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

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE MATERIALS

EST200 DESIGN & 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 Mechanical Engineering

- ♦ Approved by AICTE New Delhi and Accredited by NAAC
- ♦ Affiliated to the University of Dr. A P J Abdul Kalam Technological University.

DEPARTMENT VISION

Producing internationallycompetitive Mechanical Engineerswith social responsibility & sustainable employability through viable strategies as well as competent exposure oriented quality education.

DEPARTMENT MISSION

1. Imparting high impacteducation by providing conductive teaching learning environment.
2. Fostering effective modes of continuous learning process with moral & ethical values.
3. Enhancing leadership qualities with social commitment, professional attitude, unity, team spirit & communication skill.
4. Introducing the present scenario in research & development through collaborative efforts blended with industry & institution.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: Graduates shall have strong practical & technical exposures in the field of Mechanical Engineering & will contribute to the society through innovation & enterprise.

PEO2: Graduates will have the demonstrated ability toanalyze, formulate & solve design engineering / thermal engineering / materials & manufacturing / design issues & real life problems.

PEO3: Graduates will be capable of pursuing Mechanical Engineering profession with good communication skills, leadership qualities, team spirit & communication skills.

PEO4: Graduates will sustain an appetite for continuous learning by pursuing higher education & research in the allied areas of technology.

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 teamwork**: 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: graduates able to apply principles of engineering, basic sciences & analytics including multi variant calculus & higher order partial differential equations..

PSO2: Graduates able to perform modeling, analyzing, designing & simulating physical systems, components & processes.

PSO3: Graduates able to work professionally on mechanical systems, thermal systems & production systems.

COURSE OUTCOMES

CO1	Explain the different concepts and principles involved in design engineering.
CO2	Apply design thinking while learning and practicing engineering.
CO3	Develop innovative, reliable, sustainable and economically viable designs incorporating knowledge in engineering.

MAPPING OF COURSE OUTCOMES WITH PROGRAM OUTCOMES

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	1					1			1			3	3	3
CO2		2				1		1				2	3	3	3
CO3			2			1	1		2	2		1	3	3	3

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

SYLLABUS

Syllabus

Module 1

Design Process:- Introduction to Design and Engineering Design, Defining a Design Process-:Detailing Customer Requirements, Setting Design Objectives, Identifying Constraints, Establishing Functions, Generating Design Alternatives and Choosing a Design.

Module 2

Design Thinking Approach:-Introduction to Design Thinking, Iterative Design Thinking Process Stages: Empathize, Define, Ideate, Prototype and Test. Design Thinking as Divergent-Convergent Questioning. Design Thinking in a Team Environment.

Module 3

Design Communication (Languages of Engineering Design):-Communicating Designs Graphically, Communicating Designs Orally and in Writing. Mathematical Modeling In Design, Prototyping and Proofing the Design.

Module 4

Design Engineering Concepts:-Project-based Learning and Problem-based Learning in Design.Modular Design and Life Cycle Design Approaches. Application of Bio-mimicry,Aesthetics and Ergonomics in Design. Value Engineering, Concurrent Engineering, and Reverse Engineering in Design.

Module 5

Expediency, Economics and Environment in Design Engineering:-Design for Production, Use, and Sustainability. Engineering Economics in Design. Design Rights. Ethics in Design

Text Books

1) YousefHaik, SangarappillaiSivaloganathan, Tamer M. Shahin, Engineering Design Process, Cengage Learning 2003, Third Edition, ISBN-10: 9781305253285,

2) Voland, G., Engineering by Design, Pearson India 2014, Second Edition, ISBN 9332535051

Reference Books

1.Philip Kosky, Robert Balmer, William Keat, George Wise, Exploring Engineering, Fourth Edition: An Introduction to Engineering and Design, Academic Press 2015, 4th Edition, ISBN: 9780128012420.

2. Clive L. Dym, Engineering Design: A Project-Based Introduction, John Wiley & Sons, New York 2009, Fourth Edition, ISBN: 978-1-118-32458-5

3. Nigel Cross, Design Thinking: Understanding How Designers Think and Work, Berg Publishers 2011, First Edition, ISBN: 978-1847886361

4. Pahl, G., Beitz, W., Feldhusen, J., Grote, K.-H., Engineering Design: A Systematic Approach, Springer 2007, Third Edition, ISBN 978-1-84628-319-2

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**Module 1: Design Process**	
1.1	Introduction to Design and Engineering Design. *What does it mean to design something? How Is engineering design different from other kinds of design? Where and when do engineers design? What are the basic vocabularyin engineering design? How to learn and do engineering design.*	1
1.2	*Defining a Design Process*-: Detailing Customer Requirements. *How to do engineering design? Illustrate the process with an example. How to identify the customer requirements of design?*	1
1.3	*Defining a Design Process*-: Setting Design Objectives, Identifying Constraints, Establishing Functions. *How to finalize the design objectives? How to identify the design constraints? How to express the functions a design in engineering terms?*	1
1.4	*Defining a Design Process*-: Generating Design Alternatives and Choosing a Design. *How to generate or create feasible design alternatives? How to identify the "best possible design"?*	1
1.5	Case Studies:- Stages of Design Process. *Conduct exercises for designing simple products going through the different stages of design process.*	1
2	**Module 2: Design Thinking Approach**	
2.1	Introduction to Design Thinking *How does the design thinking approach help engineers in creating innovative and efficient designs?*	1
2.2	Iterative Design Thinking Process Stages: Empathize, Define, Ideate, Prototype and Test. *How can the engineers arrive at better designs utilizing the iterative design thinking process (in which knowledge acquired in the later stages can be applied back to the earlier stages)?*	1
2.3	Design Thinking as Divergent-Convergent Questioning. *Describe how to create a number of possible designs and then how to refine and narrow down to the 'best design'.*	1
2.4	Design Thinking in a Team Environment. *How to perform design thinking as a team managing the conflicts ?*	1
2.5	Case Studies: Design Thinking Approach. *Conduct exercises using the design thinking approach for*	1

	designing any simple products within a limited time and budget	
3	**Module 3: Design Communication (Languages of Engineering Design)**	
3.1	Communicating Designs Graphically. *How do engineering sketches and drawings convey designs?*	1
3.2	Communicating Designs Orally and in Writing. *How can a design be communicated through oral presentation or technical reports efficiently?*	1
	First Series Examination	
3.3	Mathematical Modelling in Design. *How do mathematics and physics become a part of the design process?*	1
3.4	Prototyping and Proofing the Design. *How to predict whether the design will function well or not?*	1
3.5	Case Studies: Communicating Designs Graphically. *Conduct exercises for design communication through detailed 2D or 3D drawings of simple products with design detailing, material selection, scale drawings, dimensions, tolerances, etc.*	1
4	**Module 4: Design Engineering Concepts**	
4.1	Project-based Learning and Problem-based Learning in Design. *How engineering students can learn design engineering through projects?* *How students can take up problems to learn design engineering?*	1
4.2	Modular Design and Life Cycle Design Approaches. *What is modular approach in design engineering? How it helps?* *How the life cycle design approach influences design decisions?*	1
4.3	Application of Bio-mimicry, Aesthetics and Ergonomics in Design. *How do aesthetics and ergonomics change engineering designs?* *How do the intelligence in nature inspire engineering designs? What are the common examples of bio-mimicry in engineering?*	1
4.4	Value Engineering, Concurrent Engineering, and Reverse Engineering in Design. *How do concepts like value engineering , concurrent engineering and reverse engineering influence engineering designs?*	1
4.5	Case Studies: Bio-mimicry based Designs. *Conduct exercises to develop new designs for simple*	1

	products using bio-mimicry and train students to bring out new nature inspired designs.	
5	**Module 5: Expediency, Economics and Environment in Design Engineering**	
5.1	Design for Production, Use, and Sustainability. *How designs are finalized based on the aspects of production methods, life span, reliability and environment?*	1
5.2	Engineering Economics in Design. *How to estimate the cost of a particular design and how will economics influence the engineering designs?*	1
5.3	Design Rights. *What are design rights and how can an engineer put it into practice?*	1
5.4	Ethics in Design. *How do ethics play a decisive role in engineering design?*	1
5.5	Case Studies: Design for Production, Use, and Sustainability. *Conduct exercises using simple products to show how designs change with constraints of production methods, life span requirement, reliability issues and environmental factors.*	1
	Second Series Examination	

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	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
7	Write a short note on engineering design, design objectives and design constraints.	CO1	K2
8	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
9	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
10	Setting objectives is the primary stage of any designs. Why design objectives are so important? Substantiate your answer with suitable example.	CO1	K4
11	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
MODULE II			
1	Illustrate with example, different stages iterative design thinking process.	CO2	K2
2	What are the aims of design thinking approach?	CO2	K2
3	List the qualities required for a design engineer for design thinking	CO2	K4

	approach in a group. Also brief on brainstorming and brain writing techniques.		
4	Explain the following in context of design thinking:- (a)Empathize (b)Define (c)Ideate (d)Prototype (e)Test	CO2	K3
5	State the role of divergent-convergent questioning in design thinking.	CO2	K2
6	Explain briefly the design thinking in team environment.	CO2	K3
7	Illustrate the design thinking approach for designing____(any product like bag, walking stick, skipping rope, chair etc…)for _______(specific clients like students, old people, sports person, teachers, hospitals etc…) within a limited budget. Describe each stage of the process and the iterative procedure involved. Use hand sketches to support your arguments.	CO2	K6
8	Construct a number of possible designs and then refine them to narrow down to the best design for______________(any product like bag, walking stick, skipping rope, chair etc...)for__________(specific clients like students, old people, sports person, teachers, hospitals etc…). Show how the divergent-convergent thinking helps in the process. Provide your rationale for each step by using hand sketches only	CO2	K6
MODULE III			
1	List out different mathematical tools used for design modeling	CO1	K2
2	Explain about the outline of a technical presentation.	CO1	K2
3	Differentiate between prototype and model.	CO1	K2
4	Specify the guide lines for technical communication	CO1	K2
5	Give a sample mathematical model of headphone for hearing music	CO3	K5
6	Space is the major problem faced by the modern world. As an Engineer you should identify a solution for the parking space for a new building. Design a system by considering the following constraints: a)Minimum space must be included b)Easy parking and easy retrieval c)The design must be suitable for all types of vehicles d)Special area for service vehicles e)Area for emergency vehicle	CO3	K5

