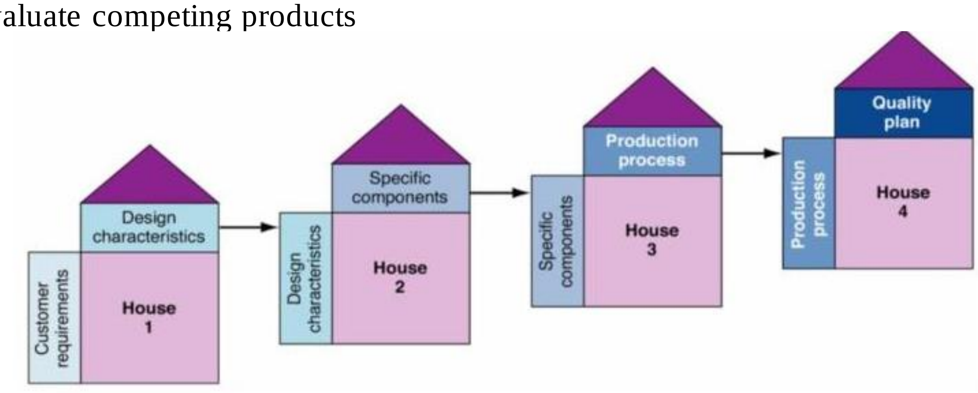
Quality function deployment (QFD) is a planning and team problem-solving tool that has been adopted by a wide variety of companies as the tool of choice for focusing a design team's attention on satisfying customer needs throughout the product development process. The term deployment in QFD refers to the fact that this method determines the important set of requirements for each phase of PDP planning and uses them to identify the set of technical characteristics of each phase that most contribute to satisfying the requirements. QFD is a largely graphical method that aids a design team in systematically identifying all of the elements that go into the product development process and creating relationship matrices between key parameters at each step of the process. Gathering the information required for the QFD process forces the design team to answer questions that might be glossed over in a less rigorous methodology and to learn what it does not know about the problem. Because it is a group decision-making activity, it creates a high level of buy-in and group understanding of the problem. QFD, like brainstorming, is a tool for multiple stages of the design process. In fact, it is a complete process that provides input to guide the design team. Quality function deployment (QFD) is a method to help transform customer needs (the voice of the customer [VOC]) into engineering characteristics (and appropriate test methods) for a product or service. It helps create operational definitions of the requirements, which may be vague when first expressed.

Benefits of adopting QFD

- Reduced time to market
- Reduction in design changes
- Decreased design and manufacturing cost
- Improved quality
- Increased customer satisfaction

Process of QFD

- Identify customer wants
- Identify how the good/service will satisfy customer wants
- Relate customer wants to product how's
- Identify relationships between the firm's how's Develop importance ratings
- Evaluate competing products



DESIGN & ENGINEERING

MODULE III

Prototyping- rapid prototyping; testing and evaluation of design; Design modifications; Freezing the design; Cost analysis. Engineering the design – From prototype to product. Planning; Scheduling; Supplychains;inventory; handling; manufacturing/construction operations; storage; packaging; shipping; marketing; feed-back on design.

Prototyping

It is highly recommended that the design team build its own physical models leading up to the proof-of-concept prototype. Product concept models, on the other hand, are often carefully crafted to have great visual appeal. These are traditionally made by firms specializing in this market or by industrial designers who are part of the design team. Computer modelling is rapidly overtaking the physical model, which by its nature is static, for this application. A 3D computer model can show cutaway views of the product as well as dynamic animations, all on a CD-ROM that can be easily produced in quantity. Nevertheless, an attractive physical model still has status appeal with important customers.

Models for **alpha-prototype** testing are typically made in the model shop, a small machine shop staffed with expert craftsmen and equipped with computer controlled machine tools and other precision machine tools. To be effective it is important to use CAD software that interfaces well with the numerically controlled (NC) machine tools, and it is important that the shop personnel be well trained in its use. Most of the time required to make a prototype by NC machining is consumed not by metal cutting but in process planning and NC programming. Recent developments have reduced the time needed for these operations so that NC machining is becoming competitive with rapid prototyping methods for the simpler geometries.

Beta-prototype models and preproduction test prototypes are made by the manufacturing department using the actual materials and processes in which the product will be produced.

Rapid Prototyping

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using **3D printing** or "additive layer manufacturing" technology.

Note that the time to make a RP model may take from 8 to 24 hours, so the term rapid may be something of a misnomer. However, the time from detail drawing to prototype is typically shorter than if the part was made in a model shop due to issues of scheduling and programming the machine tools. Also, RP processes are able to produce very complex shapes in one step, although typically they are made from a plastic, not a metal.

Three-dimensional Printing (3DP) is a RP process that is based on the principle of the inkjet printer. 50 A thin layer of metal, ceramic, or polymer powder is spread over a part-build bed. Using inkjet printing technology, fine droplets of a binder material are deposited on the powder in the two-dimensional geometry defined by the digital slice of the three-dimensional part. The inkjet is under computer control as in the other RP processes described previously. The droplets agglomerate powder particles, bonding them together into a primitive volume element, or voxel. The binder droplets also bond voxels together within the plane and to the plane below it. Once a layer is deposited, the powder bed and part are lowered and a new layer of powder is spread out and the binder is applied by the jet. This layer-by-layer process is repeated until the part is completed and removed from the powder bed.

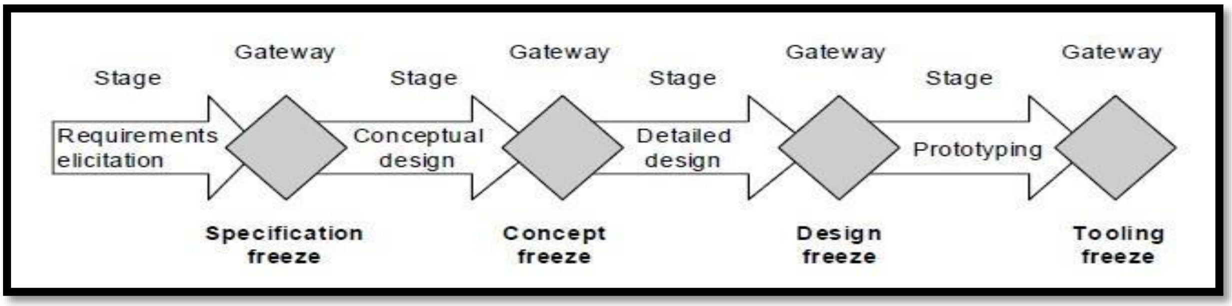
Prototype testing and evaluation:

There is a trade-off between the number of prototypes that will be built for a product design and tested and the cost and length of the product development cycle. Prototypes help to verify the product but they have a high cost in money and time. As a result, there is a strong trend, particularly in large companies, to replace physical prototypes with computer models (virtual prototypes) because simulation is cheaper and faster. A significant counter example to this trend is Toyota, which sticks by its longstanding practice of using extensive physical prototypes in component design.

- Testing and evaluation, allows the client / customer to view the prototype and to give his/her views. Changes and improvements are agreed and further work carried out.
- A focus group can try out the prototype and give their views and opinions. Faults and problems are often identified at this stage. Suggestions for improvement are often made at this stage.
- Safety issues are sometimes identified, by thorough testing and evaluation. The prototype can be tested against standards.
- The prototype can be tested against any relevant regulations and legislation. Adjustments / improvements to the design can then be made.
- Evaluating a prototype allows the production costs to be assessed and finalized.
- Component failure is often identified during the testing process. This may mean a component is redesign and not the entire product.

Freezing the design

'Design Freeze' describes the end point of the design phase at which a technical product description is handed over to production. Although Design Freeze refers to an unchanging design, in reality a complete freeze is not possible.



Design freeze time may be set by company authorities to time bound any design process or otherwise a continuously changing design will leads to money loss as well as time loss in industries. After proclaiming the design freeze, design team will never change any design aspects and this indicates that the product is ready to handover into manufacturing unit. As similar to design freeze the team may set freeze on any other stages of design process as indicated in above diagram.

Cost analysis

An engineering design is not complete until we have a good idea of the cost required to build the design or manufacture the product. Generally, among functionally equivalent alternatives, the lowest-cost design will be successful in a free marketplace. The fact that we have placed this chapter on cost evaluation toward the end of the text does not reflect the importance of the subject. Understanding the elements that make up cost is vital because competition between companies and between nations is fiercer than ever. The world is becoming a single gigantic marketplace in which newly developing countries with very low labor costs are acquiring technology and competing successfully with the well-established industrialized nations. Maintaining markets requires a detailed knowledge of costs and an understanding of how new technology can lower costs.

Cost estimates are used in the following ways:

1. To provide information to establish the selling price of a product or a quotation for a good or service.
2. To determine the most economical method, process, or material for manufacturing a product.
3. To become a basis for a cost-reduction program.
4. To determine standards of production performance that may be used to control costs.
5. To provide input concerning the profitability of a new product **Categories of cost:**

We can divide all costs into two broad categories: product costs and period costs. Product costs are those costs that vary with each unit of product made. Material cost and labor cost are good examples. Period costs derive their name from the fact that they occur over a period of time regardless of the amount (volume) of product that is made or sold. An example would be the insurance on the factory equipment or the expenses associated with selling the product. Another name for a product cost is variable cost, because the cost varies with the volume of product made. Another name for period cost is fixed cost, because the costs remain the same regardless of the volume of product made. Fixed costs cannot be readily allocated to any particular product or service that is produced.

Yet another way of categorizing costs is by direct cost and indirect cost. A direct cost is one that can be directly associated with a particular unit of product that is manufactured. In most cases, a direct cost is also a variable cost, like materials cost. Advertising for a product would be a direct cost when it is assignable to a specific product or product line, but it is not a variable cost because the cost does not vary with the quantity produced. An indirect cost cannot be identified with any particular product. Examples are rent on the factory building, cost of utilities, or wages of the shop floor supervisors. Often the line between direct costs and indirect costs is fuzzy. For example, equipment maintenance would be considered a direct cost if the machines are used exclusively for a single product line, but if many products were manufactured with the equipment; their maintenance would be considered an indirect cost.

Returning to the cost classifications of fixed and variable costs, examples are:

Fixed costs:

1. Indirect plant cost

    (a) Investment costs

    Depreciation on capital investment

    Interest on capital investment and inventory

    Property taxes

    Insurance

    (b) Overhead costs (burden)

    Technical services (engineering)

    Product design and development

    Nontechnical services (office personnel, security, etc.)

    General supplies

    Rental of equipment

2. Management and administrative expenses

    (a) Share of cost of corporate executive staff

    (b) Legal staff

    (c) Share of corporate research and development staff (d) Marketing staff

3. Selling expenses

    (a) Sales force

    (b) Delivery and warehouse costs

    (c) Technical service staff

Variable costs:

1. Materials
2. Direct labor (including fringe benefits)

3. Direct production supervision
4. Maintenance costs
5. Power and utilities
6. Quality-control staff
7. Royalty payments
8. Packaging and storage costs
9. Scrap losses and spoilage

Another important cost category is working capital, the funds that must be provided in addition to fixed capital and land investment to get a project started and provide for subsequent obligations as they come due. It consists of raw material on hand, semi-finished product in the process of manufacture, finished product in inventory, accounts receivable, 1 and cash needed for day-to-day operation. The working capital is tied up during the life of the plant, but it is considered to be fully recoverable at the end of the life of the project.

Cost analysis helps to:

- To determine actual cost of a product or the process.
- To compare the actual cost with the estimated cost.
- To provide the management with actual cost figures so that it can frame practical sales policies and cost structure etc.
- To ascertain departmental efficiency on the basis of an actual cost it incurs for production
- To determine profitability of products.

Engineering the Design: From Prototype to Product

Conceptual design is often a cognitive process in which a designer formulate his/her ideas through critical thinking process. After too many iterative design steps a designer stepped to materialize those ideas. On the beginning of embodiment design, designer starts to check the viability of design through prototype testing. The final goal of any design will be manufacturing the product and commercially introduce that product in to market. Hence the post design work flow starts from the designer to end user through different manufacturing processes, a designer should aware about these post design procedure in order to reduce issues during these process. Certain design considerations can reduce cost of post design procedures effectively.

Planning

Planning (also called forethought) is the process of thinking about and organizing the activities required to achieve a desired goal. It involves the creation and maintenance of a plan, such as psychological aspects that require conceptual skills. There are even a couple of tests to measure someone's capability of planning well. As such, planning is a fundamental property of intelligent behavior.

Planning for Manufacturing:

A great deal of detailed planning must be done to provide for the production of the design. A method of manufacture must be established for each component in the system. As a usual first step, a process sheet is created; it contains a sequential list of all manufacturing operations that must be performed on the component. Also, it specifies the form and condition of the material and the tooling and production machines that will be used.

- Specifying the production plant that will be used (or designing a new plant) and laying out the production lines
- Planning the work schedules and inventory controls (production control)
- Planning the quality assurance system
- Establishing the standard time and labor costs for each operation
- Establishing the system of information fl ow necessary to control the manufacturing operation

All of these tasks are generally considered to fall within industrial or manufacturing engineering.

Planning for Distribution:

Important technical and business decisions must be made to provide for the effective distribution to the consumer of the products that have been produced. In the strict realm of design, the shipping package may be critical. Concepts such as the shelf life of the product may also be critical and may need to be addressed in the earlier stages of the design process. A system of warehouses for distributing the product may have to be designed if none exists. The economic success of the design often depends on the skill exercised in marketing the product. If it is a consumer product, the sales effort is concentrated on advertising in print and video media, but highly technical products may require that the marketing step be a technical activity supported by specialized sales brochures, performance test data, and technically trained sales engineers.

Planning for Use:

The use of the product by the consumer is all-important, and considerations of how the consumer will react to the product pervade all steps of the design process. The following specific topics can be identified as being important user-oriented concerns in the design process: ease of maintenance, durability, reliability, product safety, and convenience in use (human factors engineering), aesthetic appeal, and economy of operation. Obviously, these consumer-oriented issues must be considered in the design process at its very beginning. They are not issues to be treated as afterthoughts.

Planning for the Retirement of the product:

The final step in the design process is the disposal of the product when it has reached the end of its useful life. Useful life may be determined by actual deterioration and wear to the point at which the design can no longer function, or it may be determined by technological obsolescence, in which a competing design performs the product’s functions either better or cheaper. In consumer products, it may come about through changes in fashion or taste. In the past, little attention has been given in the design process to product retirement. This is rapidly changing, as people the world over are becoming concerned about environmental issues. There is concern with depletion of mineral and energy resources, and with pollution of the air, water, and land as a result of manufacturing and technology advancement.

Benefits of planning

- ✓ Planning reduces uncertainty, risk and confusion in operation
- ✓ Planning guides decision making by managers
- ✓ Planning helps in achieving coordination and control
- ✓ Planning is an element of flexibility makes an organization capable of coping with changing environment challenges
- ✓ Planning leads to economy and efficiency in operations

Scheduling

Scheduling is the process of arranging, controlling and optimizing work and workloads in a production process or manufacturing process. Scheduling is used to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials. It is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process. In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment. Production scheduling aims to maximize the efficiency of the operation and reduce costs.

- ➢ The schedule must portray the activities required to support the project plan.
- ➢ Provides time-scaled network schedules that define when work tasks are to be performed.
- ➢ Produces reports that provide the Project Manager, the information necessary to monitor schedule status and to initiate corrective action if required.
- ➢ Provides assistance in implementation of corrective action when required

Before we can do any real scheduling, we have to know what we have to do every single day that takes up time. We already know we have client work that eats up significant chunks of our time, but there are other things we do as well: email, general admin work, answering phone calls, meetings, sending invoices, estimating projects, self-education, etc. We have to come to terms with how much time we spend doing these things on the daily basis and how much time we have left for client work.