	You can use the mechanisms like lifts, moving platforms or any supportive arrangements. Sketch the solution and explain briefly.		
7	Enumerate the applications of prototyping, and write a short note on benefits and limitations of prototyping	CO1	K2
8	Show how sketches and drawings convey designs	CO1	K2
9	Graphically communicate the design of an iron box. Draw the detailed 2D drawings of the same with design detailing, material selection, scale drawings, dimensions, tolerances, etc. Use only hand sketches.	CO2	K5
10	Applying mathematical model communicate design of a water bottle which has capacity of one litre.	CO2	K5
	MODULE IV		
1	Establish the importance of life cycle design	CO1	K2
2	What are the factors affecting ergonomic design	CO1	K1
3	Write a short note on the common examples of bio-mimicry in engineering?	CO1	K2
4	Establish the differences between problem based learning and project based learning	CO1	K4
5	Graphically communicate the design of a thermo flask used to keep hot coffee. Draw the detailed 2D drawings of the same with design detailing, material selection, scale drawings, dimensions, tolerances, etc. Use only hand sketches.	CO2	K6
6	Show the development of a nature inspired design for a solar powered bus waiting shed beside a highway. Relate between natural and man-made designs. Use hand sketches to support your arguments.	CO3	K6
7	Analyze the five most popular social media platforms for teens, then predict and design a new platform based on existing trends and past trajectory of change.	CO3	K6
8	Explain about anthropometry and how anthropometry relates with ergonomic design. Use suitable examples.	CO1	K2
9	What is the role of life cycle design in engineering?	CO1	K2
10	Design a bicycle using modular design. Highlight 3 parts and give its design	CO2	K6
11	Show the development of a nature inspired design for a solar powered bus waiting shed beside a highway. Relate between natural	CO2	K6

	and man-made designs. Use hand sketches to support your arguments.		
12	Derive a bio-mimicry of a cradle.	CO1	K3
	MODULE V		
1	Elaborate on “Design for production” with an example	CO1	K3
2	Elaborate on “Design for Use” with an example.	CO1	K3
3	Elaborate on “Design for Sustainability” with an example.	CO1	K3
4	Illustrate how concepts like value engineering, concurrent engineering and reverse engineering influence engineering designs?	CO1	K2
5	Show how designs are varied based on the aspects of production methods, life span, reliability and environment?	CO3	K3
6	Explain how economics influence the engineering designs?	CO3	K2
7	Elaborate on engineering economics in design.	CO3	K2
8	Explain on design rights. (How and when to obtain design rights)	CO1	K3
9	Explain the aspect of ethics in design.	CO3	K3
10	Examine the changes in design of foot ware with constraints of 1)production method, 2)life span requirement, 3)reliability issues and 4)environmental factors. Use hand sketches and give proper rationalization for the changes in design.	CO3	K6
11	Design a candle light stand (*can be any familiar product*) for manufacturing and elaborate on each step of DFM. Also brief on DFA.	CO3	K6
12	Describe how to estimate the cost of a particular design using Any of the following: 1)a website, 2)the layout of a plant, 3)elevation of a building, 4)an electrical or electronic system or device, 5)a car. Show how economics will influence the engineering designs. Use hand sketches to support your arguments.	CO3	K6

APPENDIX 1	
CONTENT BEYOND THE SYLLABUS	
S: NO.	**WEB SOURCE REFERENCES**
1	https://www.interaction-design.org/literature/article/5-stages-in-the-design-thinking-process
2	https://www.interaction-design.org/literature/article/what-is-design-thinking-and-whyis-it-so-popular
3	https://static1.squarespace.com/static/57c6b79629687fde090a0fdd/t/5b19b2f2aa4a99e99b26b6bb/1528410876119/dschool_bootleg_deck_2018_final_sm+%282%29.pdf
4	https://pidoco.com/en/help/ux/card-sorting
5	https://youtu.be/XbH7-Qa9xaU

MODULE 1

DESIGN

A design is a plan or specification for the construction of an object or system or for the implementation of an activity or process, or the result of that plan or specification in the form of a prototype, product or process. The verb to design expresses the process of developing a design. In some cases, the direct construction of an object without an explicit prior plan (such as in craftwork, some engineering, coding, and graphic design) may also be considered to be a design activity. The design usually has to satisfy certain goals and constraints, may take into account aesthetic, functional, economic, or socio-political considerations, and is expected to interact with a certain environment. Major examples of designs include architectural blueprints, engineering drawings, business processes, circuit diagrams, and sewing patterns.

DESIGNER

The person who produces a design is called a designer, which is a term generally used for people who work professionally in one of the various design areas—usually specifying which area is being dealt with (such as a textile designer, fashion designer, product designer, concept designer, web designer or interior designer), but also others such as architects and engineers. A designer's sequence of activities is called a design process, possibly using design methods. The process of creating a design can be brief (a quick sketch) or lengthy and complicated, involving considerable research, negotiation, reflection, modeling, interactive adjustment and re-design.

ENGINEERING DESIGN

Engineering design is the method that engineers use to identify and solve problems. It has been described and mapped out in many ways, but all descriptions include some common attributes:

ENGINEERING DESIGN PROCESS

The engineering design process is a common series of steps that engineers use in creating functional products and processes. The process is highly iterative - parts of the process often need to be repeated many times before another can be entered - though the part(s) that get iterated and the number of such cycles in any given project may vary.

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

What does it mean to design something? Is engineering design different from other kinds of design?

PEOPLE HAVE been designing things for as long as we can archaeologically uncover. Our earliest ancestors designed flint knives and other tools to help meet their most basic needs. Their wall paintings were designed to tell stories and to make their primitive caves more attractive. Given the long history of people designing things, it is useful to set some context for engineering design and to start developing a vocabulary and a shared understanding of what we mean by engineering design.

What does it mean for an engineer to design something? When do engineers design things? Where? Why? For whom?

An engineer working for a **large company** that processes and distributes various food products could be asked to design a container for a new juice product. He could work for a **design-and-construction company**, designing part of a highway bridge embedded in a larger transportation project, or for an **automobile company** that is developing new instrumentation clusters for its cars, or for a school system that wants to design specialized facilities to better serve students with orthopedic disabilities.

There are common features that make it possible to identify a design process and the context in which it occurs. In each of these cases, **three "roles"** are played as the design unfolds. First there is a **client**, a person or group or company that wants a design conceived. There is also a **user** who will employ or operate whatever is being designed. Finally, there is a **designer** whose job is to solve the client's problem in a way that meets the user's needs. The client could be internal (e.g., a person at the food company in charge of the new juice product) or external (e.g., the government agency that contracts for the new highway system). While a designer may relate differently to internal and external clients, it is typically the client who motivates and presents the starting point for design. That is why a designer's first task is to question the client to clarify what the client really wants and translate it into a form that is useful to her as an engineer.

The user is a key player in the design effort. In the contexts mentioned above, the users are, respectively, consumers who buy and drink a new juice drink, drivers on a new interstate highway, and students with orthopedic disabilities (and their teachers). Users have a stake in the design process because designs have to meet their needs. Thus, the designer, the client, and the user form a triangle. The designer has to understand what both the client and users want and need. Often the client speaks to the designer on behalf of the intended users.

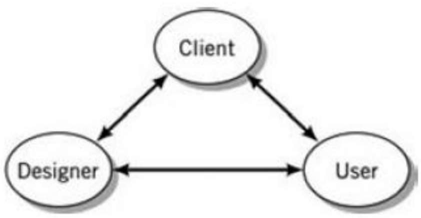


Figure 1.1 The designer–client–user triangle shows three parties involved in a design effort: a client, who has objectives that must be realized; the users of the design, who have their own wishes; the designer, who must design something that can be built and that satisfies everybody.

A BASIC VOCABULARY FOR ENGINEERING DESIGN

Engineering design is a systematic, intelligent process in which engineers generate, evaluate, and specify solutions for devices, systems, or processes whose form(s) and function(s) achieve clients' objectives and users' needs while satisfying a specified set of constraints. In other words, engineering design is a thoughtful process for generating plans or schemes for devices, systems, or processes that attain given objectives while adhering to specified constraints.

Design objective: A feature or behavior that we wish the design to have or exhibit.

Design constraint: A limit or restriction on the features or behaviors of the design. A proposed design is unacceptable if these limits are violated.

Functions: Things a designed device or system is supposed to do. Engineering functions almost always involve transforming or transferring energy, information, or material.

Means: A way or a method to make a function happen. For example, friction is a means of fulfilling a function of applying a braking force.

Form: The shape and structure of something as distinguished from its material.

Metric: A standard of measurement; in the context of engineering design, a scale on which the achievement of a design's objectives can be measured and assessed.

Specification(s): A scale on which the achievement of a design's functions can be measured. Specifications are engineering statements of the extent to which functions are performed by a design.

LEARNING AND DOING ENGINEERING DESIGN

Engineering Design Problems are Challenging: Engineering design problems are challenging because they are usually ill structured and open-ended.

Design problems are considered **ill structured** because their solutions cannot normally be found by applying mathematical formulas or algorithms in a routine or structured way. While mathematics is both useful and essential in engineering design, it is not possible to apply formulas to problems that are not well bounded or even defined. In the early stages of design, "formulas" are either unavailable or inapplicable. In fact, some experienced engineers find design difficult, simply because they can't fall back on structured, formulaic knowledge—but that's also what makes design a fascinating experience.

Design problems are **open-ended** because they typically have several acceptable solutions. Uniqueness, so important in many mathematics and analysis problems, simply does not apply to design solutions. In fact, more often than not, designers work to reduce or bound the number of design options they consider, lest they be overwhelmed by the possibilities.

Learning Design by Doing: Teaching someone how to do design is not that simple. Like riding a bike, painting, or dancing, it often seems easier to tell a student, "Watch what I'm doing and then try to do it yourself." There is an **element of learning by doing**, which we call a studio aspect, in trying to teach any of these activities. One of the reasons that it is hard to teach someone how to do design—or to throw a ball or draw or dance—is that people are often better at demonstrating a skill than they are at articulating what they know about applying their individual skills. Some of the skill sets just mentioned involve physical capabilities, but the difference of most interest to us is not simply that some people are more gifted physically than others. designers, like dancers and athletes, use drills and exercises to perfect their skills, rely on coaches to help them improve both the mechanical and interpretive aspects of their work, and pay close attention to other skilled practitioners of their art.

DESIGN

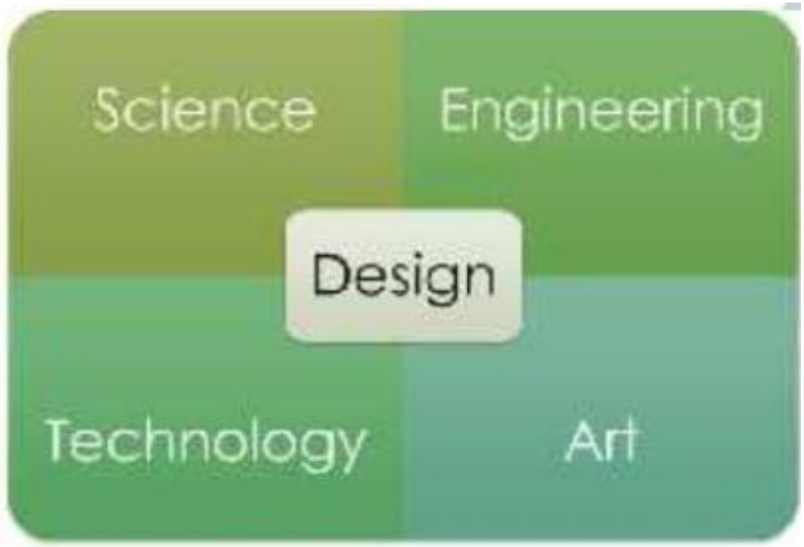
Introduction

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 manipulatesnature, 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 ofhumankind 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.

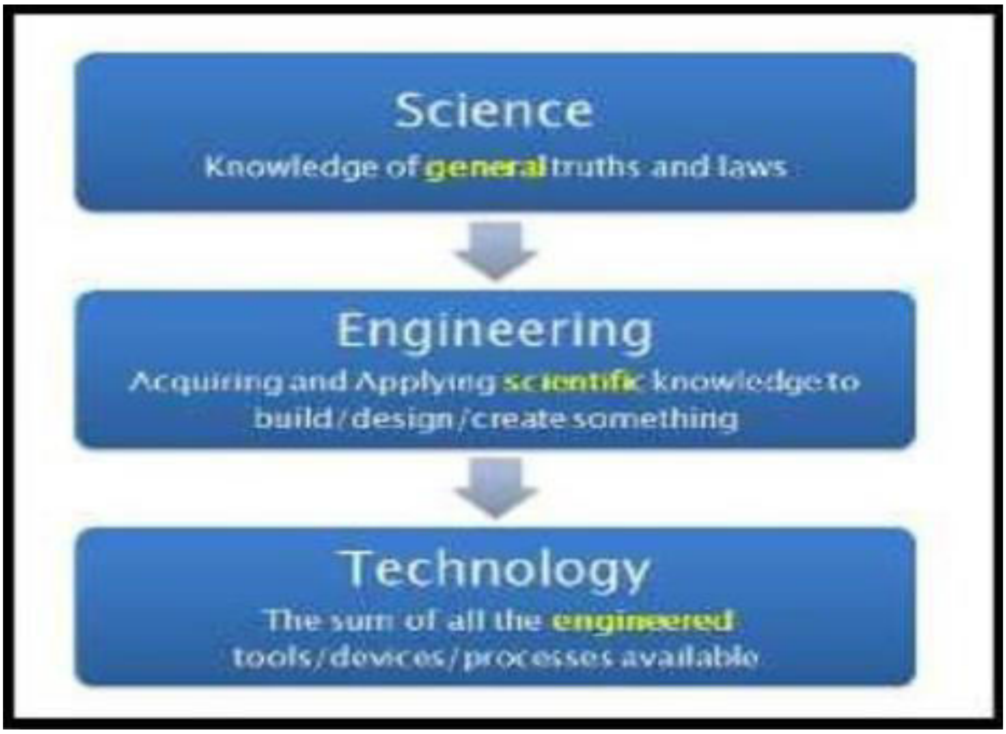
Eg-1:

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.

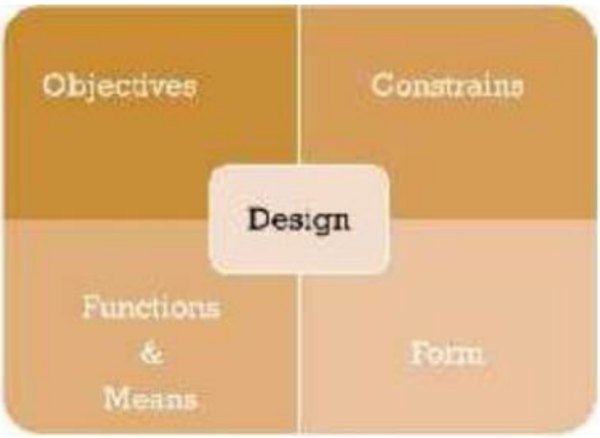
Technology: Fire can be used to cook food.

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’sfirst 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 designprocess 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.

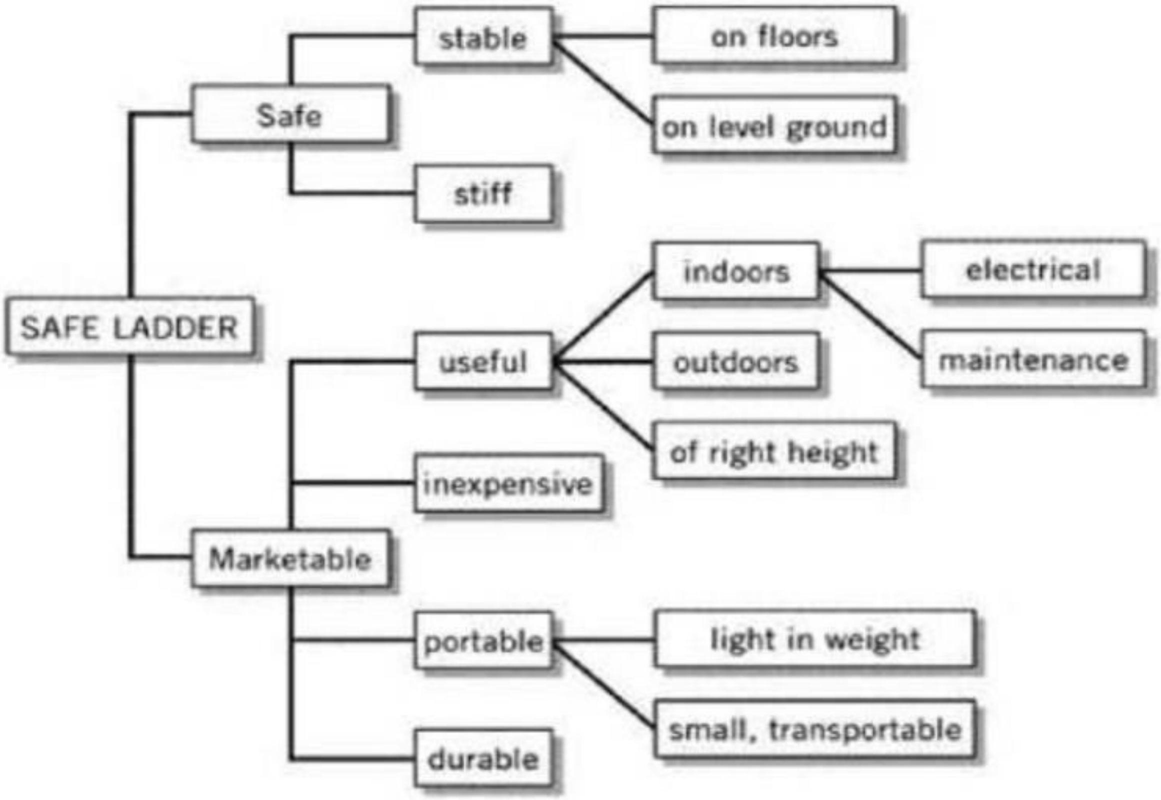
Function: a specific thing a designed device or system is expected to do. Functions are typically expressed as “doing” terms in a verb—noun pairing. Often they refer to engineering functions, such as the second function in Table 3.1: “Must not conduct electricity.” Note that this function is also a constraint.

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 arerelevant. 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 alimited 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 thebrainstorming 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 turnoff 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."
- ✓ Aska 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.

<u>Preliminary Research on Customer Needs</u>

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 mustidentify 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 mustbe 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 attributesthe 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 productunique and distinguish it from the competition. Note that the absence of an exciter willnot make customers unhappy, since they do not know what is missing.

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.

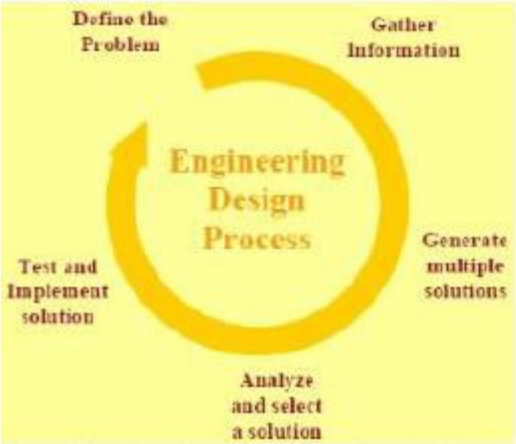
The five steps used for solving design problems are:

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.

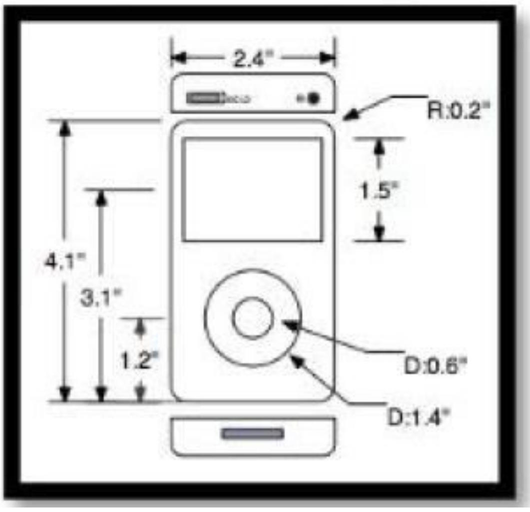
- Is the problem real and its statement accurate?
- Is there really a need for a new solution or has the problem already been solved?
- What are the existing solutions to the problem?
- What is wrong with the way the problem is currently being solved?
- What is right about the way the problem is currently 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.

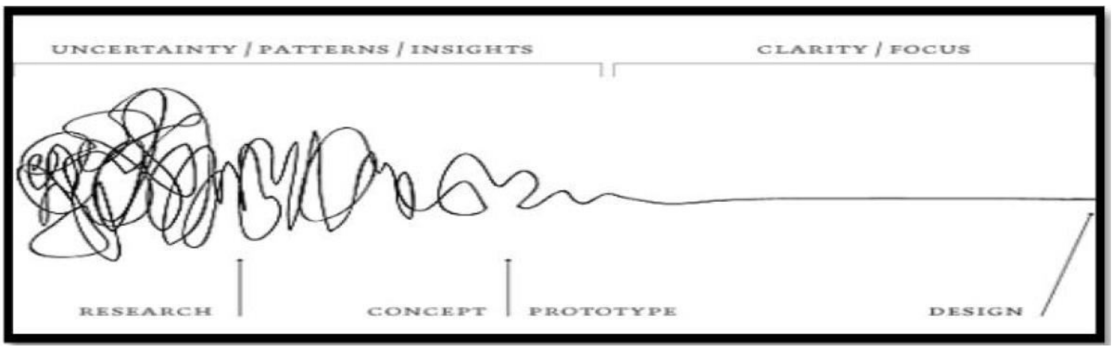
Analysis of Design Solutions:

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

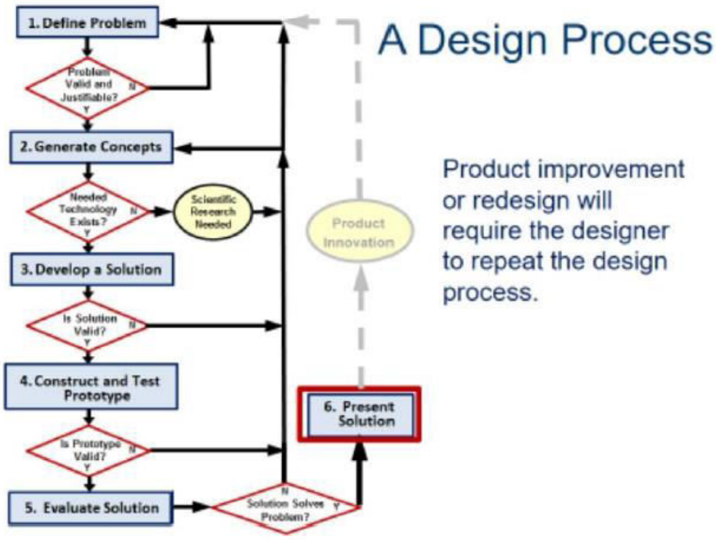
Testing and verification are important parts of the design process. Atall steps in the process, you may find that your potential solution is flawed and have to back up to a previous step to get a workable solution. Without proper testing at all stages in the process, you may find yourself making costly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

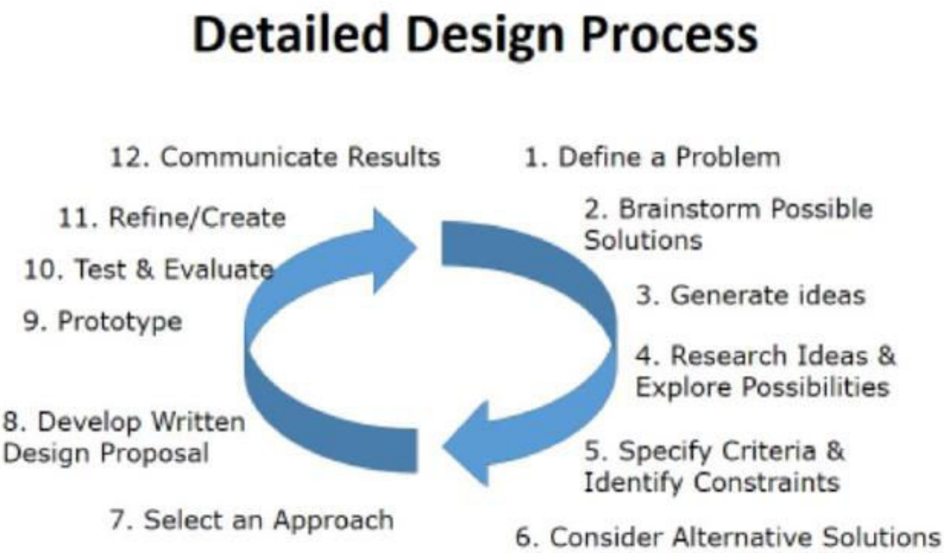
6. Present solutions

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.