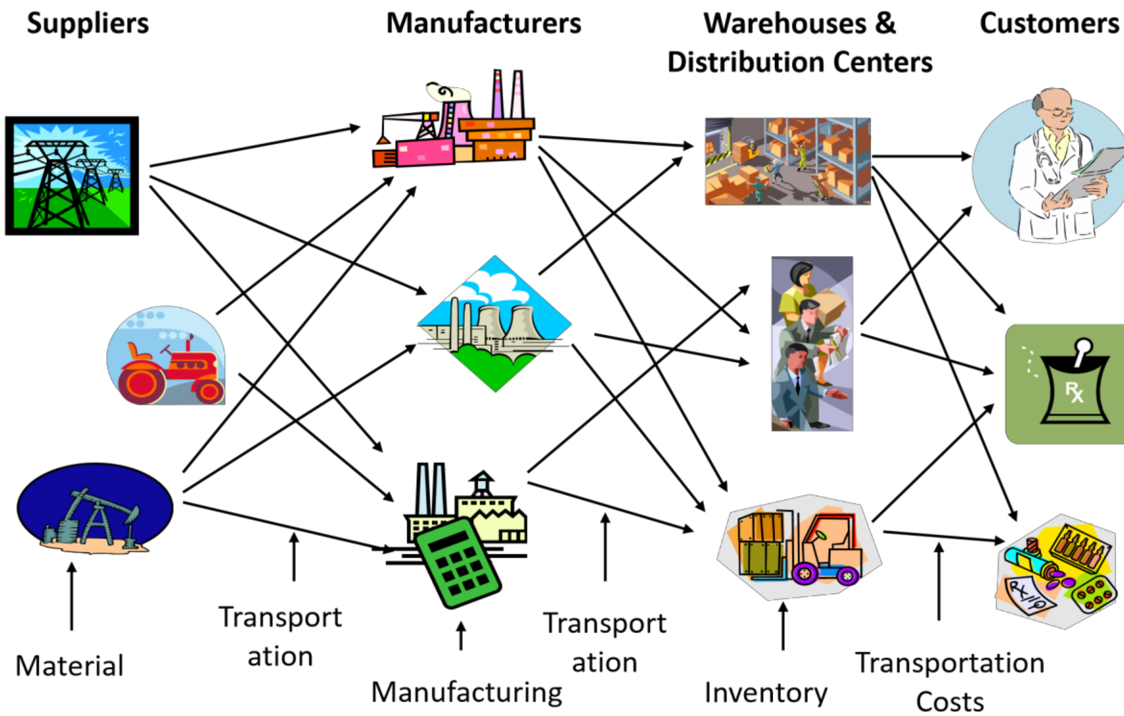
Batch production scheduling is the practice of planning and scheduling of batch manufacturing processes. Although scheduling may apply to traditionally continuous processes such as refining, it is especially important for batch processes such as those for pharmaceutical active ingredients, biotechnology processes and many specialty chemical processes. Batch production scheduling shares some concepts and techniques with finite capacity scheduling which has been applied to many manufacturing problems.

Supply Chain Management

Supply chain management (SCM) is the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Interconnected or interlinked networks, channels and node businesses are involved in the provision of products and services required by end customers in a supply chain.

Supply chain management has been defined as the "design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally.

- Supply chain management is the management of network of interconnected businesses involved in the ultimate provision of goods and services required by the end customer.
- Supply chain management spans all movement and storage of raw materials, work- in process inventory and finished goods from point-of-origin to point-of-consumption.



Organizations increasingly find that they must rely on effective supply chains, or networks, to compete in the global market and networked economy. Successful SCM requires a change from managing individual functions to integrating activities into key supply chain processes. In an example scenario, a purchasing department places orders as its requirements become known. The marketing department, responding to customer demand, communicates with several distributors and retailers as it attempts to determine ways to satisfy this demand. Information shared between supply chain partners can only be fully leveraged through process integration.

Inventory Management

Inventory management is a science primarily about specifying the shape and percentage of stocked goods. It is required at different locations within a facility or within many locations of a supply network to precede the regular and planned course of production and stock of materials. The scope of inventory management concerns the fine lines between replenishment lead time, carrying costs of inventory, asset

management, inventory forecasting, inventory valuation, inventory visibility, future inventory price forecasting, physical inventory, available physical space for inventory, quality management, replenishment, returns and defective goods, and demand forecasting. Balancing these competing requirements leads to optimal inventory levels, which is an ongoing process as the business needs shift and react to the wider environment.

Successful inventory management involves creating a purchasing plan that will ensure that items are available when they are needed (but that neither too much nor too little is purchased) and keeping track of existing inventory and its use. Two common inventory-management strategies are the just-in-time method, where companies plan to receive items as they are needed rather than maintaining high inventory levels, and materials requirement planning, which schedules material deliveries based on sales forecasts.

Inventory management involves a retailer seeking to acquire and maintain a proper merchandise assortment while ordering, shipping, handling, and related costs are kept in check. It also involves systems and processes that identify inventory requirements, set targets, provide replenishment techniques, report actual and projected inventory status and handle all functions related to the tracking and management of material. This would include the monitoring of material moved into and out of stockroom locations and the reconciling of the inventory balances.

Why Inventory?

1. **Time:** The time lags present in the supply chain, from supplier to user at every stage, requires that you maintain certain amounts of inventory to use in this lead time. However, in practice, inventory is to be maintained for consumption during 'variations in lead time'. Lead time itself can be addressed by ordering that many days in advance.
2. **Seasonal Demand**: demands vary periodically, but producer's capacity is fixed. This can lead to stock accumulation; consider for example how goods consumed only in holidays can lead to accumulation of large stocks on the anticipation of future consumption.
3. **Uncertainty:** Inventories are maintained as buffers to meet uncertainties in demand, supply and movements of goods.
4. **Economies of scale:** Ideal condition of "one unit at a time at a place where a user needs it, when he needs it" principle tends to incur lots of costs in terms of logistics. So bulk buying, movement and storing brings in economies of scale, thus inventory.
5. **Appreciation in Value:** In some situations, some stock gains the required value when it is kept for some time to allow it reach the desired standard for consumption, or for production. For example; beer in the brewing industry

Manufacturing Process

Producing the design is a critical link in the chain of events that starts with a creative idea and ends with a successful product in the marketplace. With modern technology the function of production no longer is a mundane activity. Rather, design, materials selection, and processing are inseparable. There is confusion of terminology concerning the engineering function called manufacturing. Materials engineers use the term materials processing to refer to the conversion of semi-finished products, like steel blooms or billets, into finished products, like cold-rolled sheet or hot-rolled bar. A mechanical, industrial, or manufacturing engineer is more likely to refer to the conversion of the sheet into an automotive body panel as manufacturing. Processing is the more generic term, but manufacturing is the more common term.

A manufacturing process converts a material into a finished part or product. The changes that take place occur with respect to part geometry, or they can affect the internal microstructure and therefore the properties of the material. For example, a sheet of brass that is being drawn into the cylindrical shape of a cartridge case is also being hardened and reduced in ductility by the process of dislocation glide on slip planes.

Manufacturing Process are classified into:

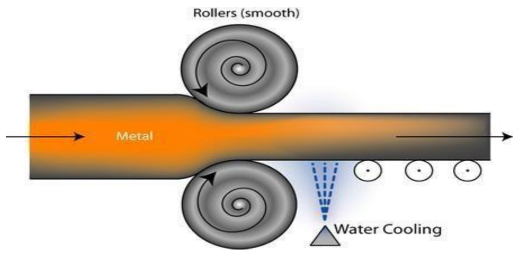
1. **Primary shaping process**
2. **Machining process**
3. **Joining process**
4. **Surface finishing process**
5. **Process affecting change in properties**

1. Primary shaping process

Two types:

- One which produce finished product (deforming process) i.e. requires no metal removal Examples: casting, forging, rolling etc.
- One which requires machining operations (material removal process)

Casting



Rolling Process

2. Machining Process

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process. The processes that have this common theme, controlled material removal, are today collectively known as subtractive manufacturing, in distinction from processes of controlled material addition, which are known as additive manufacturing.


Metal Cutting


Lathe Turning


Drilling

3. Joining & Surface finishing process

- **Welding**

In the welding process, two or more parts are heated and melted or forced together, causing the joined parts to function as one. In some welding methods a filler material is added to make the merging of the materials easier. There are many different types of welding operations, such as the various arc welding, resistance welding and oxyfuel gas welding methods. These will not be covered in this introduction, however.

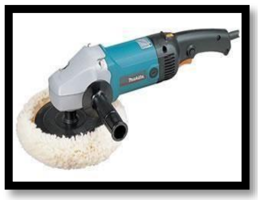
- **Brazing**

During the brazing process a filler metal is melted and distributed in between multiple solid metal components after they have been heated to the proper temperature. The filler metal must have a melting point that is above 840 degrees Fahrenheit but below the melting point of the base metals and the metal must also have high fluidity and wettability. No melting of the base metals occurs during brazing.

- **Soldering**

Soldering is similar to brazing; the only real difference being that in soldering the melting point of the filler metal is below 840 degrees Fahrenheit. Again, no melting of the base metals occurs, but the filler metal wets and combines with the base metals to form a metallurgical bond.

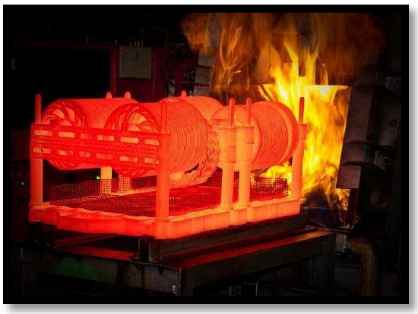
- **Buffing**



Polishing and buffing are finishing processes for smoothing a work piece's surface using an abrasive and a work wheel or a leather strop. Technically polishing refers to processes that use an abrasive that is glued to the work wheel, while buffing uses a loose abrasive applied to the work wheel. Polishing is a more aggressive process while buffing is less harsh, which leads to a smoother, brighter finish.

4. Process effecting change in properties

Heat treating is a group of industrial and metalworking processes used to alter the physical, and sometimes chemical, properties of a material. The most common application is metallurgical. Heat treatments are also used in the manufacture of many other materials, such as glass. Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve a desired result such as hardening or softening of a material. Heat treatment techniques include annealing, case hardening, precipitation strengthening, tempering, normalizing and quenching. It is noteworthy that while the term heat treatment applies only to processes where the heating and cooling are done for the specific purpose of altering properties intentionally, heating and cooling often occur incidentally during other manufacturing processes such as hot forming or welding.



Job production & Batch production:

Job Production is used when a product is produced with the labor of one or few workers and is scarcely used for bulk and large scale production. It is mainly used for one-off products or prototypes (hence also Prototype Production), as it is inefficient; however, quality is greatly enhanced with job production compared to other methods. Individual wedding cakes and madeto-measure suits are examples of job production. New small firms often use job production before they get a chance or have the means to expand. Job Production is highly motivating for workers because it gives the workers an opportunity to produce the whole product and take pride in it.

- ✓ Small number of pieces produced only once - Prototype
- ✓ Small number of pieces when need arises- Parts of stopped models
- ✓ Small number of pieces periodically after time interval – Raincoats

Batch production is the method used to produce or process any product in groups or batches where the products in the batch go through the whole production process together. An example would be when a bakery produces each different type of bread separately and each object (in this case, bread) is not produced continuously. Batch production is used in many different ways and is most suited to when there is a need for a quality/quantity balance. This technique is probably the most commonly used method for organizing manufacture and promotes specialist labor, as very often batch production involves a small number of persons. Batch production occurs when many similar items are produced together. Each batch goes through one stage of the production process before moving onto next stage.

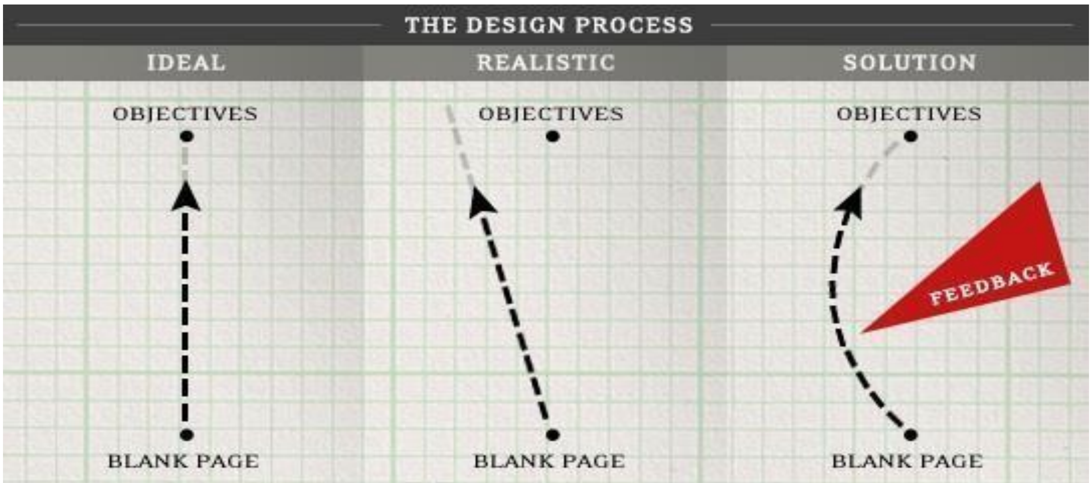
- ✓ Batch produced only once
- ✓ Batch produced repeatedly at irregular intervals
- ✓ Batch produced periodically at non intervals to satisfy continuous demands

So job production involves less quantity and more varieties while batch production involves large quantity of identical parts.

Feedback on Design

At a project's start, the possibilities are endless. That clean slate is both lovely and terrifying. As designers, we begin by filling space with temporary messes and uncertain experiments. We make a thousand tiny decisions quickly, trying to shape a message that will resonate with our audience. Then in the middle of a flow, we must stop and share our unfinished work with colleagues or clients.

The critique as a collaborative tool: When we embrace a truly collaborative process, critiques afford the incredible intersection of vision, design, strategy, technology, and people. The critique is a corrective step in the process that allows different ways of thinking to reach common ground—for example, compromising on visual vs. technological requirements.
Critiquing an unfinished design mitigates the risk of completely missing a project's ultimate goals. Acting as a wedge in the creative process, good feedback can readjust the design message and help us figure out what we're really trying to say



It's important to remember that critiques are meant to improve output rather than hinder process. Encouraging the overlap of ideas from multiple people, as in critiques, facilitates these breakthroughs.

For a designer, a good feedback can:

- ❖ prevent a meandering design from veering too far from timeline, budget, scope, or other project constraints
- ❖ allow others to help, teach, and guide when there are weaknesses or confusion, accustom others to the shoddy state of unfinished designs to talk about bigger ideas and strategy
- ❖ familiarize colleagues, managers, and clients with the design process, invest everyone in the project early on, circumvent alarming change requests by responding immediately as a team
- ❖ distribute responsibility for developing creative output
- ❖ help build team trust, and eliminate destructive ego

DESIGN & ENGINEERING

MODULE-IV

Design for X

Design for –X covering quality, reliability, safety, manufacturing/construction, assembly, maintenance, logistics, handling; disassembly; recycling; re-engineering etc.