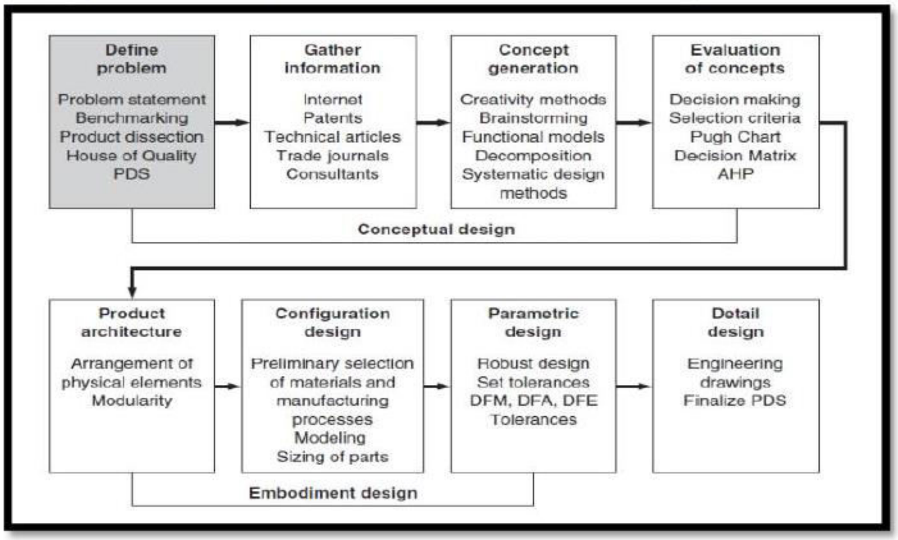
Schematic representations of design process





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.

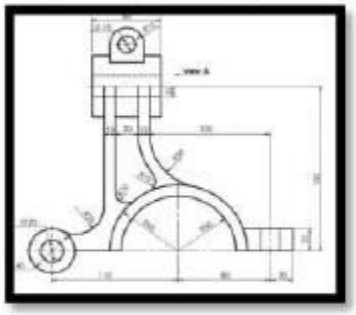
- Finally, detail design concludes with a design review before the decision is made to pass the design information on to manufacturing.

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.

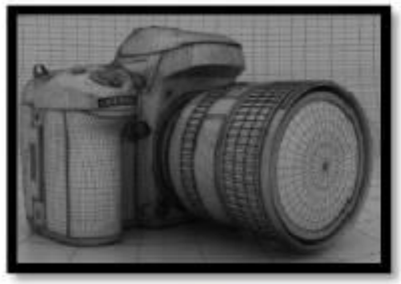
Generally these phases of design are carried out elsewhere in the organization than in the engineering department or product development department. As the project proceeds into the new phases, the expenditure of money and personnel time increases greatly.

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



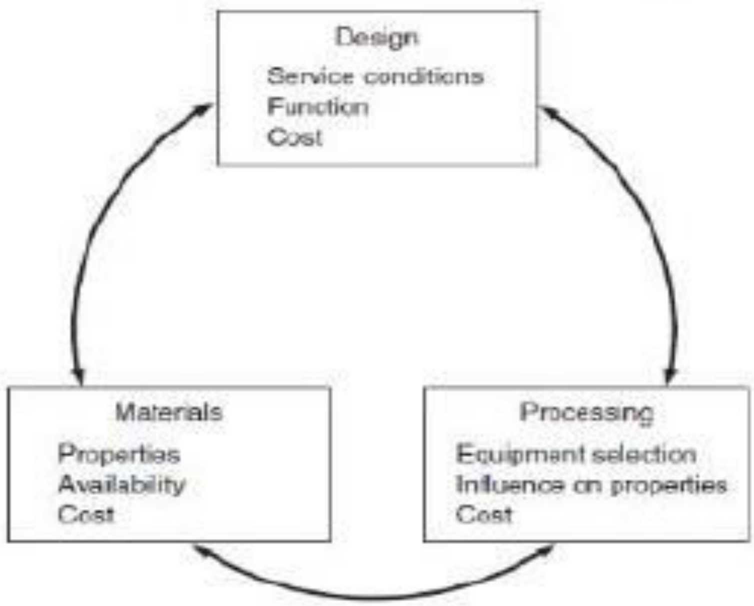
3D Drawings

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.

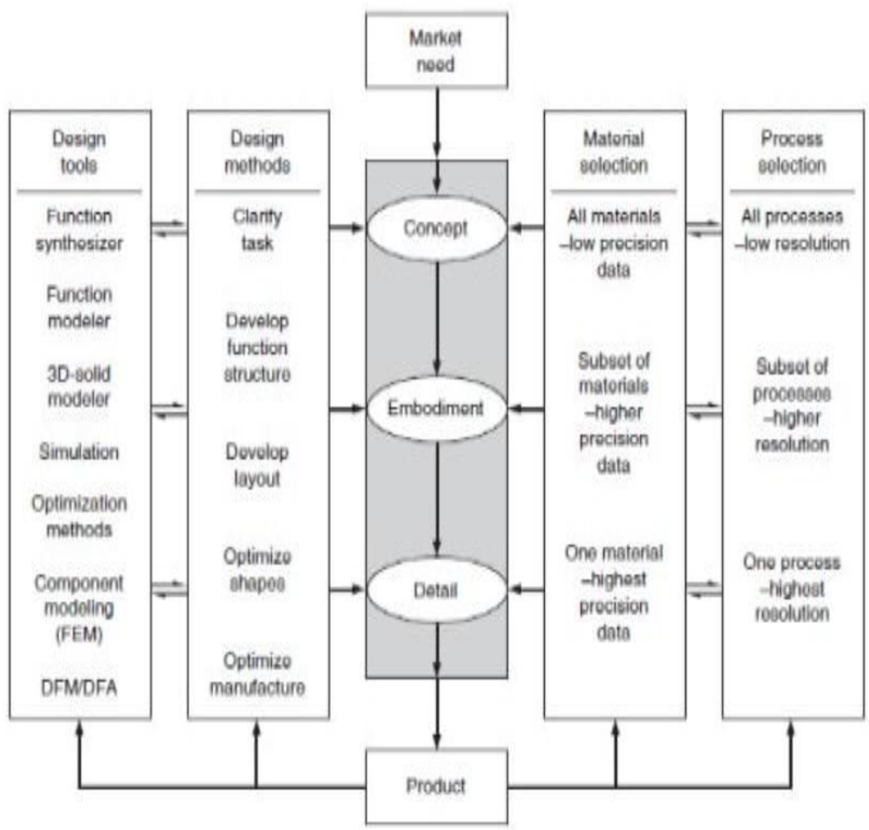


Moreover, the pressures of worldwide competition have increased level of automation in manufacturing to the point where material costs comprise 60 percent or more of the cost for most products. Finally, the extensive activity in materials science worldwide has created a variety of new materials and focused 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

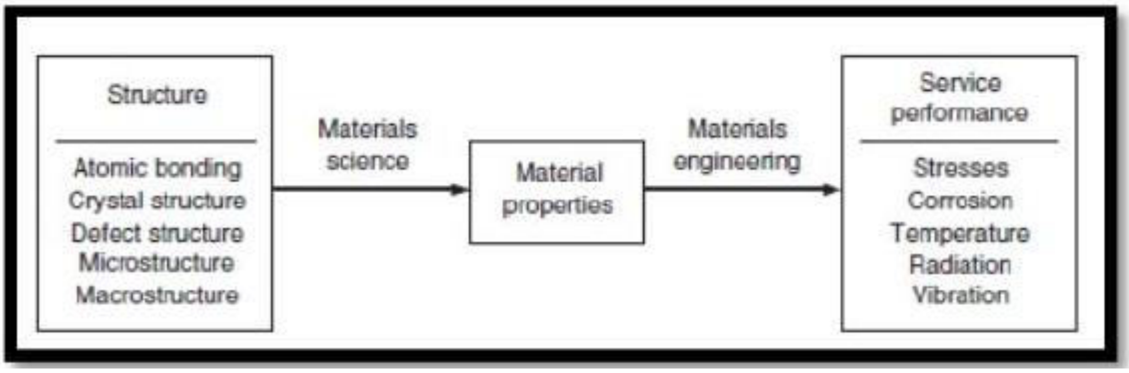
Materials selection, like other aspects engineering design, is a decision-making process. The

steps in the process are as follows:

1. Analysis of the materials requirements. Determine the conditions of service and environment that the product must

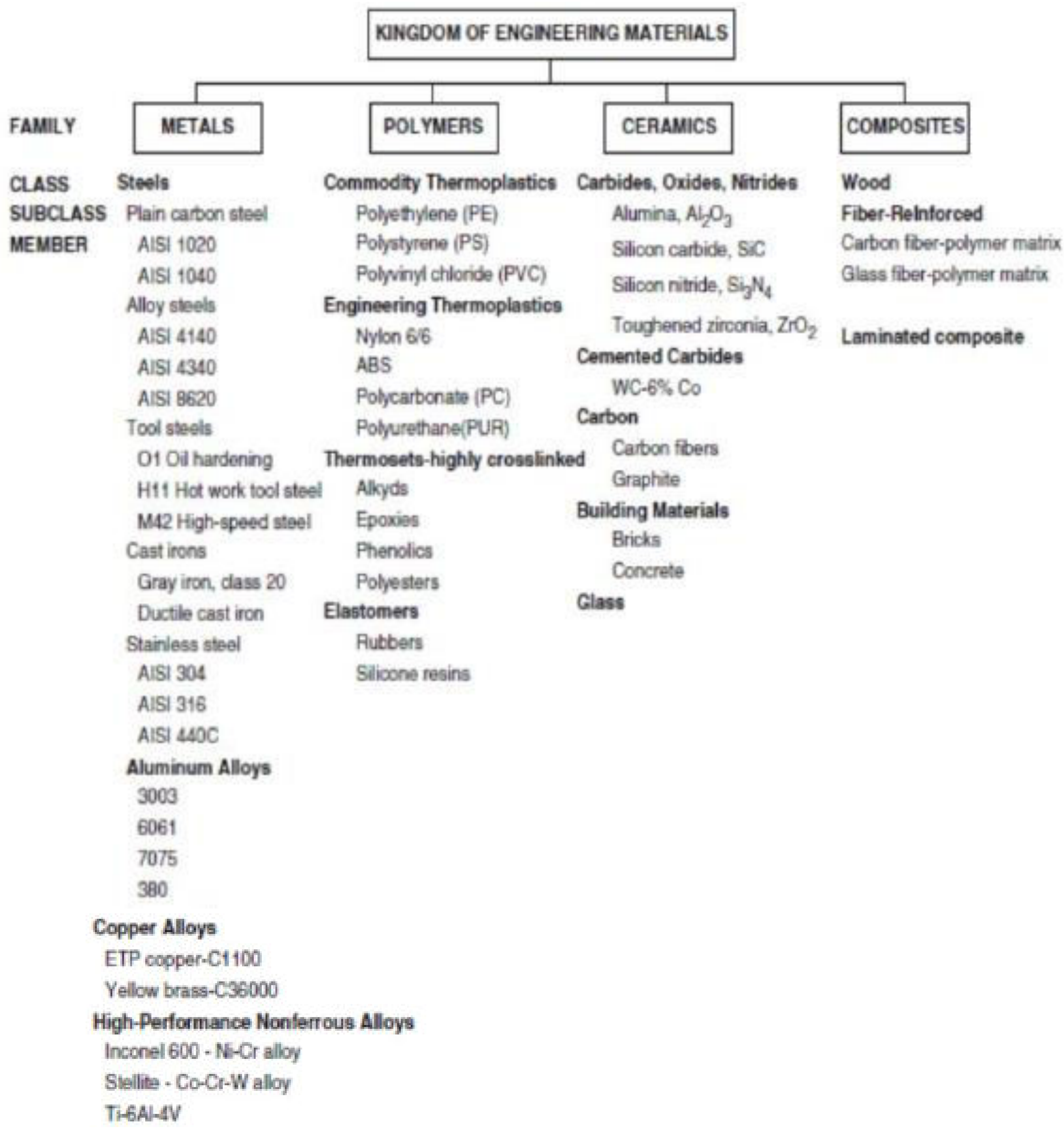
withstand. Translate them into material properties.

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.



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

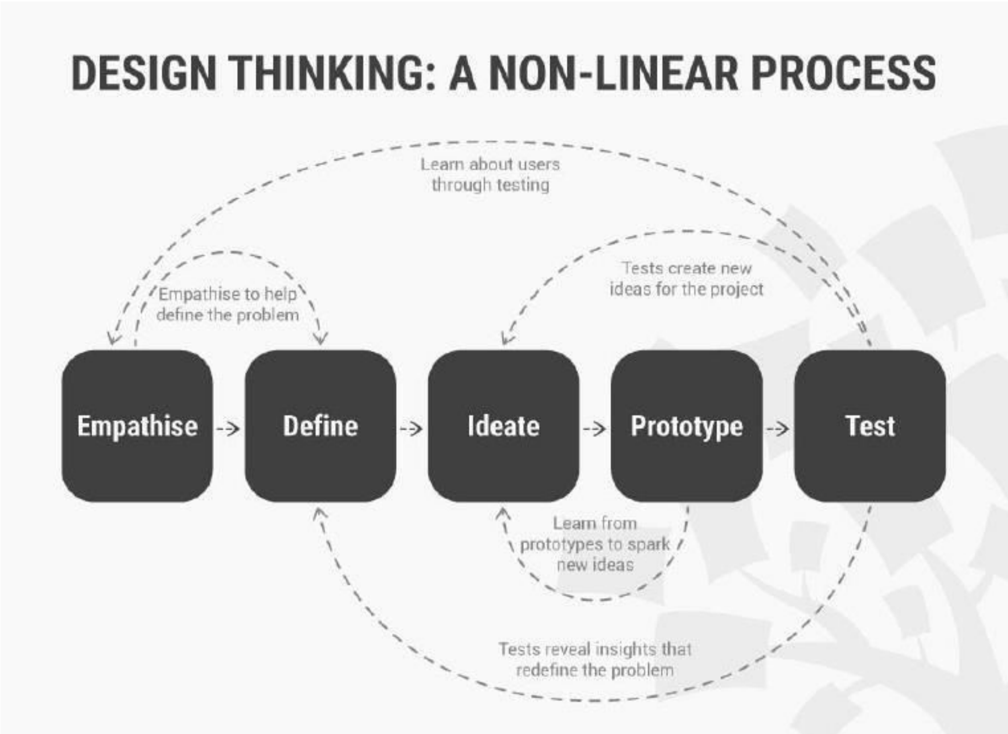
- Identify customer wants
- Identify how the good/service will satisfy customer wants
- Relate customer wants to product how's
- Identify relationships between the firm's how's Develop importance ratings
- Evaluate competing products

MODULE 2

DESIGN THINKING PROCESS

- Design Thinking is a design methodology that provides a solution-based approach to solving problems.
- Design thinking is a non-linear, iterative process that teams use to understand users, challenge assumptions, redefine problems and create innovative solutions to prototype and test.
- Involving five phases—Empathize, Define, Ideate, Prototype and Test—it is most useful to tackle problems that are ill-defined or unknown.

THE FIVE STAGES OF DESIGN THINKING



Empathize

WHAT is the Empathize mode Empathy is the centerpiece of a human-centered design process. The Empathize mode is the work you do to understand people, within the context of your design challenge. It is your effort to understand the way they do things and why, their physical and emotional needs, how they think about world, and what is meaningful to them. WHY empathize As a design thinker, the problems you are trying to solve are rarely your own—they are those of a particular group of people; in order to design for them, you must gain empathy for who they are and what is important to them.

Observing what people do and how they interact with their environment gives you clues about what they think and feel. It also helps you learn about what they need. By watching people, you can capture physical manifestations of their experiences – what they do and say. This will allow you to infer the intangible meaning of those experiences in order to uncover insights. These insights give you direction to create innovative solutions. The best solutions come out of the best insights into human behavior. But learning to recognize those insights is harder than you might think. Why? Because our minds automatically filter out a lot of information without our even realizing it. We need to learn to see things "with a fresh set of eyes," and empathizing is what gives us those new eyes. Engaging with people directly reveals a tremendous amount about the way they think and the values they hold. Sometimes these thoughts and values are not obvious to the people who hold them, and a good conversation can surprise both the designer and the subject by the unanticipated insights that are revealed. The stories that people tell and the things that people say they do—even if they are different from what they actually do—are strong indicators of their deeply held beliefs about the way the world is. Good designs are built on a solid understanding of these beliefs and values.

HOW to empathize To empathize, you: - Observe. View users and their behavior in the context of their lives. As much as possible do observations in relevant contexts in addition to interviews. Some of the most powerful realizations come from noticing a disconnect between what someone says and what he does. Others come from a work-around someone has created which may be very surprising to you as the designer, but she may not even think to mention in conversation. - Engage. Sometimes we call this technique 'interviewing' but it should really feel more like a conversation. Prepare some questions you'd like to ask, but expect to let the conversation deviate from them. Keep the conversation only loosely bounded. Elicit stories from the people you talk to, and always ask "Why?" to uncover deeper meaning. Engagement can come through both short 'intercept' encounters and longer scheduled conversations. - Watch and Listen. Certainly you can, and should, combine observation and engagement. Ask someone to show you how they complete a task. Have them physically go through the steps, and talk you through why they are doing what they do. Ask them to vocalize what's going through their mind as they perform a task or interact with an object. Have a conversation in the context of someone's home or workplace – so many stories are embodied in artifacts. Use the environment to prompt deeper questions

Transition: Empathize >> Define Unpack: When you move from empathy work to drawing conclusions from that work, you need to process all the things you heard and saw in order to understand the big picture and grasp the takeaways of it all. Unpacking is a chance to start that process – sharing what you found with fellow designers and capturing the important parts in a visual form. Get all the information out of your head and onto a wall where you can start to make connections—post pictures of your user, post-its with quotes, maps of journeys or experiences—anything that captures impressions and information about your user. This is the beginning of the synthesis process, which leads into a 'Define' mode.

Define

WHAT is the Define mode The Define mode of the design process is all about bringing clarity and focus to the design space. It is your chance, and responsibility, as a design thinker to define the challenge you are taking on, based on what you have learned about your user and about the context. After becoming an instant-expert on the subject and gaining invaluable empathy for the person you are designing for, this stage is about making sense of the widespread information you have gathered. The goal of the Define mode is to craft a meaningful and actionable problem statement – this is what we call a point-of-view. This should be a guiding statement that focuses on insights and needs of a particular user, or composite character. Insights don't often just jump in your lap; rather they emerge from a process of synthesizing information to discover connections and patterns. In a word, the Define mode is sensemaking. WHY define The Define mode is critical to the design process because it results in your point-of-view (POV): the explicit expression of the problem you are striving to address. More importantly, your POV defines the RIGHT challenge to address, based on your new understanding of people and the problem space. It may seem counterintuitive but crafting a more narrowly focused problem statement tends to yield both greater quantity and higher quality solutions when you are generating ideas. The Define mode is also an endeavor to synthesize your scattered findings into powerful insights. It is this synthesis of your empathy work that gives you the advantage that no one else has: discoveries that you can leverage to tackle the design challenge; that is, INSIGHT.

HOW to define Consider what stood out to you when talking and observing people. What patterns emerge when you look at the set? If you noticed something interesting ask yourself (and your team) why that might be. In asking why someone had a certain behavior or feeling you are making connections from that person to the larger context. Develop an understanding of the type of person you are designing for – your USER. Synthesize and select a limited set of NEEDS that you think are important to fulfill; you may in fact express a just one single salient need to address. Work to express INSIGHTS you developed through the synthesis of information your have gathered through empathy and research work. Then articulate a point-of-view by combining these three elements – user, need, and insight – as an actionable problem statement that will drive the rest of your design work. A good point-of-view is one that: - Provides focus and frames the problem - Inspires your team - Informs criteria for evaluating competing ideas - Empowers your team to make decisions independently in parallel - Captures the hearts and minds of people you meet - Saves you from the impossible task of developing concepts that are all things to all people (i.e. your problem statement should be discrete, not broad.)

Transition: Define >> Ideate In the Define mode you determine the specific meaningful challenge to take on, and in the Ideate mode you focus on generating solutions to address that challenge. A well-scoped and -articulated point-of-view will lead you into ideation in a very natural way. In fact, it is a great litmus test of your point-of-view to see if brainstorming topics fall out your POV. A great transition step to take is to create a list of "How-Might-We . . .?" brainstorming topics that flow from your problem statement. These brainstorming topics typically are subsets of the entire problem, focusing on different aspects of the challenge. Then when you move into ideation you can select different topics, and try out a few to find the sweet spot of where the group can really churn out a large quantity of compelling ideas.

Ideate

WHAT is the Ideate mode Ideate is the mode of the design process in which you concentrate on idea generation. Mentally it represents a process of "going wide" in terms of concepts and outcomes. Ideation provides both the fuel and also the source material for building prototypes and getting innovative solutions into the hands of your users. WHY ideate You ideate in order to transition from identifying problems to creating solutions for your users. Ideation is your chance to combine the understanding you have of the problem space and people you are designing for with your imagination to generate solution concepts. Particularly early in a design project, ideation is about pushing for a widest possible range of ideas from which you can select, not simply finding a single, best solution. The determination of the best solution will be discovered later, through user testing and feedback. Various forms of ideation are leveraged to: - Step beyond obvious solutions and thus increase the innovation potential of your solution set - Harness the collective perspectives and strengths of your teams - Uncover unexpected areas of exploration - Create fluency (volume) and flexibility (variety) in your innovation options - Get obvious solutions out of your heads, and drive your team beyond them

HOW to ideate You ideate by combining your conscious and unconscious mind, and rational thoughts with imagination. For example, in a brainstorm you leverage the synergy of the group to reach new ideas by building on others' ideas. Adding constraints, surrounding yourself with inspiring related materials, and embracing misunderstanding all allow you to reach further than you could by simply thinking about a problem. Another ideation technique is building – that is, prototyping itself can be an ideation technique. In physically making something you come to points where decisions need to be made; this encourages new ideas to come forward. There are other ideation techniques such as bodystorming, mindmapping, and sketching. But one theme throughout all of them is deferring judgment – that is, separating the generation of ideas from the evaluation of ideas. In doing so, you give your imagination and creativity a voice, while placating your rational side in knowing that your will get to the examination of merits later.

Transition: Ideate >> Prototype In order to avoid losing all of the innovation potential you have just generated through ideation, we recommend a process of considered selection, by which you bring multiple ideas forward into prototyping, thus maintaining your innovation potential. As a team, designate three voting criteria (we might suggest "the most likely to delight," "the rational choice," "the most unexpected" as potential criteria, but they're really up to you) to use to vote on three different ideas that your team generated during brainstorming. Carry the two or three ideas that receive the most votes forward into prototyping. In this way, you preserve innovation potential by carrying multiple ideas forward—a radically different approach than settling on the single idea that at least the majority of the team can agree upon.