Design for X

When a company is given the task of designing a new product or redesigning an existing product, it is important to keep in mind the three main goals of cost, quality and speed. These goals can be further split into more quantitative criteria which are relevant throughout the product's life cycle. Designing for manufacture and assembly are typical examples of two criteria which will have a large impact on the cost, quality and speed at which the product is developed. The methodology of design that meets an all-encompassing range of criteria is known as designing for 'X'.

A successful design must satisfy many requirements other than functionality, appearance, and cost. Durability and reliability have been recognized as needed attributes for many years. As more attention was focused on improving the design process, effort has been given to improving many other "ilities" such as manufacturability, maintainability, testability, and serviceability. As more life-cycle issues came under study, the terminology to describe a design methodology became known as Design for X, where X represents a performance measure of design, as in Design for Manufacture (DFM), Design for Assembly (DFA), or Design for the Environment (DFE). The development of the DFX methodologies was accelerated by the growing emphasis on concurrent engineering. It also emphasizes consideration of all aspects of the product life cycle from the outset of the product design effort. The ability to do this has been greatly facilitated by the creation and use of computer software design tools. These DFX tools are sometimes referred to as concurrent engineering tools.

The steps in implementing a DFX strategy are:

1. Determine the issue (X) targeted for consideration.
2. Determine where to give your focus: the product as a whole, an individual component, a subassembly, or a process plan.
3. Identify methods for measuring the X characteristics, and techniques to improve them. These techniques may include mathematical or experimental methods, computer modeling, or a set of heuristics.
4. The DFX strategy is implemented by insisting the product development team focus on the X and by using parametric measurements and improvement techniques as early in the design process as possible.

The reason why DFX is used is simple: it works! It is limited here in space to enumerate all successful case studies. Benefits can be grouped into three categories. These benefits are directly related to the competitiveness measures, including improved quality, compressed cycle time, reduced life-cycle costs, increased flexibility, improved productivity, more satisfied customers, safer workplace and happier workforce, and lower adverse environment impact. If anyone wants to benefit from a DFX project, then involvement and participation are necessary in exchange. DFX is primarily about improving a subject product. Therefore, design engineers are almost always involved.

Design for Manufacturability (DFM)

Design for manufacturability (DFM) is the general engineering art of designing products in such a way that they are easy to manufacture. Design for Manufacturing (DFM) and design for assembly (DFA) are the integration of product design and process planning into one common activity. The goal is to design a product that is easily and economically manufactured. The importance of designing for manufacturing is underlined by the fact that about 70% of manufacturing costs of a product (cost of materials, processing, and assembly) are determined by design decisions, with production decisions (such as process planning or machine tool selection) responsible for only 20%. The heart of any design for manufacturing system is a group of design principles or guidelines that are structured to help the designer reduce the cost and difficulty of manufacturing an item. The following is a listing of these rules.

Designs that are constructed to be easy to manufacture during the conceptual stage of a product development are much more likely to avoid redesign later when the system is being certified for production readiness. The best way to ensure a concept can be manufactured is to have active involvement from the production and supply chain organizations during concept generation and selection.

DFM and DFA are systematic approaches that the DFSS team can use to carefully analyze each design parameter that can be defined as part or subassembly for manual or automated manufacture and assembly to gradually reduce waste. Waste, or “muda”, the Japanese term, may mean any of several things. It may mean products or features that have no function (do not add value) and those that should have been trimmed (reduced, streamlined). It may also mean proliferation of parts that can be eliminated.

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. A part that does not need to have relative motion with respect to other parts, does not have to be made of a different material, or that would make the assembly or service of other parts extremely difficult or impossible, is an excellent target for elimination. Some approaches to part-count reduction are based on the use of one-piece structures and selection of manufacturing processes such as injection moulding, extrusion, precision castings, and powder metallurgy, among others.
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. However, the connection can be a limiting factor when applying this rule.

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. Furthermore, the use of standard components refers to the production pressure to the supplier, relieving in part the manufacture's concern of meeting production schedules.
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. Also, there can be elements that besides their principal function have guiding, aligning, or self-fixturing features to facilitate assembly, and/or reflective surfaces to facilitate inspection, etc.
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. The result is a set of standard part families from which multi-use parts are created. After organizing all the parts into part families, the manufacturing processes are standardized for each part family. The production of a specific part belonging to a given part family would follow the manufacturing routing that has been setup for its family, skipping the operations that are not required for it. Furthermore, in design changes to existing products and especially in new product designs, the standard multi-use components should be used.

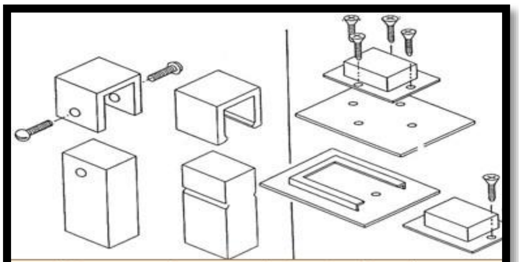

Bike engine casing act as heat dissipater

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.

Design for Assembly (DFA)

Design for assembly (DFA) is a process by which products are designed with ease of assembly in mind. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs. In addition, if the parts are provided with features which make it easier to grasp, move, orient and insert them, this will also reduce assembly time and assembly costs. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur. The Guidelines for DFA practice are

1. **Avoid separate fasteners**

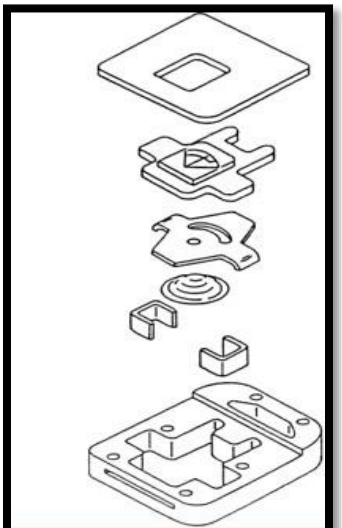


Avoid separate fasteners: design the fastening functions into the parts.

The use of fasteners increases the cost of manufacturing a part due to the handling and feeding operations that have to be performed. Besides the high cost of the equipment required for them, these operations are not 100% successful, so they contribute to reducing the overall manufacturing efficiency. In general, fasteners should be avoided and replaced, for example, by using tabs or snap fits. If fasteners have to be used, then some guides should be followed for selecting them. Minimize the number, size, and variation used; also, utilize standard components whenever possible. Avoid screws that are too long, or too short, separate washers, tapped holes, and round heads and flatheads (not good for vacuum pickup). Self-tapping and chamfered screws are preferred because they improve placement success. Screws with vertical side heads should be selected vacuum pickup.

Minimize assembly directions or unidirectional assembly

Unidirectional assembly design reduce the time for assembly and hence speed up the production. A designer can support assembly unit by arranging components in such a way that it can be assembled form any one of the direction or avoid part insertion from different directions.



Design for unidirectional assembly preferably using gravity. Assembly to a stable base

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.

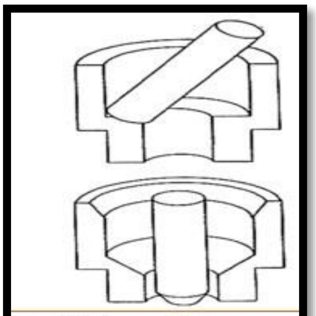
Unidirectional assembly become more crucial when manufacturing done by automated robotic arm, by reducing the assembly direction we can reduce the unnecessary movements of robotic arms. It will reduce the assembly time as well as programming time.

2. **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 non-functional external elements to help detect hidden features. For the assembly process, selection of a rigid-base part, tactile sensing capabilities, and vision systems are example of compliance. A simple solution is to use high-quality parts with designed-in-compliance, a rigid-base part, and selective compliance in the assembly tool.

3. **Minimize handling**

   Handling consists of positioning, orienting, and fixing a part or component. To facilitate orientation, symmetrical parts should be used whenever 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. The subsequent operations should be designed so that the orientation of the part is maintained. Also, magazines, tube feeders, part strips, and so on, should be used to keep this orientation between operations. Avoid using flexible parts - use slave circuit boards instead. If cables have to be used, then include a dummy connector to plug the cable (robotic assembly) so that it can be located easily. When designing the product, try to minimize the flow of material waste, parts, and so on, in the manufacturing operation; also, take packaging into account, select appropriate and safe packaging for the product.

   Self Aligned Parts

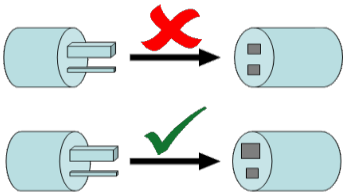
4. **Minimize the part count**

   Design for the minimum number of without sacrificing quality.

   Fewer parts means

   - ✓ a faster and more accurate assembly process
   - ✓ it results in:
   - ✓ Reduced inventory and number of vendors
   - ✓ Reduced assembly time and savings in material costs
   - ✓ Simplified assembly processes
   - ✓ It can be accomplished by:
   - ✓ Minimizing numbers and types of fasteners, cables, etc.
   - ✓ Encouraging modular, interchangeable assemblies
   - ✓ Building in self-fastening features
   - ✓ Minimizing the number of levels of assembly

Poka-Yoke Error proofing assembly method:



Poka-yoke example: Ethernet cable plug is designed to be plugged in only one orientation.

The DFMA approach usually benefits from poka-yoke (error-proofing) techniques, which may be applied when components are taking form and manufacturing and assembly issues are considered simultaneously. Poka-yoke is a technique for avoiding human error at work. The Japanese manufacturing engineer Shigeo Shingo developed the technique to achieve zero defects and came up with this term, which means "errorproofing." A defect exists in either of two states: (1) it already has occurred, calling for defect detection, or (2) is about to occur, calling for defect prediction. Poka-yoke has three basic functions to use against defects: shutdown, control, and warning. The technique starts by analyzing the process for potential problems, identifying parts by the characteristics of dimension, shape, and weight, detecting processes deviating from nominal procedures and norms.

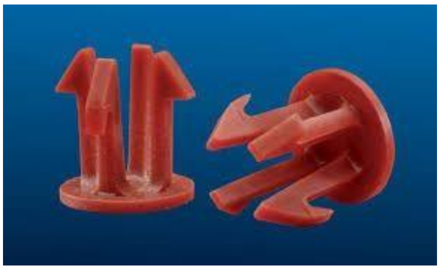
Hustle free Joining Methods:

Snap joints are a very simple, economical and rapid way of joining two different components.

All types of snap joints have in common the principle that a protruding part of one component, a hook, stud or bead is deflected briefly during the joining operation and catches in a depression (undercut) in the mating component. After the joining operation, the snap-fit features should return to a stress-free condition. The joint may be separable or inseparable depending on the shape of the undercut; the force required to separate the components varies greatly according to the design. It is particularly important to bear the following factors in mind when designing snap joints:

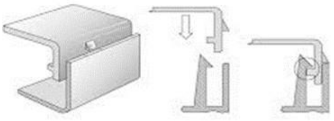
- Mechanical load during the assembly operation.
- Force required for assembly

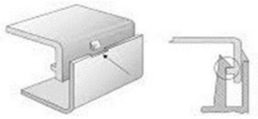
The design of the Snap-fit determines what it can be used for. There are three main types of snap-fits: annular, cantilever, and torsional. Most snap-fit joints have a common design of a



protruding edge and a snap-in area. The specific name of the snap-fit is usually named after the type of stress or strain it utilizes; the torsional snap-fit uses torque to hold parts in place.

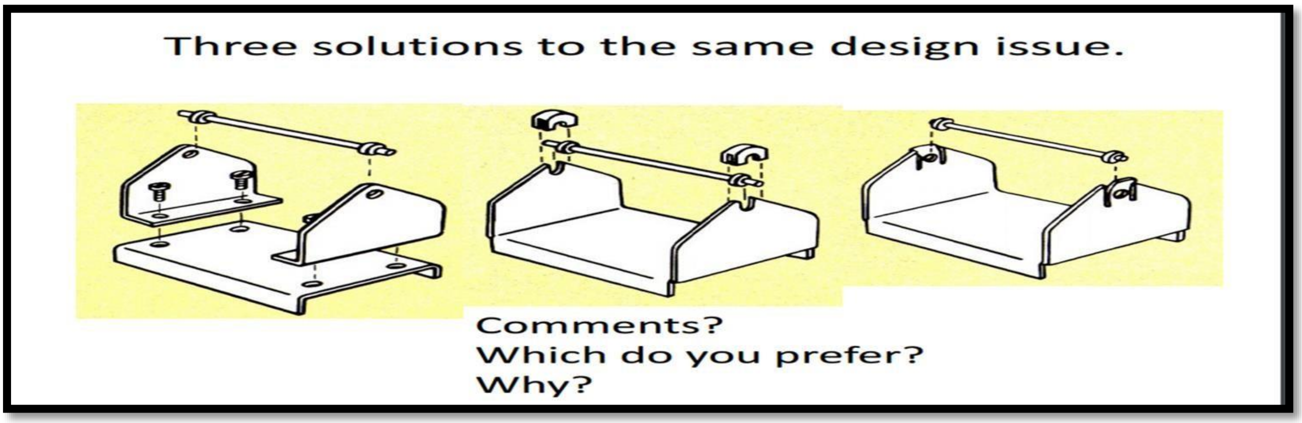
While snap-fits may reduce assembly costs, the cost of designing the parts may wipe out the savings unless manufacturing volumes are very high. Snap-fit assembly has many advantages over assembly with loose fasteners. Snap-fits can decrease product cost by reducing the overall part count and lowering labour costs. However, these savings are best realized with high-volume products that have a long manufacturing life.





Unfortunately, products today have a very short shelf life, and new models must be introduced frequently. As a result, manufacturers produce less of a particular model than they used to, and time to market has become very important. In that light, the cost and time required to design the parts and manufacture the tooling are critical. Snap-fits often take longer to design and tool than simpler assembly methods. For a relatively low-volume product, the total cost of snap-fits may actually be higher than for other assembly methods.

Example for DFMA (Design for Assembly and Manufacturability)



Above figure representing three different design pattern for a same product. The third one gives the best DFMA based design solution because,

- ✓ Minimum number of components
- ✓ Vomited unwanted fasteners or screws
- ✓ Minimum requirements of manufacturing process and hence reduce manufacturing cost
- ✓ Reduced maintenance

Design for Reliability

Reliability is the probability that a physical entity delivers its functional requirements (FRs) for an intended period under defined operating conditions. The time can be measured in several ways. For example, time in service and mileage are both acceptable for automobiles, while the number of open-close cycles in switches is suitable for circuit breakers. The DFSS team should use DFR while limiting the life-cycle cost of the design. The assessment of reliability usually involves testing and analysis of stress strength and environmental factors and should always include improper usage by the end user. A reliable design should anticipate all that can go wrong.

If a medical device fails it can have a detrimental effect on the patient's safety, on revenue, and on the company's reputation. Therefore it is important that a device is designed for reliability, keeping its required service life in mind. Different products will have different reliability requirements, for example: disposable needles have a short service life over which they must be reliable. Products with longer service lives can have their reliability increased with Preventative Maintenance.