Prototype

WHAT is the Prototype mode The Prototype mode is the iterative generation of artifacts intended to answer questions that get you closer to your final solution. In the early stages of a project that question may be broad – such as "do my users enjoy cooking in a competitive manner?" In these early stages, you should create low-resolution prototypes that are quick and cheap to make (think minutes and cents) but can elicit useful feedback from users and colleagues. In later stages both your prototype and question may get a little more refined. For example, you may create a later stage prototype for the cooking project that aims to find out: "do my users enjoy cooking with voice commands or visual commands". A prototype can be anything that a user can interact with – be it a wall of post-it notes, a gadget you put together, a role-playing activity, or even a storyboard. Ideally you bias toward something a user can experience. Walking someone through a scenario with a storyboard is good, but having them role-play through a physical environment that you have created will likely bring out more emotions and responses from that person. WHY prototype To ideate and problem-solve. Build to think. To communicate. If a picture is worth a thousand words, a prototype is worth a thousand pictures. To start a conversation. Your interactions with users are often richer when centered around a conversation piece. A prototype is an opportunity to have another, directed conversation with a user. To fail quickly and cheaply. Committing as few resources as possible to each idea means less time and money invested up front. To test possibilities. Staying low-res allows you to pursue many different ideas without committing to a direction too early on. To manage the solution-building process. Identifying a variable also encourages you to break a large problem down into smaller, testable chunks.

HOW to prototype Start building. Even if you aren't sure what you're doing, the act of picking up some materials (post-its, tape, and found objects are a good way to start!) will be enough to get you going. Don't spend too long on one prototype. Let go before you find yourself getting too emotionally attached to any one prototype. ID a variable. Identify what's being tested with each prototype. A prototype should answer a particular question when tested. That said, don't be blind to the other tangential understanding you can gain as someone responds to a prototype. Build with the user in mind. What do you hope to test with the user? What sorts of behavior do you expect? Answering these questions will help focus your prototyping and help you receive meaningful feedback in the testing phase.

Transition: Prototype >> Test Prototype and Test are modes that you consider in tandem more than you transition between. What you are trying to test and how you are going to test that aspect are critically important to consider before you create a prototype. Examining these two modes in conjunction brings up the layers of testing a prototype. Though prototyping and testing are sometimes entirely intertwined, it is often the case that planning and executing a successful testing scenario is a considerable additional step after creating a prototype. Don't assume you can simply put a prototype in front of a user to test it; often the most informative results will be a product of careful thinking about how to test in a way that will let users give you the most natural and honest feedback.

Test

WHAT is the Test mode The Test mode is when you solicit feedback, about the prototypes you have created, from your users and have another opportunity to gain empathy for the people you are designing for. Testing is another opportunity to understand your user, but unlike your initial empathy mode, you have now likely done more framing of the problem and created prototypes to test. Both these things tend to focus the interaction with users, but don't reduce your "testing" work to asking whether or not people like your solution. Instead, continue to ask "Why?", and focus on what you can learn about the person and the problem as well as your potential solutions. Ideally you can test within a real context of the user's life. For a physical object, ask people to take it with them and use it within their normal routines. For an experience, try to create a scenario in a location that would capture the real situation. If testing a prototype in situ is not possible, frame a more realistic situation by having users take on a role or task when approaching your prototype. A rule of thumb: always prototype as if you know you're right, but test as if you know you're wrong—testing is the chance to refine your solutions and make them better. WHY test To refine prototypes and solutions. Testing informs the next iterations of prototypes. Sometimes this means going back to the drawing board. To learn more about your user. Testing is another opportunity to build empathy through observation and engagement—it often yields unexpected insights. To refine your POV. Sometimes testing reveals that not only did you not get the solution right, but also that you failed to frame the problem correctly

HOW to test Show don't tell. Put your prototype in the user's hands – or your user within an experience. And don't explain everything (yet). Let your tester interpret the prototype. Watch how they use (and misuse!) what you have given them, and how they handle and interact with it; then listen to what they say about it, and the questions they have. Create Experiences. Create your prototypes and test them in a way that feels like an experience that your user is reacting to, rather than an explanation that your user is evaluating. Ask users to compare. Bringing multiple prototypes to the field to test gives users a basis for comparison, and comparisons often reveal latent needs.

Iteration and making the process your own Iteration is a fundamental of good design. Iterate both by cycling through the process multiple times, and also by iterating within a step—for example by creating multiple prototypes or trying variations of a brainstorming topics with multiple groups. Generally as you take multiple cycles through the design process your scope narrows and you move from working on the broad concept to the nuanced details, but the process still supports this development. For simplicity, the process is articulated here as a linear progression, but design challenges can be taken on by using the design modes in various orders; furthermore there are an unlimited number of design frameworks with which to work. The process presented here is one suggestion of a framework; ultimately you will make the process your own and adapt it to your style and your work. Hone your own process that works for you. Most importantly, as you continue to practice innovation you take on a designerly mindset that permeates the way you work, regardless of what process you use

DIVERGENT THINKING

- It is a thought process or method used to generate creative ideas by exploring many possible solutions.
- It typically occurs in a spontaneous, free-flowing, "non-linear" manner, such that many ideas are generated in an emergent cognitive fashion.
- Divergent thinking uses the imagination to open the mind to new possibilities and solutions, and ultimately become more innovative.

CONVERGENT THINKING

- It is the opposite of divergent thinking.
- It generally means the ability to give the "correct" answer to standard questions that do not require significant creativity, for instance in most tasks in school and on standardized multiple-choice tests for intelligence.
- Convergent thinking moves from broad thoughts to concrete understanding, where the thoughts from divergent thinking can be narrowed down to the most promising ideas and solutions.

DESIGN THINKING IN A TEAM ENVIRONMENT

- Members of a Design Thinking team need to be open minded, curious, collaborative and allow their assumptions to be challenged, ready for change, and be adaptable.
- Cross-disciplinary teams will provide you with the best results.
- Teams may consist of people unfamiliar with each other, with external members brought on board either as specialists or facilitators depending on the availability of skills.
- To make a Design Thinking project successful, we need T-shaped people.
- T-shaped people have a depth of knowledge and experience in their own fields but they can also reach out and connect with others horizontally and create meaningful collaborations.
- All team members should be encouraged to respect each other's inputs, in order to discover deeper and to build upon each other's findings.

SOME OF THE AIMS OF DESIGN THINKING'S APPROACH ARE TO CREATE

- Greater inclusiveness (quality of covering or dealing with a range of subjects/areas)
- Better team cohesion (fact of forming a united whole)
- Higher levels of collaboration and interaction -increased creative confidence
- Everyone thinks, feels, and experiences things differently. Differences are what we need.

MODULE 3

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:

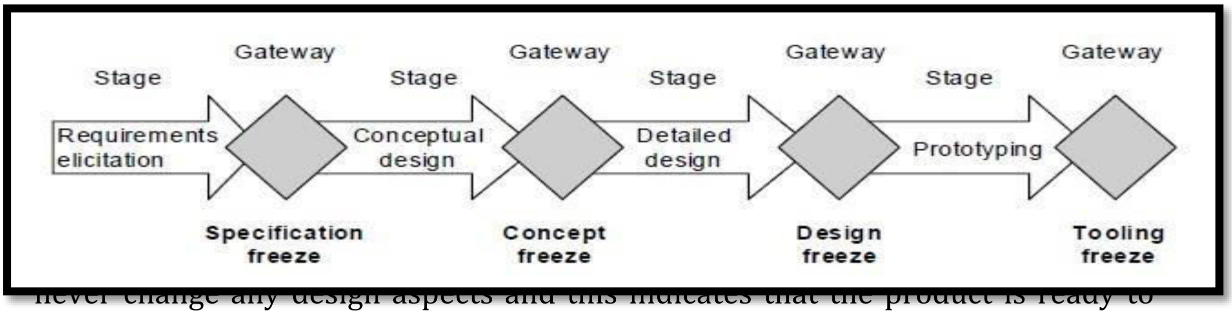
There is a trade-off between the number of prototypes that will be built for a product design and tested and the cost and length of the product development cycle. Prototypes help to verify the product but they have a high cost in money and time. As a result, there is a strong trend, particularly in large 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.

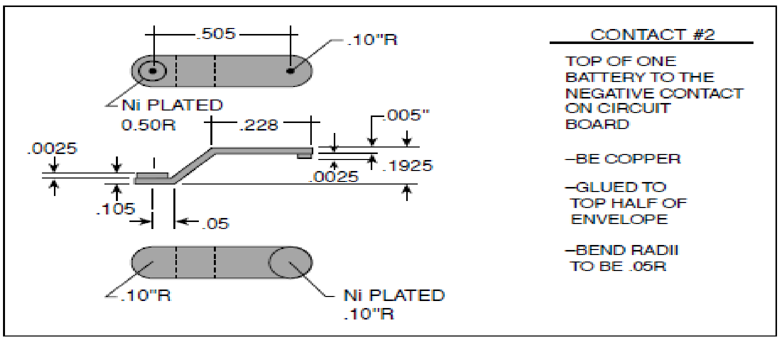


never change any design aspects and this indicates that the product is ready to handover into manufacturing unit. As similar to design freeze the team may set freeze on any other stages of design process as indicated in above diagram.

ENGINEERING SKETCHES

- Drawing is very important in design because a lot of information is created and transmitted in the drawing process.
- Design drawings include sketches, freehand drawings, and
- computer-aided design and drafting (CADD) models that extend from simple

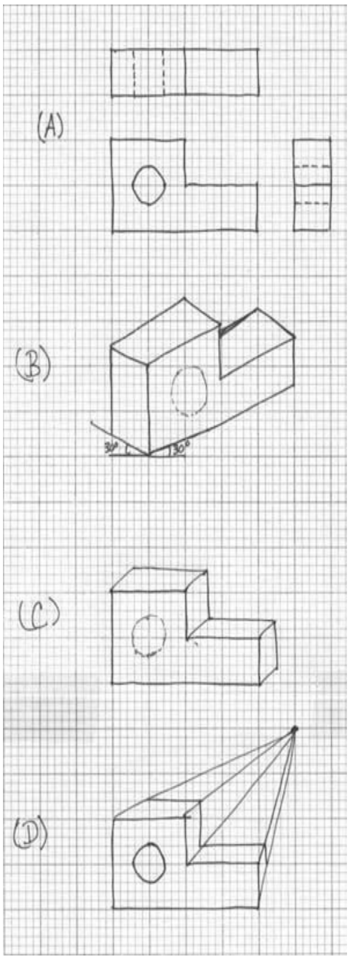
  wire-frame drawings through elaborate solid models



- In brief, graphic images are used to communicate with other designers, the client, and the manufacturing organization. Sketches and drawings:
  - serve as a launching pad for a brand-new design;
  - support the analysis of a design as it evolves;

- simulate the behavior or performance of a design;
- record the shape or geometry of a design;
- communicate design ideas among designers;
- ensure that a design is complete (as a drawing and its associated marginalia may remind us of still-undone parts of that design);
- communicate the final design to the manufacturing specialists.

SKETCHING



- Sketching is a powerful tool in design because it enables us to convey our design ideas to others quickly and concisely.
- Types
  - A. Orthographic sketches
    - lay out the front, right and top views of a part
  - B. Axonometric sketches

- start with an axis, typically a vertical line with two lines 30

  drgree from the horizontal.

C. Oblique sketches

- The front view is blocked in roughly first, depth lines are then added, and details such as rounded edges are added last.

D. Perspective sketches

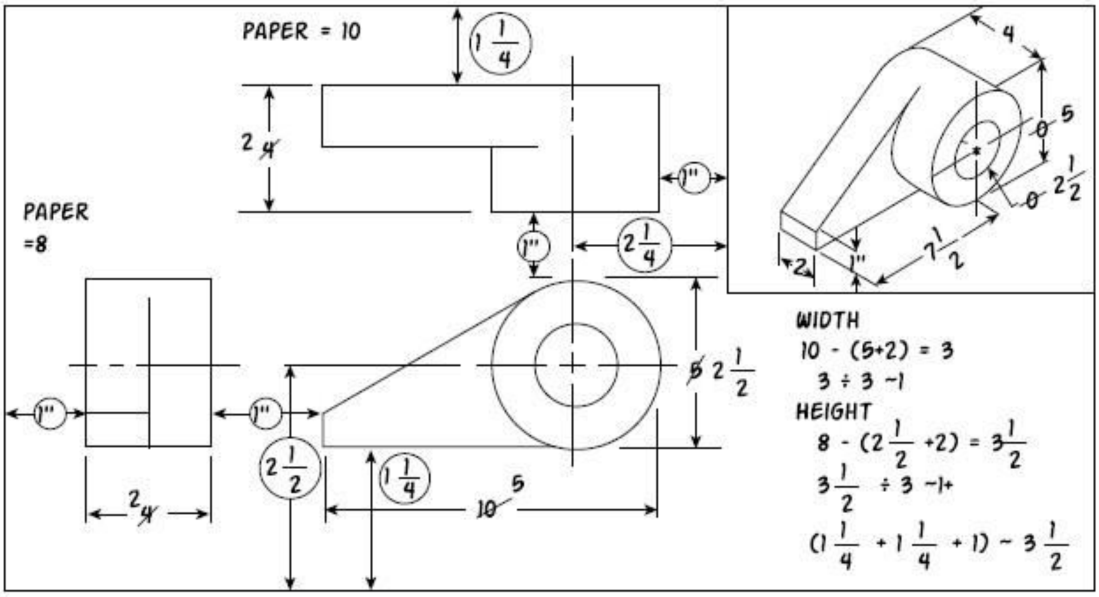
THE SEVERAL FORMS OF ENGINEERING DRAWINGS

- When we communicate design results to a manufacturer, we must think very carefully about the fabrication specifications that we are creating in drawings, as well as those we write.
- we must ensure that our drawings are both appropriate to our design and prepared in accordance with relevant engineering practices and standards.

DESIGN DRAWINGS

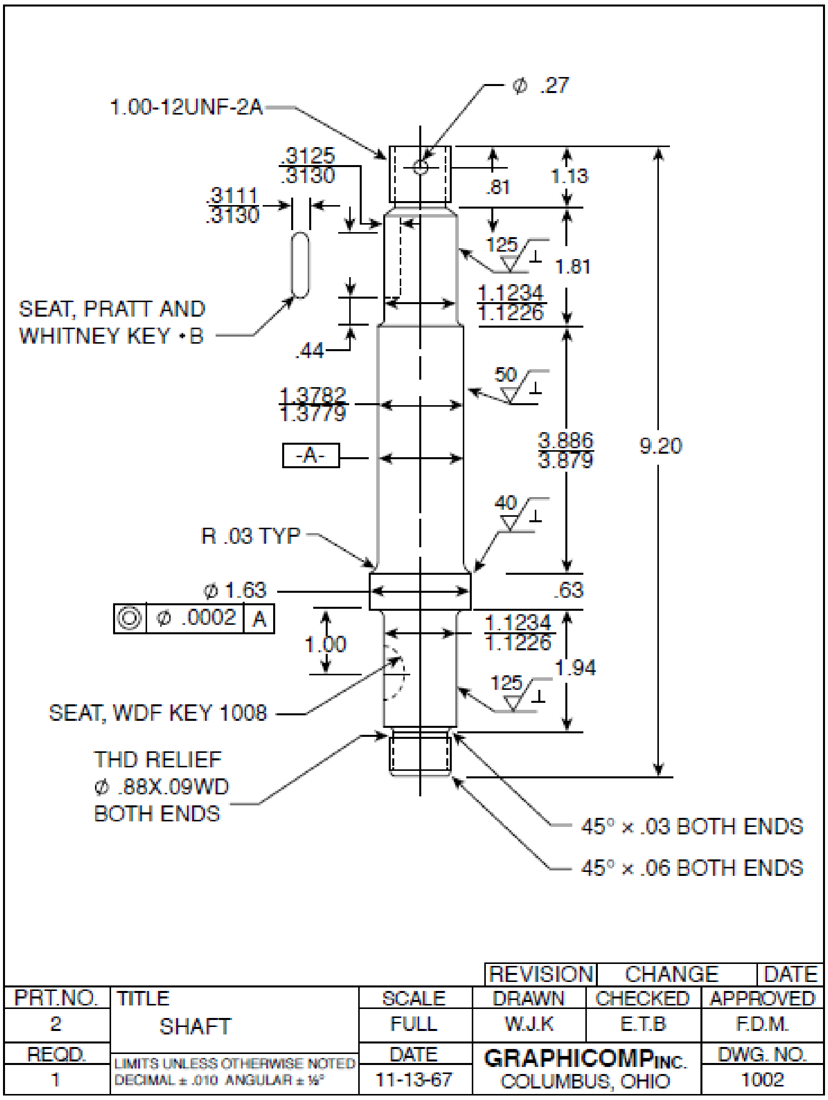
- Layout drawings
  - working drawings that show the major parts or components of a device and their relationship

  They are usually drawn to scale, do not show tolerances, and are subject to change as the design process evolves

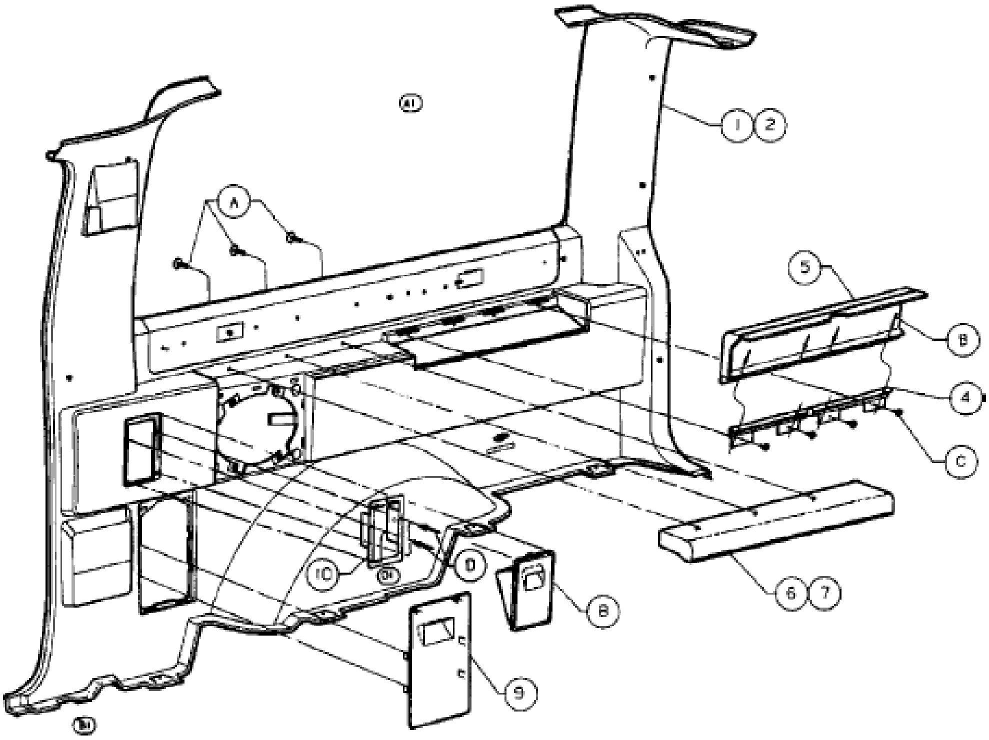


- Detail drawings
  - show the individual parts or components of a device and their relationship

- These drawings must show tolerances, and they must also specify materials and any special processing requirements.
- Detail drawings are drawn in conformance with existing standards, and are changed only when a formal change order provides authorization.



- Assembly drawings
    - show how the individual parts or components of a device fit together. An exploded view is commonly used to show such “fit” relationships



- These drawings are used to communicate the details of our design to the manufacturer or machinist.
- They must contain as much information as possible while being both as clear and as

  uncluttered as possible.
- There are certain essential components that every drawing must have to ensure that it is interpreted as it is intended
  - standard drawing views;
  - standard symbols to indicate particular items;
  - clear lettering;
  - clear, steady lines;
  - appropriate notes, including specifications of materials;
  - a title on the drawing;
  - the designer's initials and the date it was drawn;
  - dimensions and units; and
  - permissible variations, or tolerances.

CAD – MODELS

- Good for digital visualization
- The making of 3D models in computers software is called geometric modelling
- Lots of CAD software are available

  depending on the application
- These software provide many features such as color rendering shading texting etc. to communicate the design more close to the reality
- The modelled part can be rotated, sectioned and zoomed so that any Complex shape can be communicated to the another person without confusion

COMMUNICATING DESIGNS ORALLY AND IN WRITING

- REPORTING is an essential part of a design project
- We communicate final design results in several ways, including oral presentations, final reports (that may include design drawings and/or fabrication specifications), and prototypes and models.
- The primary purpose of such communication is to inform our client about the design, including explanations of how and why this design was chosen over competing design alternatives.
- It is most important that we convey the results of the design process.
- we should ensure that final reports and presentations are ***not narratives*** or chronologies of our work
- Rather, the presentations and reports should be lucid descriptions of ***design outcomes***, as well as the processes with which those outcomes were ***achieved***.

GUIDELINES FOR TECHNICAL COMMUNICATION

1. Know your purpose.
2. Know your audience.
3. Choose and organize the content around your purpose and your audience.
4. Write precisely and clearly.
5. Design your pages well.
6. Think visually.
7. Write ethically!

1. ***Know your purpose***

    - This is the writing analog of understanding objectives and functions for a designed

    artifact.

    - Just as we want to understand what the designed object must be and must do, we need to understand the goals of a report or presentation.
    - design documentation seeks to inform the client about the features of a selected design
    - design team may be trying to persuade a client that a design is the best alternative.
    - a designer may wish to report how a design operates to users, whether beginners or highly experienced ones.

2. ***Know your audience***

    - When documenting a design, it is essential that a design team structure its materials to its targeted audience.
    - Taking time to understand the target audience will help ensure that its members appreciate your documentation

3. Choose and organize the content around your purpose and your audience

- The key element is to structure the presentation to best reach the audience
- There are many different ways to organize information
    - going from general concepts to specific details (analogous to deduction in logic),
    - going from specific details to general concepts (analogous to induction or inference),
    - describing devices or systems.
- Once an organizational pattern is chosen, no matter which form is used, the design team should translate it into a written outline.This allows the team to develop a unified, coherent document or presentation while avoiding needless repetition.

4. Write precisely and clearly

- Some specific elements that seem to occur in all good writing and presentations.

- These include effective use of short paragraphs that have a single common thesis or topic
- Direct sentences that contain a subject and a verb; and active voice and action verbs that allow a reader to understand directly what is being said or done.
- Opinions or viewpoints should be clearly identified as such.
- As long as the designer remembers that the goals of both technical and nontechnical communications remain the same.