Reliability pertains to a wide spectrum of issues that include human errors, technical malfunctions, environmental factors, inadequate design practices, and material variability. The DFSS team can **improve the reliability of the design by**:

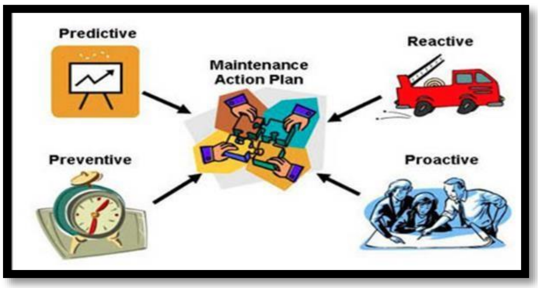
1. Minimizing damage from shipping, service, and repair
2. Counteracting the environmental and degradation factors
3. Reducing design complexity.
4. Maximizing the use of standard components
5. Determining all root causes of defects, not symptoms, using DFMEA
6. Controlling the significant and critical factors using SPC (statistical process control) where applicable
7. Tracking all yield and defect rates from both in-house and external suppliers and developing strategies to address them

To minimize the probability of failure, it is first necessary to identify all possible modes of failure and the mechanism by which these failures occur. Detailed examination of DFR is developed after physical and process structure development, followed by prototyping; however, considerations regarding reliability should be taken into account in the conceptual phase. The team should take advantage of existing knowledge and experience of similar entities and any advanced modelling techniques that are available. Failure avoidance, in particular when related to safety, is key. Various hazard analysis approaches are available. In general, these approaches start by highlighting hazardous elements and then proceed to identify all events that may transform these elements into hazardous conditions and their symptoms. The team then has to identify the corrective actions to eliminate or reduce these conditions. One of these approaches is called fault-tree analysis (FTA). FTA uses deductive logic gates to combine events that can produce the failure or the fault of interest. Other tools that can be used in conjunction with FTA include FMECA as well as the fishbone diagram.

Design for Maintainability

The objective of Design for Maintainability is to assure that the design will perform satisfactorily throughout its intended life with a minimum expenditure of budget and effort. Design for maintainability (DFM), Design for Serviceability (DFS), and Design for Reliability (DFR) are related because minimizing maintenance and facilitating service can be achieved by improving reliability. An effective DFM minimizes:

- The downtime for maintenance
- User and technician maintenance time
- Personnel injury resulting from maintenance tasks
- Cost resulting from maintainability features
- Logistics requirements for replacement parts, backup units, and personnel



Maintenance actions can be preventive, corrective, or recycle and overhaul. Design for Maintainability encompasses access and control, displays, fasteners, handles, labels, positioning and mounting, and testing.

Guidelines for Design for Maintainability

- Minimize the number of serviceable design parameters (DPs) with simple procedures and skills
- Provide easy access to the serviceable DPs by placing them in serviceable locations. This will also enhance the visual inspection process for failure identification
- Use common fasteners and attachment methods
- Design for minimum hand tools
- Provide for safety devices (guards, covers, switches, etc.)
- Design for minimum adjustment and make adjustable DPs accessible.

Placing projector bulb at accessible location reduce maintenance

Easy access to Watch battery is a Maintainability consideration

In above examples both projector bulb and watch battery are placed in such a way that they are easily accessible for maintenance, hence a repairer can easily replace this parts without damaging other components.

Design for Serviceability

After the DFSS team finished DFR and DFMA exercises, the next step is to embark on Design for Serviceability, another member of the DFX family. Design for Serviceability (DFS) is the ability to diagnose, remove, replace, replenish, or repair any DP (component or subassembly) to original specifications with relative ease. Poor serviceability produces warranty costs, customer dissatisfaction, and lost sales and market share due to loss loyalty. The DFSS team may check their VOC (voice-of-the-customer) studies such as QFD for any voiced serviceability attributes. Ease of serviceability is a performance quality in the Kano analysis. DFSS strives to have serviceability personnel involved in the early stages, as they are considered a customer segment.

The DFSS team should visit the following considerations of DFS:

(1) Customer service attributes

(2) Labor time

(3) Parts cost

(4) Safety

(5) Diagnosis

(6) Service simplification

(7) Repair frequency and occurrence

(8) Special tools

(9) Failures caused by the service procedures

Design for Environment (DFE)

Design for the Environment (DFE) is a design approach to reduce the overall human health and environmental impact of a product, process or service, where impacts are considered across its life cycle. Different software tools have been developed to assist designers in finding optimized products or processes/services.

Design for the Environment is a global movement targeting design initiatives and incorporating environmental motives to improve product design in order to minimize health and environmental impacts. The Design for the Environment (DFE) strategy aims to improve technology and design tactics to expand the scope of products. By incorporating eco-efficiency into design tactics, DFE takes into consideration the entire life-cycle of the product, while still making products usable but minimizing resource use. The key focus of DFE is to minimize the environmental-economic cost to consumers while still focusing on the life-cycle framework of the product. By balancing both customer needs as well as environmental and social impacts DFE aims to "improve the product use experience both for consumers and producers, while minimally impacting the environment".

Practicing Design for Environment

Four main concepts that fall under the DFE umbrella.

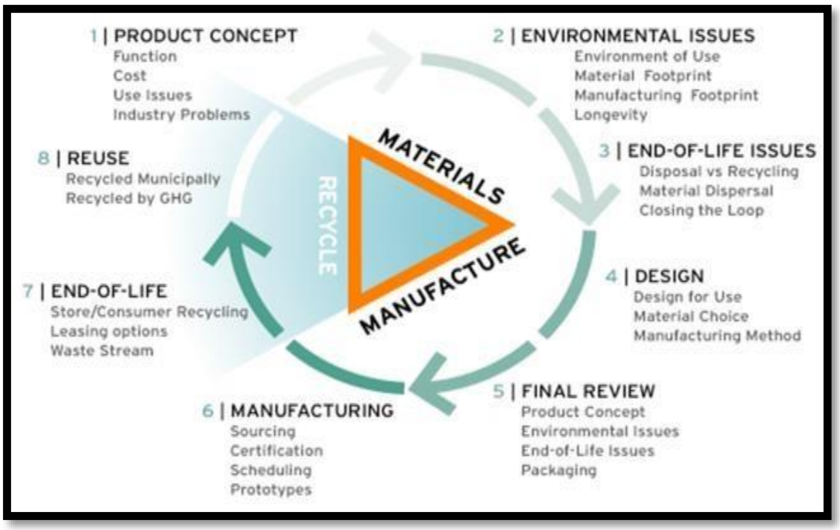
1. Design for environmental processing and manufacturing: This ensures that raw material extraction (mining, drilling, etc.), processing (processing reusable materials, metal melting, etc.) and manufacturing are done using materials and processes which are not dangerous to the environment or the employees working on said processes. This includes the minimization of waste and hazardous by-products, air pollution, energy expenditure and other factors.
2. Design for environmental packaging: This ensures that the materials used in packaging are environmentally friendly, which can be achieved through the reuse of shipping products, elimination of unnecessary paper and packaging products, efficient use of materials and space, use of recycled and/or recyclable materials.
3. Design for disposal or reuse: The end-of-life of a product is very important, because some products emit dangerous chemicals into the air, ground and water after they are disposed of in a landfill. Planning for the reuse or refurbishing of a product will change the types of materials that would be used, how they could later be disassembled and reused, and the environmental impacts such materials have.
4. Design for energy efficiency: The design of products to reduce overall energy consumption throughout the product's life.

Design for Life Cycle

Designing for the Life Cycle can be closely associated with economics. This is very understandable when one considers the fact that the natural resources of the world are limited. Therefore, the materials and natural effects of nature must be clearly understood and considered in order for the engineer to satisfy the concerns and requirements associated with the needs of the project he/she is designing. The challenge is for the engineer to determine how the physical environment can be altered, or used to advantage, to create the maximum amount of useful product at the lowest possible cost. In addition, the engineer should design with the idea of bettering the best. To do this the design must account for tomorrow's technology today.

The life cycle of a product or system begins with the identification of a need. It subsequently extends through conceptual, preliminary and detailed design, as well as production and/or construction, installation, customer use, support, decline and disposal. Simply put, the principal behind life-cycle engineering is that the entire life of the product should be considered in its original design. An engineering design should not only transform a need into an idea that produces the desired product, but should ensure the design's compatibility with related physical and functional requirements during manufacturing and operation. This includes taking into account the life of the product (as measured by its performance), reliability, and maintainability.

Life-cycle engineering goes beyond the life of the product itself. It is simultaneously concerned with the parallel life of the manufacturing process and of the product service system. In essence, there are actually three coordinated life cycles going on at the same time. These parallel life cycles are initiated when the need for the product is first recognized.

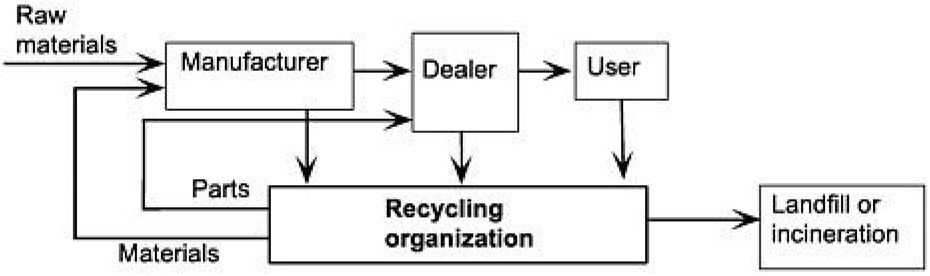


During conceptual design, it follows that consideration should simultaneously be given to the product's manufacture. This begins the second life cycle, i.e., the creation of a manufacturing process including production planning, plant layout, equipment selection, process planning, and other similar activities. The third life cycle should also be initiated at the preliminary design phase. It involves the development of a service system for the product and a maintenance system for manufacturing.

Traditionally, engineers have focused mainly on the acquisition phase of the product's life cycle. However, experience shows that in order to produce a successfully competitive product, performance and maintenance must also be considered at the time of the original design. When too great an emphasis is placed on the engineering of a product's primary function, side effects often occur. These negative impacts often manifest themselves in problems dealing with operation. Although sufficient specialized knowledge exists to solve many of these problems (Failure Modes and Effects Analysis, Root Cause Analysis, Reliability Centered Maintenance, etc.), this knowledge is most useful if it has been integrated into systematic solutions during the original design.

Design for Recycling (DFR)

The designed-for-recycling1 method incorporates recycling and recyclability criteria into the design phase of products, with the aim of obtaining recycled and/or recyclable products. The environmental variable is just another requirement of the product that is added to all the others, such as its cost, its safety, its manufacturability, its use, etc.



The application of this variable does not affect the rest of the properties of the product, and price and environmental improvement are combined with the aim of manufacturing products with a reduced environmental impact associated to its entire life cycle and competitive prices.

Recycled products are those which are manufactured using recycled materials or components from products no longer in use.

Recyclable products are those that are manufactured to be recycled at the end of their useful life. In other words, mono-materials are used, the toxic and hazardous substances are eliminated and a modular manufacturing system is used that produces easily-dismantled products, compatible materials are used, material that is difficult to use is identified by means of codes, and so on.

Guidelines for Recyclability:

1. Recyclable materials: Use easily recycled materials in products and label them so recycling partners can identify and put them toward the best possible reuse. Strive to make packaging as eco-friendly as possible, using highly renewable, recyclable materials like mushroom and bamboo. Also try to use recycled-content materials in products whenever possible, which helps further the overall recycling life cycle.
2. Modularity: The majority of components found inside products should be easily removable, with standardized parts. This makes it easier to reuse or recycle them.
3. Easy disassembly: The less complexity, the better. By designing smarter, we can cut down on the number of screws in our products, and the ones that remain are easier to access and more consistent in type. All parts should design wisely so that they can easily separable with commonly found tools.
4. Minimal glues and adhesives: Glues and adhesives can create processing challenges for recyclers, so designer should adopt other methods, such as innovative snap fits, to accomplish the same design goals.
5. Restrictions on paints and coatings: Prefer integral finishes instead of exterior coatings, which can interfere with the recycling process or degrade certain plastics during processing. If paint is the only option, use paint that is compatible with recycling.

Design for Disassembly (DFD)

Design for Disassembly is a design strategy that considers the future need to disassemble a product for repair, refurbish or recycle. Will a product need to be repaired? Which parts will need replacement? Who will repair it? How can the experience be simple and intuitive? Can the product be reclaimed, refurbished, and resold? If it must be discarded, how can we facilitate its disassembly into easily recyclable components? By responding to questions like these, the DfD method increases the effectiveness of a product both during and after its life. In given environmental and cost constraints, our challenge is as much product de-creation as it is creation. And DfD strategies are applied throughout the entire design cycle; designers will need to educate the

A floss container comprised of two metal halves and a plastic spool.

team, discover waste, set goals, create solutions, and then monitor results through production, release, use, and end-of-life.

Designing for disassembly has several benefits. It can make it easier for your product to be repaired or upgraded, thereby prolonging its useful life. It can also help ensure your product is recycled and enable whole components to be reused. In fact, the degree to which your product can be disassembled easily often determines how the product will end its life.

Guidelines to Design for Disassembly

1. The fewer parts you use, the fewer parts there are to take apart.
2. As with parts, the fewer fasteners you use, the better.
3. Common and similar fasteners that require only a few standard tools will help to simplify and speed disassembly.
4. Screws are faster to unfasten than nuts and bolts.
5. Glues should be avoided.
6. Building disassembly instructions into the product will help users understand how to take it apart.
7. When using electrical circuits:
    - mount components on a printed circuit board with detachable leads, do not solder
    - use plugs that push into place and can easily be pulled out
    - when considering which fixings to use:
    - be consistent in size and type of fixing screws
    - use self-threading screws rather than bolts
    - use fixings which snap, clip or slot into place
    - avoid using adhesives which may require chemical processing to dissolve,
    - if adhesives are necessary: use adhesives with low hazardous solvent emission
    - minimize the use of silicone
    - choose seals which can be easily removed
    - remember clean surfaces facilitate recycling
8. When considering the use of labels
    - avoid mixing of non-compatible polymer materials
    - avoid plastic labels on metal parts if they are not critical
    - consider stamping instead
    - avoid PVC materials in labels

DESIGN & ENGINEERING

Module-5

Product centred and user centred design. Product centred attributes and user centred attributes. Bringing the two closer. Example: Smart phone. Aesthetics and ergonomics.
Value engineering, Concurrent engineering, Reverse engineering in design; Culture based design; Architectural designs; Motifs and cultural background; Tradition and design; Study the evolution of Wet grinders; Printed motifs; Role of colours in design.

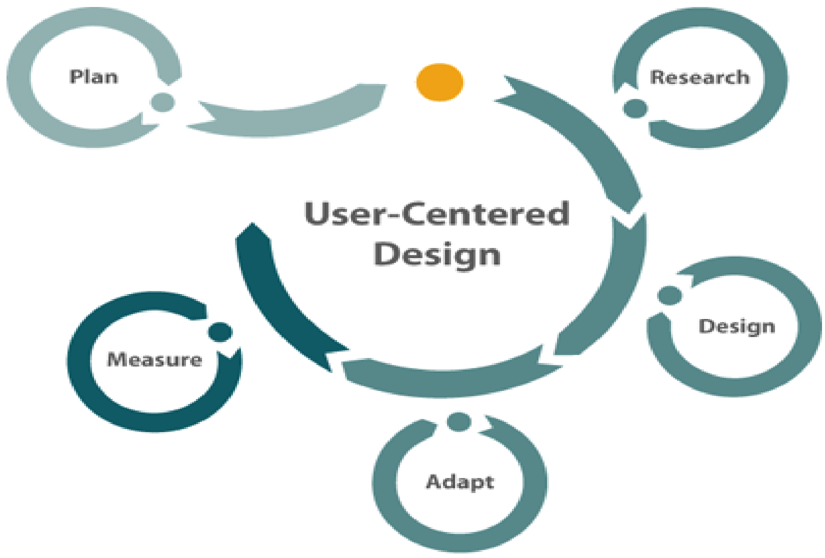
User Centered Design & Product Centered Design

User-centered design (UCD) is a framework of processes (not restricted to interfaces or technologies) in which the needs, wants, and limitations of end users of a product, service or process are given extensive attention at each stage of the design process. User-centered design can be characterized as a multi-stage problem solving process that not only requires designers to analyze and foresee how users are likely to use a product, but also to test the validity of their assumptions with regard to user behavior in real world tests with actual users at each stage of the process from requirements, concepts, pre-production models, mid production and post production creating a circle of proof back to and confirming or modifying the original requirements. Such testing is necessary as it is often very difficult for the designers of a product to understand intuitively what a first-time user of their design experiences, and what each user's learning curve may look like.

The chief difference from other product design philosophies is that user-centered design tries to optimize the product around how users can, want, or need to use the product, rather than forcing the users to change their behavior to accommodate the product.

These are some key principles that will ensure a design to become user centered:

1. The design is based upon an explicit understanding of users, tasks and environments
2. Users are involved throughout design and development
3. The design is driven and refined by user-centered evaluation
4. The process is iterative
5. The design addresses the whole user experience
6. The design team includes multidisciplinary skills and perspectives
7. Make it easy to determine what actions are possible at any moment.
8. Make things visible, including the conceptual model of the system, the alternative actions, and the results of actions
9. Make it easy to evaluate the current state of the system.
10. Follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state.



How to involve user in Design?

It is necessary to think carefully about who is a user and how to involve users in the design process. Obviously users are the people who will use the final product or artefact to accomplish a task or goal. But there are other users as well. The people who manage the users have needs and expectations too.

These are some methods which designer can practice to impart UCD in their designs.

Technique	Purpose	Stage of the Design Cycle
Background Interviews and questionnaires	Collecting data related to the needs and expectations of users; evaluation of design alternatives, prototypes and the final artifact	At the beginning of the design project
Sequence of work interviews and questionnaires	Collecting data related to the sequence of work to be performed with the artifact	Early in the design cycle
Focus groups	Include a wide range of stakeholders to discuss issues and requirements	Early in the design cycle
On-site observation	Collecting information concerning the environment in which the artifact will be used	Early in the design cycle
Role Playing, walkthroughs, and simulations	Evaluation of alternative designs and gaining additional information about user needs and expectations; prototype	Early and mid-point in the design cycle

Examples:

Consider these two equipment's, first one offering more function than the second design more ever it can replace to many other tools and providing a numerous number of tools within single module but the second design only offers limited number of functions and tools.

Which one is better?

Obviously you will choose second one because of its usability and simple appearance. Since second one can be handles easily and it won't make any confusions to user this design is more ergonomic than first one. However in this can you can notice that the second design is designed under the considerations of user and his emotional requirements.

Aesthetics & Ergonomics

Aesthetics:

Aesthetics is concerned with how things look. This can be influenced by an objects' appearance and its style. The appearance of an object is the feature that people notice first. In some ways appearance can be very personal and is influenced by things like the materials from which the object is made and the type of finish applied to its surface.

It is important that products have visual appeal. In a world where many new products function in a similar way, it is often the appearance which sells the product. Aesthetics is a pan of design which is difficult to analyze and describe in words. However there are aspects of appearance which can be considered separately.

Line: Lines are the basic starting point in our attempts to represent design ideas. We use lines to enclose space and create shapes. Lines can be used to express feelings and emotion. Lines may be thick or thin, solid or broken, straight or curved. By changing the type of line many visual effects can be created. Straight or wavy lines can express rhythm, give the impression of light and shade as well as texture. A feeling of anxiety, depression and calm can be created. Lines can be used to deceive the eye.

Shape and Form: These terms are often confused. Shape is created when lines overlap and cross to create an enclosed space. Shapes are two dimensional. Shapes can be used as the starting point for a design.

Geometric shapes - Circles, squares etc. Natural shapes - Sea shells, flowers etc. Manmade shapes - Bridge structures etc.

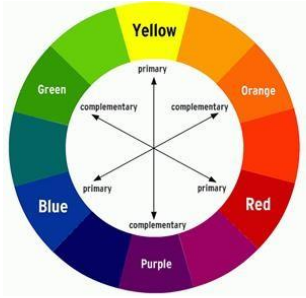
Form is three dimensional. To describe a form fully it is necessary to give details of its shape, size, proportion, colour and texture. When experimenting with form it is generally best to start with simple geometric forms such as cubes and cylinders. These forms can then be manipulated to create more complex forms.

Size and proportion: The size of an object is found by measuring its length, width, and height. These are known as linear dimensions. Proportion is the relationship between an object's heights compared to its width.

Symmetry: Symmetry is when a shape or form can be divided down the middle and one half is the mirror image of the other. A shape or form which is not symmetrical is asymmetrical.

Pattern: Pattern involves the division of area. Pattern helps to create interest to plain surfaces. Patterns can be random or made up from elements which are repeated. Patterns can be used to create rhythm and movement.

Colour



Colour has no form, but can complement form. Used badly colour can completely ruin a design. Alternatively, used well colour can make a good design great! Colours can be mixed. Mixing rimary colours at the centre of the colour wheel produces secondary colours. These secondary colours can be further mixed to create tertiary colours. Colours close to each other on the colour wheel produce harmony e.g. red and orange. Colours opposite each other on the colour wheel create contrast e.g. red and green. Colour has three properties:-

- Intensity - brightness e.g. bright red or dull red.
- Temperature - warm colours e.g. red and orange. Cold colours e.g. blue and green.
- Tone - the lightness or darkness of a colour. Small quantities of white or black can be added to basic colours to create light and dark shades of a colour.

Style:

The style of an object is created by combining tone, colour, texture, form etc. Many designers have a recognisable style which they apply to their work

Charles Rennie Mclntosh's Glasgow style.

Style is constantly changing, what is popular today may not be popular in a year or two. The designer has the responsibility of making sure that the style of his or her design will appeal to those who will buy it. Art Nouveau, Victorian and Gothic are well known styles. Each style has its own particular look. Whilst designers have argued for years over the importance of style and function, it is probably true to say that the best designs have a good balance of the two.

When you come to design a product you should try to take account of aesthetics - but remember a design which looks great but doesn't work or is difficult to use is not a good design!

Ergonomics:

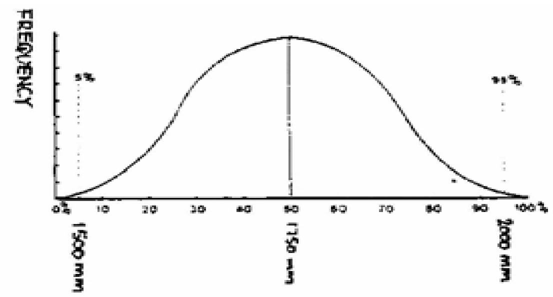
Ergonomics is a design factor which is of critical importance. By using ergonomics the designer is taking into consideration the user of the design. To help you consider the user you should use the following checklist:-

1. Begin by looking closely at how the product will be used, decide on the characteristics of the user and the product and the relationship between them.
2. Consider the factors which will ensure health, safety, convenience and comfort of the user.
3. Compare your design ideas with what you find in 1 and 2 above, i.e. carry out tests to see if the product is designed well from the ergonomic point of view.

Obviously when designing products for people you must take into account their physical size, weight, reach and movement. In order to do this you will need data relating to human dimensions.

Anthropometry

Data on human dimensions can be found in tables of anthropometric data. Anthropometric data is available on all aspects of human dimension e.g. height, arm length and distance between the eyes. This data is available for men and women and for different age groups. As people are all different sizes it is necessary to select data which is appropriate to the design situation. For example let's consider the height of a doorway. Obviously to find this dimension we must consider the height of people.



The graph shows the range of heights of men and the number of men at each height. You will see that few men are very small i.e. 1500 mm. Few men are very tall i.e. 2000 mm. However there are large numbers of men who are around average height i.e. 1750 mm.

Similar graphs can be drawn to show the distribution of any human dimension, either of men or of women, young or old.

You may think that when choosing the height of a doorway that you would simply choose the size of the tallest man but this is not the case. The chances of the largest person in the world using the doorway are so slim that it is not practical to use this size for a door. In fact when designers require upper dimensions as in the case of the doorway they ignore the upper 5%. The dimension chosen is called the 95th percentile (95th %le). See the graph. Similarly if the designer requires to consider small individuals they ignore the smallest 5%. The dimension used is called the 5th percentile.

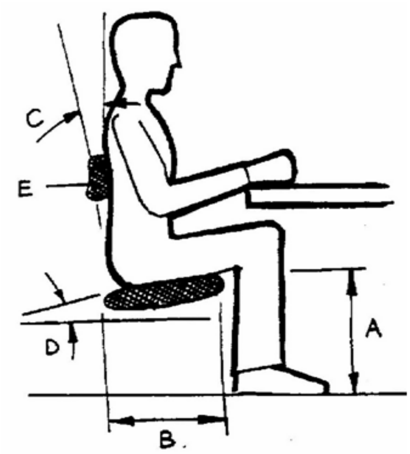
Examples:

1. **Door Design**

If we once again consider the doorway height it should be apparent that the designer will choose the 95th %le man (the 95th %le woman's dimension will be smaller). Let's look at another example. Imagine we were trying to find the maximum height that a shelf should be in a supermarket. We are of course looking at an individual's reach here. Obviously it is the smallest individual we should consider, i.e. 5th %le woman. Setting the shelf at a height suitable for the 5th %le woman means that the shelf will be within the reach of all other individuals.

Occasionally a compromise dimension is required. In a situation where to choose the 95th % would prove inconvenient to the 5th % user (or vice versa) the designer will choose a dimension in between. This dimension is called the 50th percentile. A good example of this would be the height of a wall mounted mirror.

2. Seat Design



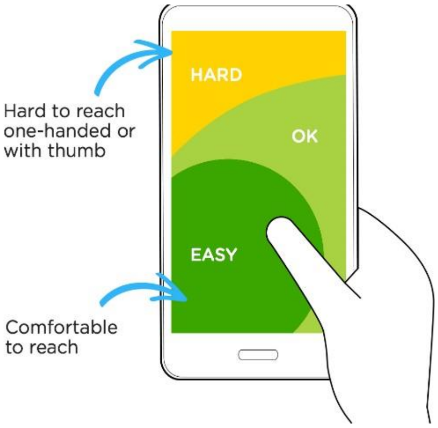
Seats are used for a variety of activities and each activity will require a different design of chair. The design of a chair to be used at a desk will be very different from the design of an easy chair!

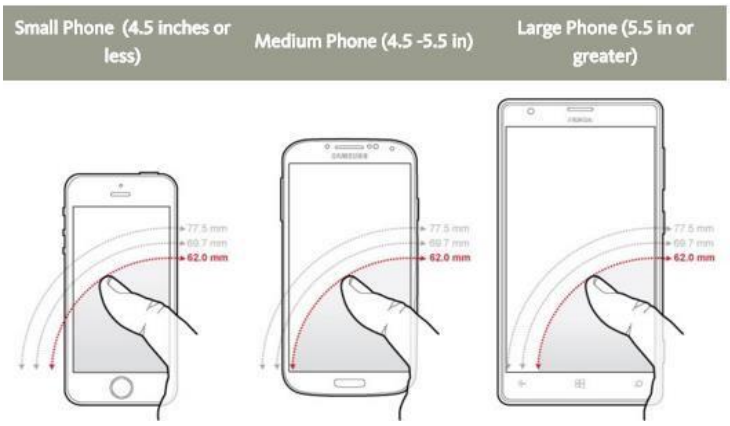
Measurements and considerations in chair design are:-

- Seat height A suited to work level. Seat depth B to provide clearance.
- Seat back and angle C should support the natural curve of the spine.
- Seat angle D should be horizontal or sloping back.
- Back rest E should be adjustable for a work chair and should also allow free movement of the shoulders.
- Chair seat should be padded unless it is designed to be used for short periods only

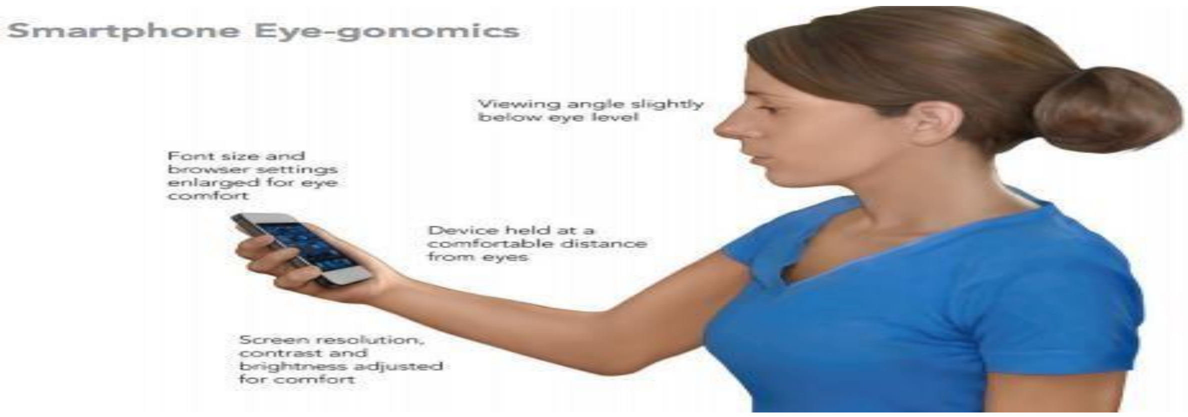
3. Smart phones

The size shape of smart phone is optimized based on the human comfort. These ergonomic considerations improve the user centered attributes of these products.



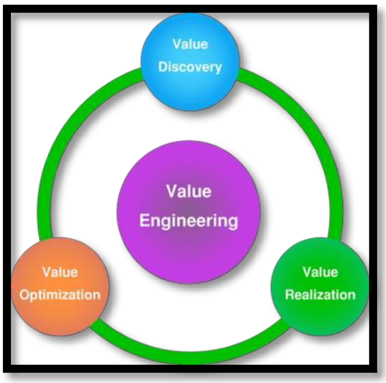


This figure representing choosing better screen size for a smartphone that being handles on palms.



Value Engineering

Value engineering (VE) is systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.



The reasoning behind value engineering is as follows: if marketers expect a product to become practically or stylistically obsolete within a specific length of time, they can design it to only last for that specific lifetime. The products could be built with higher-grade components, but with value engineering they are not because this would impose an unnecessary cost on the manufacturer, and to a limited extent also an increased cost on the purchaser. Value engineering will reduce these costs. A company will typically use the least expensive components that satisfy the product's lifetime projections.

The benefits of Value Engineering:

4. Value Engineering helps your organization in:
5. Lowering Operating and Management costs
6. Improving quality management
7. Improving resource efficiency
8. Simplifying procedures
9. Minimizing paperwork
10. Lowering staff costs
11. Increasing procedural efficiency
12. Optimizing construction expenditures
13. Developing value attitudes in staff
14. Competing more successfully in marketplace

Value Engineering helps you to learn how to:

1. Improve your career skills
2. Separate "Symptoms" from "problems"
3. Solve "root cause" problems and capture opportunities
4. Become more competitive by improving "benchmarking" process
5. Take command of a powerful problem solving methodology to use in any situation

Value engineering techniques can be applied to any product process procedure system or service in any kind of business or economic activity including health care, governance, construction, industry and in the service sector. It focuses on those value characteristics which are deemed most important from the customer point of view. However it's a vital tool in design used to achieve impressive savings, much greater than what is possible through conventional cost reduction exercise even when cost reduction is the objective of the task.

Improving Value of Designs (Examples):

Whenever you try to improve the value of any designs remember these points

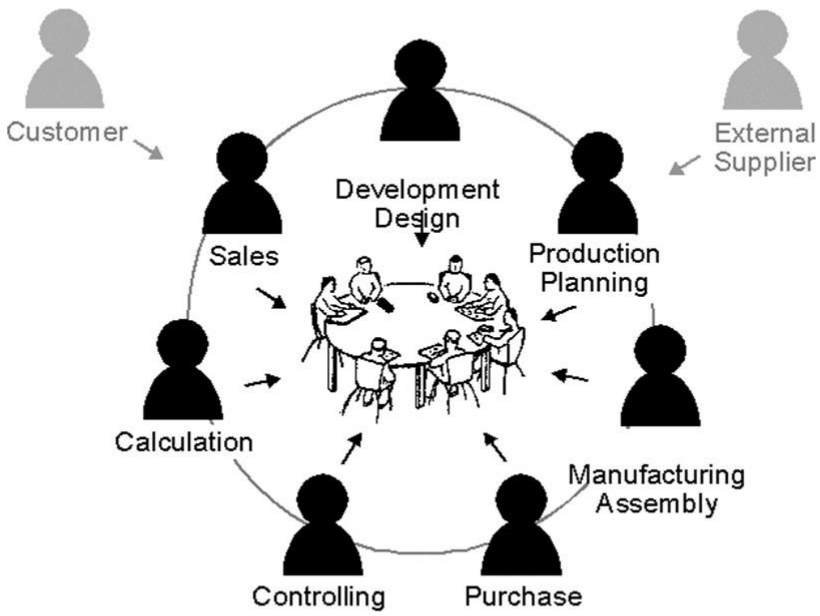
1. Value engineering (VE) is systematic method to improve the "value" of goods or products and services by using an examination of function.
2. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost.
3. It is a primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements

$$\textbf{Value} = \frac{\textbf{Worth}}{\textbf{Cost}} = \frac{\textbf{Function(Utility)}}{\textbf{Cost}}$$

Concurrent Engineering

Concurrent engineering, also known as simultaneous engineering, is a method of designing and developing products, in which the different stages run simultaneously, rather than consecutively. It decreases product development time and also the time to market, leading to improved productivity and reduced costs.

Concurrent Engineering is a long term business strategy, with long term benefits to business. Though initial implementation can be challenging, the competitive advantage means it is beneficial in the long term. It removes the need to have multiple design reworks, by creating an environment for designing a product right the first time round.



Benefits of Concurrent Engineering:

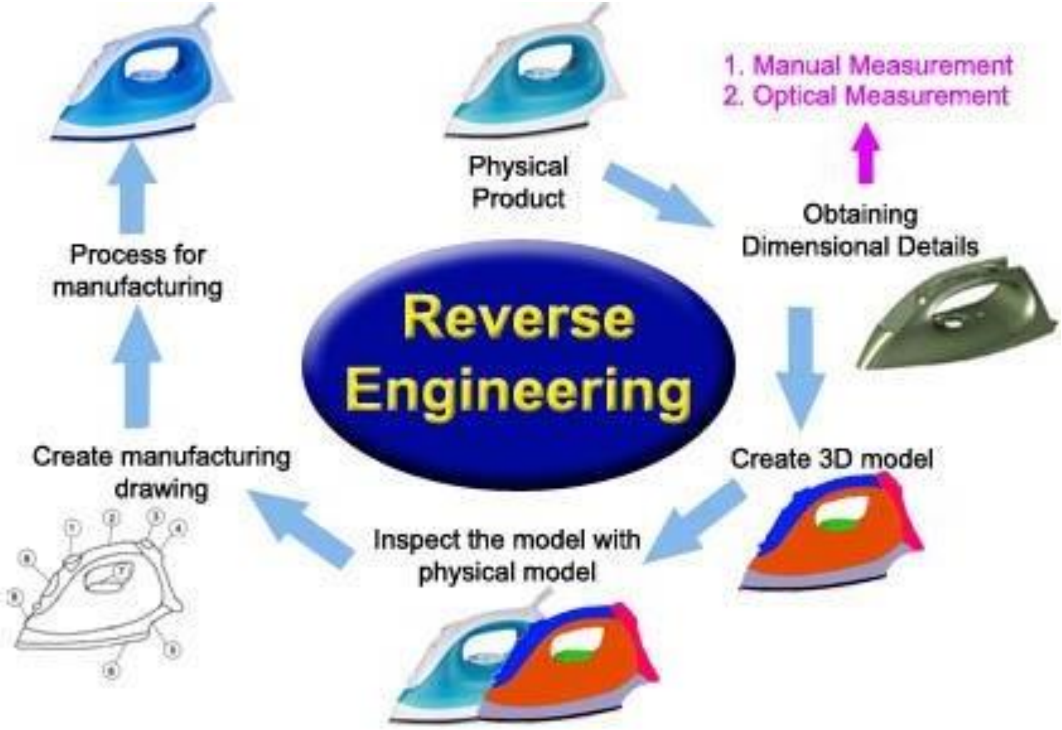
1. Competitive Advantage- reduction in time to market means that businesses gain an edge over their competitors.
2. Enhanced Productivity- earlier discoveries of design problems means potential issues can be corrected soon, rather than at a later stage in the development process.
3. Decrease Design and Development Time- make products which match their customer's needs, in less time and at a reduced cost

Example, if the manufacturing department has a part that is difficult to manufacture due to the poor design, considerable time will be expended in order to manufacture the part. To accomplish this, sometimes, the manufacturing department introduces changes to the original design such as either updating the part tolerances or changing the number of parts in the design. At the same time, the changes in the product design may not be either communicated to others in the product realization process or too late to prevent decisions that are based on the original product design. At any rate the traditional model is vulnerable to a costly and error prone product realization.

Reverse Engineering

Reverse engineering, also called back engineering, is the processes of extracting knowledge or design information from anything man-made and re-producing it or re-producing anything based on the extracted information. The process often involves disassembling something (a mechanical device, electronic component, computer program, or biological, chemical, or organic matter) and analysing its components and workings in detail.

The reasons and goals for obtaining such information vary widely from every day or socially beneficial actions, to criminal actions, depending upon the situation. Often no intellectual property rights are breached, such as when a person or business cannot recollect how something was done, or what something does, and needs to reverse engineer it to work it out for themselves. Reverse engineering is also beneficial in crime prevention, where suspected malware is reverse engineered to understand what it does, and how to detect and remove it, and to allow computers and devices to work together ("interoperate") and to allow saved files on obsolete systems to be used in newer systems. By contrast, reverse engineering can also be used to "crack" software and media to remove their copy protection or to create a (possibly improved) copy or even a knockoff; this is usually the goal of a competitor.



Reverse engineering has its origins in the analysis of hardware for commercial or military advantage. However, the reverse engineering process in itself is not concerned with creating a copy or changing the artefact in some way. It is only an analysis in order to deduce design features from products with little or no additional knowledge about the procedures involved in their original production.

Tradition & Design

Increasing globalization has led to product manufacturers seeking cooperation with other companies at an international level, not only for production but also for product development. In such cooperation engineering designers from different cultural backgrounds participate in the design process. Their cultures will not only influence the product, but also the development process. A study of the literature has shown that, so far, cultural influences on the development process have not been studied. As a consequence there is a lack of knowledge on how to deal with or exploit various cultures within design processes. The main objective of this research is to support engineering designers working in intercultural design processes, i.e. processes in which engineering designers of different cultures work together. This paper describes the research approach, i.e. how to investigate cultural influences and their effects on the design process. For this, the characteristics to be investigated are derived from the literature on design and on cultural studies. An empirical study will be carried out to identify relevant cultural factors and determine their effects. On the basis of the results, guidelines for engineering designers and project leaders will be developed to deal with cultural influences.

Design and Culture have always been closely interrelated, but in many instances design is flaunted as the true measure of culture, rather than belonging to part of cultural context of the society. Design has become the embodiment of a larger process of creative 'culture-mongering' that has become a means to capture ideation, innovation and enterprise and made to stand for cultural identity.

However, in the 21st Century the task of capturing Culture has become more and more difficult in terms of expressing culture through the medium of design. Design increasingly struggles for a clear sense of definition, and one is left asking, what can Culture really mean today, if it is no longer tied to consumer lifestyle? We remain in a post-contemporary state where we require a redefinition of meaning, value and identity.

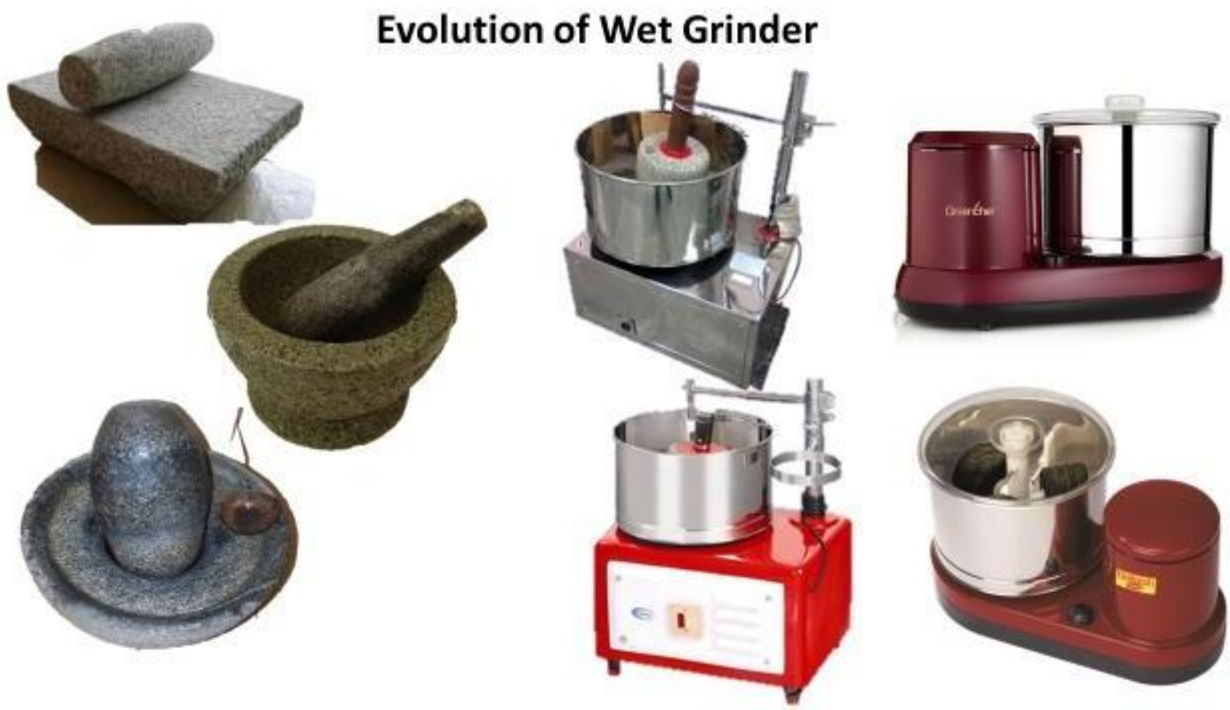
Traditional Design evolved through Innovative ideas

Modern Design evolved through technology

Modern design with traditional influence

Evaluation of Wet Grinder:

Wet grinders are closely related to Indian culture and food preparation styles. It can be considered as an example that describes how cultural motifs influencing designs and product development.



Here engineering converts traditional home needs in to automated products with the help of technology. But the specialty of these designs is that after automation the equipment still exhibit same features and feel that of traditional wet grinders. In other words the user will experience the same feel which he/she experienced from traditional product while using modern product. Hence traditional based designs are more concerned with human emotion and cultural influence.

DESIGN & ENGINEERING

Module-VI

Modular design; Design optimization; Intelligent and Autonomous products; User interfaces; communication between products; autonomous products; internet of things; human psychology and the advanced products. Design as a marketing tool; Intellectual Property rights – Trade secret; patent; copy-right; trademarks; product liability.

Modular Design

Modular design, or "modularity in design", is a design approach that subdivides a system into smaller parts called modules or skids that can be independently created and then used in different systems. A modular system can be characterized by functional partitioning into discrete scalable, reusable modules, rigorous use of well-defined modular interfaces, and making use of industry standards for interfaces.

Besides reduction in cost (due to less customization, and shorter learning time), and flexibility in design, modularity offers other benefits such as augmentation (adding new solution by merely plugging in a new module), and exclusion. Examples of modular systems are cars, computers, process systems, solar panels and wind turbines, elevators and modular buildings. Earlier examples include looms, railroad signaling systems, telephone exchanges, pipe organs and electric power distribution systems. Computers use modularity to overcome changing customer demands and to make the manufacturing process more adaptive to change.

Benefits of Modular Design:

1. Minimizing cost, by reducing the diversity of parts in a product range
2. Savings in design time, as assemblies/modules are simply selected like bought out parts, as their reliability, cost and quality are documented and easily available.
3. Modular products enable faster, easier and more efficient customization of standard products to unique user needs.
4. Related to the above point, a popular version of a product can be increased to meet increased demand in a short period of time.
5. Modules can be modified or replaced without changing anything else on the product.
6. Modular design simplifies the information processing in a design project.
7. Modular design enables quick and easy upgrades (driven by either technology or user improvement), thus enabling products to evolve.
8. Modular design resists obsolescence and shortens the redesign cycle. A new generation product can reuse most of the old modules and change is provided by a few improved modules.
9. Replacement of worn parts (which can then be recycling).
10. Flexibility in use, as the way customers use products can change over time.
11. Easy and quick installation of products
12. Easy and quick servicing and maintenance of products
13. Modular design delivers shorter learning curves when new employees have to become familiar with products and the way they work.
14. Modular design gives businesses the possibility to outsource the assembly of some modules, therefore freeing-up manufacturing capacity and increasing the number of products delivered on time.
15. During design, different modules can be developed by separate groups of engineers at the same time. Designing modules/assemblies simultaneously like this (often referred to as concurrent engineering), reduces overall time-to-market for a product, therefore maximizing total sales and revenue.
16. Production facilities can be organized specifically to assemble particular modules.

Examples:

1. **Automobiles**

Aspects of modular design can be seen in cars or other vehicles to the extent of there being certain parts to the car that can be added or removed without altering the rest of the car. Although this is true but it's not all the time like this.

The modular design of the Unimog offers attachment capabilities for various different implements

A simple example of modular design in cars is the fact that, while many cars come as a basic model, paying extra will allow for "snap in" upgrades such as a more powerful engine or seasonal tires; these do not require any change to other units of the car such as the chassis, steering, electric motor or battery systems.

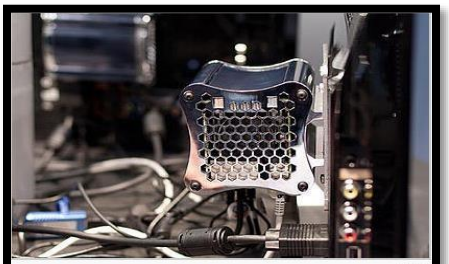
2. **Workstations**

An office building can be built using modular parts such as walls, frames, doors, ceilings, and windows. The office interior can then be partitioned (or divided) with more walls and furnished with desks, computers, and whatever else is needed for a functioning workspace. If the office needs to be expanded or re-divided to accommodate employees, modular components such as wall panels can be added or relocated to make the necessary changes without altering the whole building. Later on, this same office can be broken down and rearranged to form a retail space, conference hall or any other possible type of building using the same modular components that originally formed the office building.

Modular workstations

3. **Computer**

Modular design in computer hardware is the same as modular design in other things). The idea is to build computers with easily replaceable parts that use standardized interfaces. This technique allows a user to upgrade certain aspects of the computer easily without having to buy another computer altogether. A computer is actually one of the best examples of modular design - typical modules are power supply units, processors, main boards, graphics cards, hard drives, optical drives, Etc. All of these parts should be easily interchangeable as long as the user uses parts that support the same standard interface as the part that was replaced. Similar to the computer's modularity, other tools have been developed to leverage modular design.



Modular computer design

Design Optimization

Product design and development requires that engineers consider trade-offs between product attributes in the areas of cost, weight, manufacturability, quality, and performance. Engineers are faced with the difficult challenge of determining how to arrive at the best overall design, making the right compromises, and not sacrificing critical attributes like safety.

Design optimization is the process of finding the best design parameters that satisfy project requirements. Engineers typically use design of experiments (DOE), statistics, and optimization techniques to evaluate trade-offs and determine the best design. Design optimization often involves working in multiple design environments in order to evaluate the effects that design parameters have across interrelated physical domains.

Why Design Optimization?

1. There are multiple solutions to the problem; and the optimal solution is to be identified.
2. There exist one or more objectives to accomplish and a measure of how well these objectives are accomplished (measurable performance).
3. Constraints of different forms (hard, soft) are imposed.
4. There are several key influencing variables. The change of their values will influence (either improve or worsen) the "measurable performance" and the degree of violation of the "constraints.

Examples:

Aerodynamic Design of Missiles

The selection of flight profiles that yield the greatest performance plays a substantial role in the preliminary design of flight vehicles, since the use of ad-hoc profile or control policies to evaluate competing configurations may inappropriately penalize the performance of one configuration over another. Thus, to guarantee the selection of the best vehicle design, it is important to optimize the profile and control policy for each configuration early in the design process.

Consider this example. For tactical missiles, the flight profiles are determined by the thrust and load factor (lift) histories. These histories can be controlled by a number of means including such techniques as using an angle of attack command history or an altitude/downrange schedule that the missile must follow. Each combination of missile design factors, desired missile performance, and system constraints results in a new set of optimal control parameters.

Optimization is the future, since the investment cost, efficiency, energy savings, etc. are critical are critical aspects. In particular, engineering disciplines need to develop mathematical and computational optimization methods to improve the efficiency of the processes.

User Interfaces

The user interface (UI), in the industrial design field of human–machine interaction, is the space where interactions between humans and machines occur. The goal of this interaction is to allow effective operation and control of the machine from the human end, whilst the machine simultaneously feeds back information that aids the operators' decision-making process. Examples of this broad concept of user interfaces include the interactive aspects of computer operating systems, hand tools, heavy machinery operator controls, and process controls. The design considerations applicable when creating user interfaces are related to or involve such disciplines as ergonomics and psychology.

Generally, the goal of user interface design is to produce a user interface which makes it easy (self-explanatory), efficient, and enjoyable (user-friendly) to operate a machine in the way which produces the desired result. This generally means that the operator needs to provide minimal input to achieve the desired output, and also that the machine minimizes undesired outputs to the human.

User interface of Google:

User not experiencing the complexity of algorithms running behind google search, they can easily interact with Google. UI determines the simplicity of design or product.

User interface engineering is the design of user interfaces for machines and software, such as computers, home appliances, mobile devices, and other electronic devices, with the focus on maximizing the user experience. The goal of user interface design is to make the user's interaction as simple and efficient as possible, in terms of accomplishing user goals (user-centered design). Good user interface design facilitates finishing the task at hand without drawing unnecessary attention to itself. Graphic design and typography are utilized to support its usability, influencing how the user performs certain interactions and improving the aesthetic appeal of the design; design aesthetics may enhance or detract from the ability of users to use the functions of the interface. The design process must balance technical functionality and visual elements (e.g., mental model) to create a system that is not only operational but also usable and adaptable to changing user needs. Interface design is involved in a wide range of projects from computer systems, to cars, to commercial planes; all of these projects involve much of the same basic human interactions yet also require some unique skills and knowledge.

The Seven User Centered Attributes:

1. Clarity: the information content is conveyed quickly and accurately.
2. Discriminability: the displayed information can be distinguished accurately.
3. Conciseness: users are not overloaded with extraneous information.
4. Consistency: a unique design, conformity with user's expectation.
5. Detectability: the user's attention is directed towards information required.
6. Legibility: information is easy to read.
7. Comprehensibility: the meaning is clearly understandable, unambiguous, interpretable, and recognizable.

Intelligent and Autonomous Products

Intelligence has been defined in many different ways including one's capacity for logic, abstract thought, understanding, self-awareness, communication, learning, emotional knowledge, memory, planning, creativity and problem solving. It can be more generally described as the ability to perceive information, and retain it as knowledge to be applied towards adaptive behaviors within an environment. When a designer artificially integrates these kind of human ability into machines through then that kind of intelligence know as Artificial Intelligence.

Artificial intelligence (AI) is the intelligence exhibited by machines or software. It is also the name of the academic field of study which studies how to create computers and computer software that are capable of intelligent behavior. John McCarthy, who coined the term, defines it as "the science and engineering of making intelligent machines".

Communication between products: Smart, connected products are products, assets and other things embedded with processors, sensors, software and connectivity that allow data to be exchanged between the product and its environment, manufacturer, operator/user, and other products and systems. Connectivity also enables some capabilities of the product to exist outside the physical device, in what is known as the product cloud. The data collected from these products can be then analysed to inform decision-making, enable operational efficiencies and continuously improve the performance of the product.

Example:

- Google Self Driving Car

Google self-driving car is any in a range of autonomous cars, developed by Google X as part of its project to develop technology for mainly electric cars. The software installed in Google's cars is named Google Chauffeur. Powered by an electric motor with around a 100 mile range, the car uses a combination of sensors and software to locate itself in the real world combined with highly accurate digital maps. A GPS is used, just like the satellite navigation systems in most cars, to get a rough location of the car, at which point radar, lasers and cameras take over to monitor the world around the car, 360-degrees. The software can recognise objects, people, cars, road marking, signs and traffic lights, obeying the rules of the road and allowing for multiple unpredictable hazards, including cyclists. It can even detect road works and safely navigate around them.

Design layout of Google Car

Internet of Things (IoT)

The Internet of Things (IoT) is the network of physical objects, devices, vehicles, buildings and other items, embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. The IoT allows objects to be sensed and controlled remotely across existing network infrastructure, creating opportunities for more direct integration of the physical world into computer-based systems, and resulting in improved efficiency, accuracy and economic benefit. When IoT is augmented with sensors and actuators, the technology becomes an instance of the more general class of cyber-physical systems, which also encompasses technologies such as smart grids, smart homes, intelligent transportation and smart cities. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020.

> In 2008 the number of things connected to the Internet was greater than the people living on Earth.
>
> Within 2020 the number of things connected to the Internet will be about **50 billion**.

"Things" in the IoT sense, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, electric clams in coastal waters, automobiles with built-in sensors, DNA analysis devices for environmental/food/pathogen monitoring or field operation devices that assist firefighters in search and rescue operations. Legal scholars suggest to look at "Things" as an "inextricable mixture of hardware, software, data and service". These devices collect useful data with the help of various existing technologies and then autonomously flow the data between other devices.

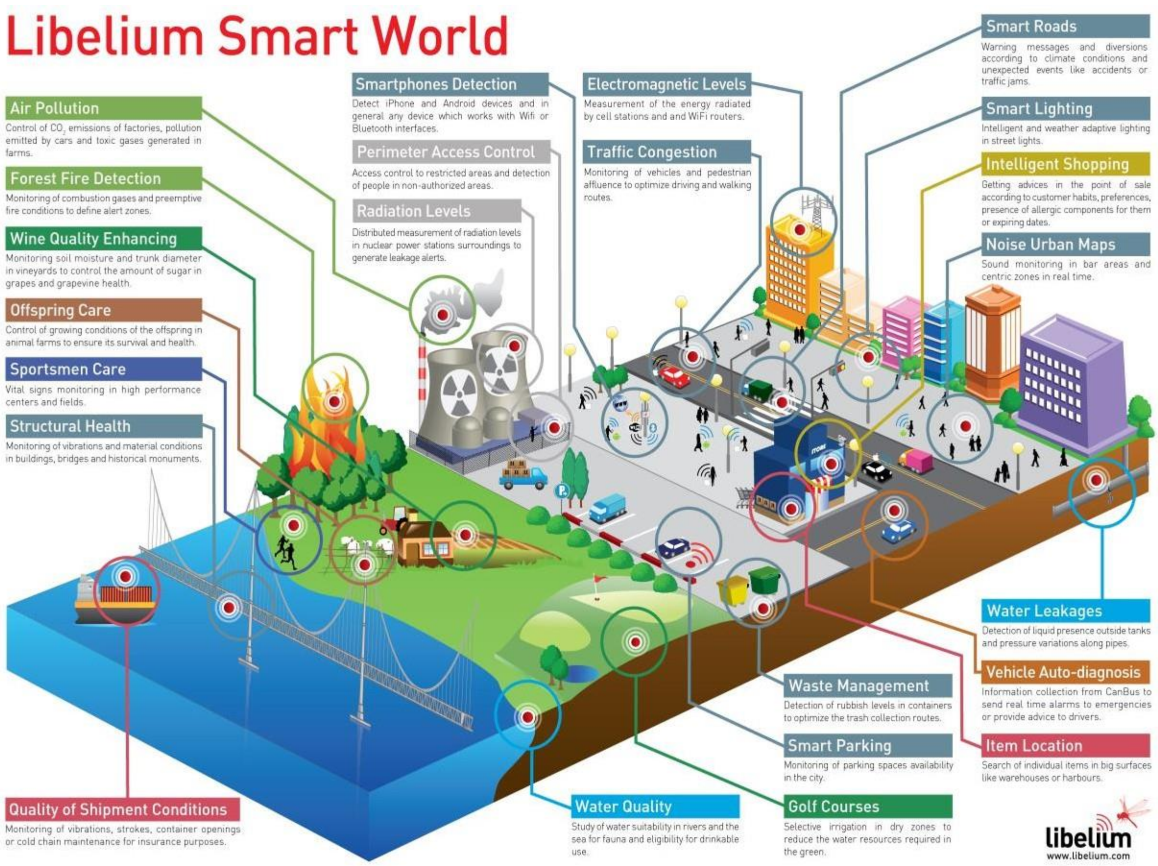
How Does IoT Impact You?

The new rule for the future is going to be, “Anything that can be connected, will be connected.” But why on earth would you want so many connected devices talking to each other? There are many examples for what this might look like or what the potential value might be.

Google Glass: A spectacle with Internet Connectivity

Say for example you are on your way to a meeting; your car could have access to your calendar and already know the best route to take. If the traffic is heavy your car might send a text to the other party notifying them that you will be late. What if your alarm clock wakes up you at 6 a.m. and then notifies your coffee maker to start brewing coffee for you? What if your office equipment knew when it was running low on supplies and automatically re-ordered more? What if the wearable device you used in the workplace could tell you when and where you were most active and productive and shared that information with other devices that you used while working?

On a broader scale, the IoT can be applied to things like transportation networks: “smart cities” which can help us reduce waste and improve efficiency for things such as energy use; this helping us understand and improve how we work and live. Take a look at the visual below to see what something like that can look like.



Smart City: The possibilities of IoT

Examples:

1. **Environmental Monitoring**

Environmental monitoring applications of the IoT typically use sensors to assist in environmental protection by monitoring air or water quality, atmospheric or soil conditions, and can even include areas like monitoring the movements of wildlife and their habitats. Development of resource constrained devices connected to the Internet also means that other applications like earthquake or tsunami early-warning systems can also be used by emergency services to provide more effective aid. IoT devices in this application typically span a large geographic area and can also be mobile. It has been argued that the standardization IoT brings to wireless sensing will revolutionize this area.

2. **Infrastructure Management**

Monitoring and controlling operations of urban and rural infrastructures like bridges, railway tracks, on- and offshore- wind-farms is a key application of the IoT. The IoT infrastructure can be used for monitoring any events or changes in structural conditions that can compromise safety and increase risk. It can also be used for scheduling repair and maintenance activities in an efficient manner, by coordinating tasks between different service providers and users of these facilities. IoT devices can also be used to control critical infrastructure like bridges to provide access to ships. Usage of IoT devices for monitoring and operating infrastructure is likely to improve incident management and emergency response coordination, and quality of service, up-times and reduce costs of operation in all aspects.

3. **Transportation**

The IoT can assist in integration of communications, control, and information processing across various transportation systems. Application of the IoT extends to all aspects of transportation systems (i.e. the vehicle, the infrastructure, and the driver or user). Dynamic interaction between these components of a transport system enables inter and intra vehicular communication, smart traffic control, smart parking, electronic toll collection systems, logistic and fleet management, vehicle control, and safety and road assistance.

4. **Home Automation**

Home automation is the use and control of home appliances remotely or automatically. Early home automation began with labour-saving machines like washing machines. Some home automation appliances are stand alone and do not communicate, such as a programmable light switch, while others are part of the internet of things and are networked for remote control and data transfer. Hardware devices can include sensors (like cameras and thermometers), controllers, actuators (to do things), and communication systems. Remote control can range from a simple remote control to a smartphone with Bluetooth, to a computer on the other side of the world connected by internet.

"SkyControl" home automation hub

Home automation systems are available which consist of a suite of products designed to work together. These typically connected through Wi-Fi or power line communication to a hub which is then accessed with a software application. Popular applications include thermostats, security systems, blinds, lighting, smoke/CO detectors, and door locks. Popular suites of products include X10, Z-Wave, and Zigbee all of which are incompatible with each other. Home automation is the domestic application of building automation.

5. **Medical and healthcare systems**

IoT devices can be used to enable remote health monitoring and emergency notification systems. These health monitoring devices can range from blood pressure and heart rate monitors to advanced devices capable of monitoring specialized implants, such as pacemakers, Fitbit electronic wristbands or advanced hearing aids. Specialized sensors can also be equipped within living spaces to monitor the health and general well-being of senior citizens, while also ensuring that proper treatment is being administered and assisting people regain lost mobility via therapy as well. Other consumer devices to encourage healthy living, such as, connected scales or wearable heart monitors, are also a possibility with the IoT.

Health Band: Monitoring Heartrate and instantly communicate with smartphone, so doctor can monitor his patients remotely

More and more end-to-end health monitoring IoT platforms are coming up for antenatal and chronic patients, helping one manage health vitals and recurring medication requirements.

Design & Human Psychology

Design is most effective when executed with knowledge of psychology. Knowing how people react to visual stimuli allows the crafting of an effective design, without psychology you are guessing. Psychology itself is a vastly fluctuating and massive subject, integrating that with design requires deeper understanding about human behaviours.

We've all experienced mild anxiety during our first interaction with a new device from setting up our TV to checking in for a doctor's appointment via an in-office kiosk. Will it work the way I need it to and the way I expect it to?

Human factors and engineering psychologists strive to make these interactions easier, more comfortable, less frustrating and, when necessary, safer. But their purview extends beyond the everyday gadgets we need to function; they also apply the science of psychology to improve life-critical products, such as medical equipment and airline computer systems.

Human factors and engineering psychologists study how people interact with machines and technology. They use psychological science to guide the design of products, systems and devices we use every day. They often focus on performance and safety.

These professionals apply what they know about human behavior to help businesses design products, systems and devices. They combine technology and psychology to improve our interactions with the systems and equipment we use daily.

Have you ever wondered why some products seem to work better than others?

The best products are thought out and tested with people trying them out in real-life situations. Better designs mean happy customers, fewer costly redesigns and less likelihood of accidents or injuries. Because of this, businesses and organizations need the expertise of human factors and engineering psychologists, who study how people behave and use that knowledge to create better processes and products.

These psychologists work in many different areas, including business, government and academia. And they can work on a range of designs from the ordinary things that touch all of our lives, such as better can openers and safer cars, to the highly specialized, such as instruments that allow pilots to land jumbo jets safely.

Smiles are the best example for human behaviour based design

There is no better approach for improving your design than gaining a better understanding of the people you are designing for. There is little practicality in dissecting every psychological principle relevant to design, but understanding a handful of key concepts can be a powerful gateway into designing with psychology in mind.

Intellectual Property Rights (IPR)

Intellectual property Right (IPR) is a term used for various legal entitlements which attach to certain types of information, ideas, or other intangibles in their expressed form. The holder of this legal entitlement is generally entitled to exercise various exclusive rights in relation to the subject matter of the Intellectual Property. The term intellectual property reflects the idea that this subject matter is the product of the mind or the intellect, and that Intellectual Property rights may be protected at law in the same way as any other form of property. Intellectual property laws vary from jurisdiction to jurisdiction, such that the acquisition, registration or enforcement of IP rights must be pursued or obtained separately in each territory of interest.

Intellectual property rights (IPR) can be defined as the rights given to people over the creation of their minds. They usually give the creator an exclusive right over the use of his/her creations for a certain period of time.

What is Intellectual Property?

Intellectual property is an intangible creation of the human mind, usually expressed or translated into a tangible form that is assigned certain rights of property. Examples of intellectual property include an author's copyright on a book or article, a distinctive logo design representing a soft drink company and its products, unique design elements of a web site, or a patent on the process to manufacture chewing gum.

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Intellectual property (IP) refers to creations of the mind: inventions, literary and artistic works, and symbols, names, images, and designs used in commerce.

Categories of Intellectual Property

One can broadly classify the various forms of IPRs into two categories:

1. IPRs that stimulate inventive and creative activities (patents, utility models, industrial designs, copyright, plant breeders' rights and layout designs for integrated circuits) and
2. IPRs that offer information to consumers (trademarks and geographical indications)

IPRs in both categories seek to address certain failures of private markets to provide for an efficient allocation of resources

IP is divided into two categories for ease of understanding:

1. Industrial Property

2. Copyright

Industrial property, which includes inventions (patents), trademarks, industrial designs, and geographic indications of source; and Copyright, which includes literary and artistic works such as novels, poems and plays, films, musical works, artistic works such as drawings, paintings, photographs and sculptures, and architectural designs. Rights related to copyright include those of performing artists in their performances, producers of phonograms in their recordings, and those of broadcasters in their radio and television programs.

Different types of Intellectual Property Rights are:

i. Patents

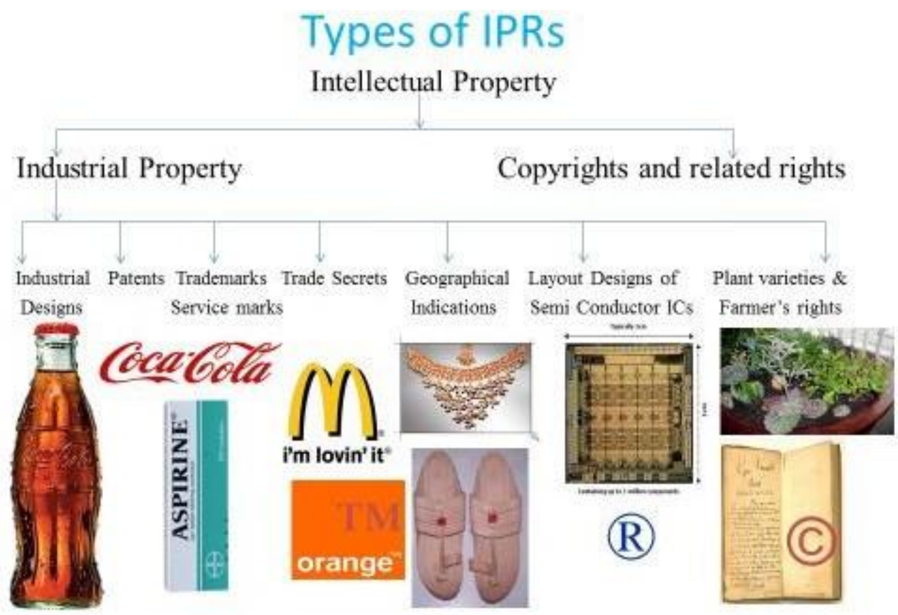
ii. Copyrights

iii. Trademarks

iv. Industrial designs

v. Protection of Integrated Circuits layout design

vi. Geographical indications of goods



i. Patents

A patent is a set of exclusive rights granted by a government to an inventor or assignee for a limited period of time in exchange for detailed public disclosure of an invention. An invention is a solution to a specific technological problem and is a product or a process.

The procedure for granting patents, requirements placed on the patentee, and the extent of the exclusive rights vary widely between countries according to national laws and international agreements.

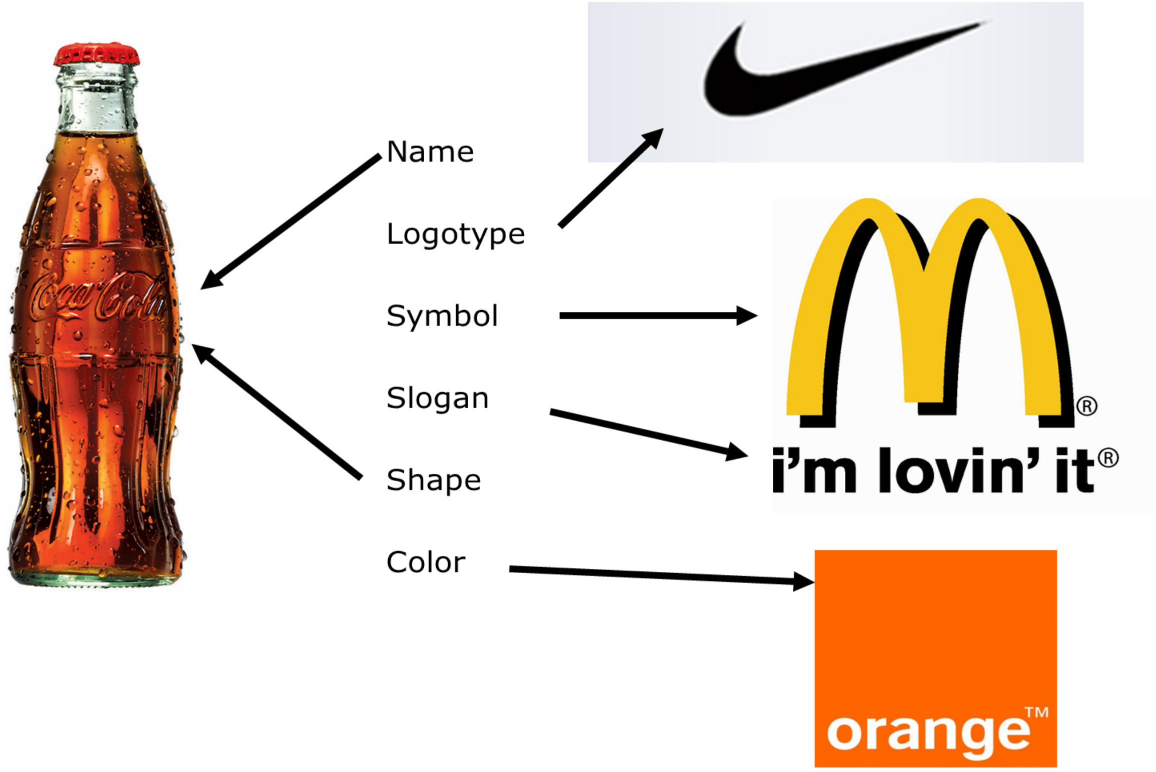
It is a monopoly right granted to a person, who invented a new product or process of making an article, for 20years under the Indian Patens Act, 1970, and can be renewed after expiration of period.

ii. Copy Rights

Copyright is a legal right created by the law of a country that grants the creator of an original work exclusive rights for its use and distribution. This is usually only for a limited time. The exclusive rights are not absolute but limited by limitations and exceptions to copyright law, including fair use. A major limitation on copyright is that copyright protects only the original expression of ideas, and not the underlying ideas themselves.

iii. Trademarks

A trademark, trade mark, or trade-mark is a recognizable sign, design, or expression which identifies products or services of a particular source from those of others, although trademarks used to identify services are usually called service marks. The trademark owner can be an individual, business organization, or any legal entity. A trademark may be located on a package, a label, a voucher, or on the product itself. For the sake of corporate identity, trademarks are being displayed on company buildings.



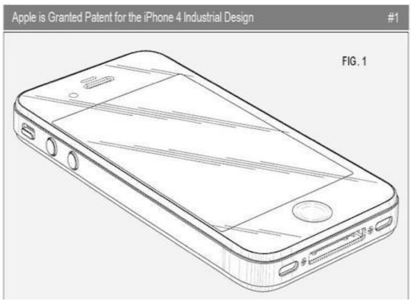
The owner of a trademark may pursue legal action against trademark infringement. Most countries require formal registration of a trademark as a precondition for pursuing this type of action. The United States, Canada and other countries also recognize common law trademark rights, which means action can be taken to protect an unregistered trademark if it is in use. Still, common law trademarks offer the holder in general less legal protection than registered trademarks.

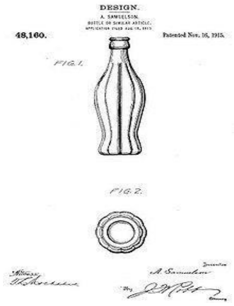
A trademark may be designated by the following symbols:

- ™ (the "trademark symbol", which is the letters "TM" in superscript, for an unregistered trademark, a mark used to promote or brand goods)
- SM (which is the letters "SM" in superscript, for an unregistered service mark, a mark used to promote or brand services)
- ® (the letter "R" surrounded by a circle, for a registered trademark)

iv. Industrial Designs

Industrial Designs: Design deals with features, shapes, patterns, etc., applied to an article by an industrial process, manual or mechanical.





Eg, chair is a utility item. However, chair itself does not qualify for IPR, but its special carvings, embossing etc., is done which increases the value of chair though it's utility remains same, it becomes eligible for IPR under Designs Act. Designs can be registered based on its originality, henceforth they can use ® or registered, with registration number.

v. Protection of Integrated Circuits layout design

The semiconductor Integrated Circuits Layout Design Act, 2000, provides protection for semiconductor IC layout designs. SICLD Act is a sui-generis (one of its kind) specifically meant for protecting IPR relating to Layout-Design (Topographies) of Semiconductor Integrated Circuit.

The subject of Semiconductor Integrated Circuits Layout Design has two parts, namely:

1. Semiconductor Integrated Circuit

Semiconductor Integrated Circuit means a product having transistors and other circuitry elements, which are inseparably formed on a semiconductor material or an insulating material or inside the semiconductor material and designed to perform an electronic circuitry function.

2. Layout-design

The layout-design of a semiconductor integrated circuit means a layout of transistors and other circuitry elements and includes lead wires connecting such elements and expressed in any manner in semiconductor integrated circuits.

vi. Geographical Indications

A geographical indication (GI) is a name or sign used on certain products which corresponds to a specific geographical location or origin (e.g. a town, region, or country). The use of a geographical indication may act as a certification that the product possesses certain qualities, is made according to traditional methods, or enjoys a certain reputation, due to its geographical origin.

Aranmula Kannadi from Kerala

Geographical Indications of Goods are defined as that aspect of industrial property which refer to the geographical indication referring to a country or to a place situated therein as being the country or place of origin of that product. Typically, such a name conveys an assurance of quality and distinctiveness which is essentially attributable to the fact of its origin in that defined geographical locality, region or country. Under Articles 1 (2) and 10 of the Paris Convention for the Protection of Industrial Property, geographical indications are covered as an element of IPRs. They are also covered under Articles 22 to 24 of the Trade Related Aspects of Intellectual Property Rights (TRIPS) Agreement, which was part of the Agreements concluding the Uruguay Round of GATT negotiations.

Product Liability

Product liability is the area of law in which manufacturers, distributors, suppliers, retailers, and others who make products available to the public are held responsible for the injuries those products cause. Although the word "product" has broad connotations, product liability as an area of law is traditionally limited to products in the form of tangible personal property.

Product liability issues are mainly classified in to:

a) Design Defects - Present in a product from the beginning, even before it is manufactured, in that something in the design of the product is inherently unsafe.
b) Manufacturing Defects - Those that occur in the course of a product's manufacture or assembly.
c) Marketing Defects - Flaws in the way a product is marketed, such as improper labeling, insufficient instructions, or inadequate safety warnings.

CONTENT BEYOND SYLLABUS

Design Concept

A design concept is a collection of embodiments that completely cover all the requirements of a design situation.

A design *concept* is different from an *idea* in that an idea covers only *some* of the requirements of a design situation, while a concept covers *all* the requirements.

An *idea* and an embodiment are basically the same thing. The difference is that while an idea refers to a principle or technology that covers one or more requirements generically, an embodiment is a principle or technology that addresses the requirements bound together as a system in a larger design project.

Design of complex interventions is a process of gradually seeking out the best of very many possible design interventions. It is easier, faster, and cheaper to develop and evaluate design concepts than it is to develop and evaluate many different fully detailed designs. Even though concepts are vague, it is possible to distinguish between those that are likely to be suitable and those that are likely to be unsuitable. The number of unsuitable designs is almost always much, much larger than the number of suitable designs, so even a qualitative assessment - based on concepts rather than fully detailed designs - is more effective and efficient.

Design concepts for all but the most trivial problems are very difficult to develop directly because the human brain just cannot keep in mind all the requirements and other information needed to do that.

We employ the classic divide and conquer technique here. If it's too hard to develop concepts directly, we can divide up the problem into smaller, easier to handle pieces, develop partial designs for each piece, then assemble the pieces back together to form a whole concept. There are two such broad methods for searching a morphological chart for suitable design concepts: the “brute force” method, and the “hill climbing” method.

Brute force search

The brute force method exhaustively checks *every* concept represented in a morphological chart. While this method guarantees that you will consider every concept in the morphological chart, it is only feasible if the morphological chart is relatively small.

Steps:

1. Identify the first 10 concepts. Write them down.
   - This list will keep changing as you replace embodiments. At the end of the process, the list will contain the 10 best concepts, based on your qualitative analysis.
   - You can do this in any order; it doesn't have to be random.
2. Identify the next concept.
3. If this concept includes inconsistent embodiments, discard it and go to Step 2.
4. Compare this concept to each of the concepts already in the list.
   - If you find a concept in the list that is worse than the new concept, replace the concept in the list with the new concept.
   - If there are multiple concepts in the list that are worse than the new concept, then replace the worst of the worst concepts with the new one.
   - If you get to the end of the list and find no concept in the list that is worse than the new concept, discard the new concept.
   - Document which concept was discarded, noting the shortcoming in the discarded concept as the reason for discarding it.
5. Go to Step 2, and continue this loop until all concepts in the morphological chart have been examined.

Hill-climbing search

Another approach could be to pick one concept at random, then iteratively improve it by comparing it to other concepts that are not very different from it (i.e., comparing two concepts that are different with respect to only one or two embodiments and choosing the better of the two). If you keep doing this,