5. Design your pages well

- A long section divided into several subsections helps readers to understand where the long section is going, and it sustains their interest over the journey.
- Tables should be treated as a single figure and should not be split over a page break.
- Simple and direct slides encourage readers to listen to the speaker without being distracted visually
- Thus, text on a slide should present succinct concepts that the presenter can amplify and describe in more detail. A slide does not have to show every relevant thought.
- It is a mistake to fill slides with so many words (or other content) that audiences have to choose between reading the slide and listening to the speaker, because then the presenter's message will almost certainly be diluted or lost.

6.Think visually

- Just as designers often find that visual approaches are helpful to them,

  audiences are helped by judicious use of visual representation of information.
- Given the enormous capabilities of word processing and presentation graphics software, there is no excuse for a team not to use visual aids in its reports and presentations.
- A team should not allow their graphics' capabilities to seduce them into

  clouding their slides with artistic backgrounds that make the words illegible.
- As it is with words, is to know your purpose and your audience, and to use your medium appropriately.

7. Write ethically!

- All results or test outcomes, even those that are not favorable, are presented and discussed.

- Ethical presentations also describe honestly and directly any limitations of a design.
- It is also important to give full credit to others, such as authors or previous researchers, where it is due

ORAL PRESENTATIONS

- TELLING A CROWDWHAT'S BEEN DONE
  - Most design projects call for a number of both formal and informal presentations to clients, users, and technical reviewers
  - Because of the variety of presentations and briefings that a team may be called upon to make, it is impossible to examine each of them in detail.
  - However, there are key elements common to most of them.
  - Foremost among these needs to
    1. Identify the audience
    2. Outline the presentation
    3. Develop appropriate supporting materials
    4. Practice the presentation

KNOWING THE AUDIENCE

- Who's Listening?
- a team planning a briefing should consider factors such as varying levels of interest, understanding, and technical skill, as well as the available time.
- Once the audience has been identified, a team can tailor its presentation to

  that audience.
- As with other deliverables, the presentation must be properly organized and structured:
  - The first step is to articulate a rough outline;
  - The second is to formulate a detailed outline;
  - The third is to prepare the proper supporting materials, such as visual aids or physical models.

THE PRESENTATION: OUTLINE

- ***A title slide*** : that identifies the client(s), the project, and the design team or organization responsible for the work being presented.This slide should include company logos.
- ***A roadmap :*** for the presentation that shows the audience the direction that the presentation will take. This can take the form of an outline, a flowchart, a big picture slide, and so on.
- ***A problem statement:*** which includes highlights of the revised problem statement that the team produced after research and consultation with the client.
- ***Background material on the problem:*** including relevant prior work and other materials developed through team research. References should be included but may be placed in a slide at the end of the presentation.
- ***The key objectives of the client and users*** : as reflected in the top level or two of the objectives tree.
- ***The key constraints*** that the design must meet.
- ***Functions that the design must perform :*** focusing on basic functions, and means for achieving those functions.
- ***Design alternatives :*** particularly those that were considered at the evaluation stage, including diagrams and descriptions of each.
- ***Highlights of the evaluation procedure and outcomes***: including key metrics or

  objectives that bear heavily on the outcome.
- ***The selected design :*** explaining why this design was chosen.
- ***Features of the design :*** highlighting aspects that make it superior to other alternatives and any novel or unique features.
- ***Proof-of-concept testing :*** especially for an audience of technical professionals for

  whom this is likely to be of great interest.
- ***A demonstration of the prototype :*** assuming that a prototype was developed and that it can be shown.Video or still photos may also be appropriate here.
- ***Conclusion(s):*** including the identification of any future work that remains to be done, or suggested improvements to the design.

PRESENTATIONS ARE VISUAL EVENTS

- At the earliest stages of the presentation planning, the design team should find out what devices (e.g., overhead projectors, computer connections, projectors, and whiteboards) are available and the general setting of the room in which it will be presenting.

- Tips & pointers
  - Limit the number of slides.
  - Be sure to introduce yourself and your teammates on the title slide.
  - Beware of “clutter.” Slides should be used to highlight key points; they are not a direct substitute for the reasoning of the final report.
  - Make points clearly, directly, and simply
  - Use color skillfully
  - Use animation appropriately
  - Do not reproduce completed design tools
  - Consider carefully the size and distance of the audience

PRACTICE MAKES PERFECT

- To be effective, speakers typically need to practice their parts in a presentation alone, then in front of others, including before an audience with at least some people who are not familiar with the topic.
- we want to speak to an audience in their language, and that we want to maintain a

professional tone.

- Practice sessions, whether solitary or with others, should be timed and done under conditions that come as close as possible to the actual environment.
- While practicing its presentation, a team ought to prepare for questions from its audience by:
  - Generating a list of questions that might arise, and their answers;
  - Preparing supporting materials for points that are likely to arise (e.g., backup slides that may include computer results, statistical charts, and other data that may be needed to answer anticipated questions)
  - Preparing to say “I don’t know,” or “We didn’t consider that.” This is very important: A team, that is, to be caught pretending to know has undermined its credibility and invited severe embarrassment.

MATHEMATICAL MODELING IN DESIGN

- MATHEMATICAL MODELS are central to design because we have to be able to predict the behavior of the devices or systems that we are designing.

- It is important for us to ask: How do we create mathematical models? How do we validate such models? How do we use them? And, are there any limits on their use?

SOME MATHEMATICAL HABITS OF THOUGHT FOR DESIGN MODELING

- We will focus on representing the behavior and function of real devices in

mathematical terms.

- Basic Principles of Mathematical Modeling
  - Why do we need a model?
  - For what will we use the model?
  - What do we want to find with this model?
  - What data are we given?
  - What can we assume?
  - How should we develop this model, that is, what are the appropriate physical principles we need to apply?
  - What will our model predict?
  - Can we verify the model's predictions (i.e., are our calculations correct?)
  - Are the predictions valid (i.e., do our predictions conform to what we observe?)
  - Can we improve the model?

ABSTRACTIONS, SCALING, AND LUMPED ELEMENTS

- ***Abstractions*** ***:*** An important decision in modeling is choosing the right level of detail for the problem, which thus dictates the level of detail for the model.
- Stated differently, thinking about finding the right level of abstraction or detail means identifying the right ***scale*** for our model means thinking about the magnitude or size of quantities measured with respect to a standard that has the same physical dimensions.
- we often say that a "real," three-dimensional object behaves like a simple spring.When we say this, we are introducing the idea of a ***lumped element*** model in which the actual physical properties of a real object or device are aggregated or lumped into less detailed, more abstract expressions.

SOME MATHEMATICALTOOLS FOR DESIGN MODELING

- **Dimensions and Units**

- Every independent term in every equation we use has to be dimensionally homogeneous or dimensionally consistent, that is, every term has to have the same net physical dimensions.
- The physical quantities used to model objects or systems represent concepts, such as time, length, and mass, to which we attach numerical measurements or values.
- ***Fundamental or primary quantities*** can be measured on a scale that is independent of those chosen for any other fundamental quantities. For example, mass, length, and time are usually taken as the fundamental mechanical dimensions or variables.
- ***Derived quantities*** generally follow from definitions or physical laws, eg :

  force is a derived quantity that is defined by Newton's law of motion.

  DIMENSIONS AND UNITS

- If mass, length, and time are chosen as primary quantities, then the dimensions of force are (mass x length)/(time)2. We use the notation of brackets [ ] to read as "the dimensions of." If M, L, and T stand for mass, length, and time, respectively, then

$$[F = \text{force}] = (\mathrm{M} \times \mathrm{L})/(\mathrm{T})^2$$

- Similarly, [A=area]=$(L)^2$ and [ρ = density] = M/(L)3.
- The units of a quantity are the numerical aspects of a quantity's dimensions expressed in terms of a given physical standard

  SOME MATHEMATICALTOOLS FOR DESIGN MODELING

- **Significant Figures**
  - In scientific notation, the number of significant figures is equal to the number of digits counted from the first nonzero digit on the left to either
    - (a) The last nonzero digit on the right if there is

  no decimal point, or
    - (b) The last digit (zero or nonzero) on the right when there is a decimal point.

- we should always remember that the results of any calculation or measurement cannot be any more accurate than the least accurate starting value.
- any calculation is only as accurate as the least accurate value we started with

TABLE 12.1 Numbers written in different forms, together with the *number of significant figures* (NSF) of each and an assessment of the NSF that can be assumed or inferred. Confusion about the NSF arises because of the meaning of the terminal zeroes is not stated

Measurement	Significant Figures	Assessment
5415	Four	Clear
5400	Two (54×10^2) or three (540×10^1) or four (5400)	Not clear
54.0	Three	Clear
54.1	Three	Clear
5.41	Three	Clear
0.00541	Three	Clear
5.41×10^3	Three	Clear
0.054	Two	Clear
0.0540	Two (0.054) or three (0.0540)	Not clear
0.05	One	Clear

SOME MATHEMATICALTOOLS FOR DESIGN MODELING

- **Dimensional Analysis**
  - We can learn a lot about some behavior by doing dimensional analysis, that is, by expressing that behavior in a dimensionally correct equation among certain variables or dimensional groups.
  - The basic method of dimensional analysis is an informal unstructured approach for determining dimensional groupings that depends on constructing a functional equation that contains all of the relevant variables, for which we know the dimensions
  - We then identify the proper dimensionless groups by thoughtfully eliminating

    dimensions.
- **Physical Idealizations, Mathematical Approximations, and Linearity**
  - First, we identify those elements that we believe are important to the problem.
  - Second, we translate our physical idealization into a mathematical model
  - Third, try to build models that are, mathematically speaking, linear models. Linearity shows up in other contexts. Consider geometrically

similar objects, that is, objects whose basic geometry is essentially the same.

CONSERVATION AND BALANCE LAWS

- Many of the mathematical models used in engineering design are statements that some property of an object or system is being conserved.
- Such balance or conservation principles are applied to assess the effect of

  maintaining levels of physical attributes.
- Conservation and balance equations are related: Conservation laws are special cases of balance laws.
- PROTOTYPING AND PROOFING THE DESIGN
- Focus on how to translate our design ideas into models and prototypes that can be used to test our design concepts and communicate our ideas to the client.
- Often the first step in such a process involves sketching or drawing our design, we can use these representations to create the prototype or model.
- 3D representation
  - As an input to a computational modeling program to simulate the design's performance under specified conditions;
  - as an input into a variety of rapid prototyping technologies, such as 3D printing;
  - to generate detailed engineering drawings of the design;
  - to guide the tool path in computer numerical-controlled (CNC) machining

PROTOTYPES

- original models on which something is patterned." They are also defined as the "first full-scale and usually functional forms of a new type or design of a construction
- prototypes are working models of designed artifacts.
- They are tested in the same operating environments in which they're expected to function as final products

MODEL

- a miniature representation of something," or a "pattern of something to be made," or "an example for imitation or emulation."
- We use models to represent some devices or processes.

- They may be paper models or computer models or physical models.
- We use them to illustrate certain behaviors or phenomena as we try to verify the validity of an underlying (predictive) theory.
- Models are usually smaller and made of different materials than are the original artifacts they represent, and they are typically tested in a laboratory or in some other controlled environment to validate their expected behavior.

PROOF OF CONCEPT

- refers to a model of some part of a design that is used specifically to test whether a particular concept will actually work as proposed.
- Doing proof-of-concept tests means doing controlled experiments to prove or disprove a concept.

WHEN DO WE BUILD A PROTOTYPE?

- “It depends.”
- the size and type of the design space,
- the costs of building a prototype,
- the ease of building that prototype,
- the role that a full-size prototype might play in ensuring the widespread acceptance of a new design,
- the number of copies of the final artifact that are expected to be made or built.
- There is no obvious correlation between the size and cost of prototyping—or the

  decision to build a prototype—and the size and type of the design space.
- it is that the project schedule and budget should reflect plans for building them.

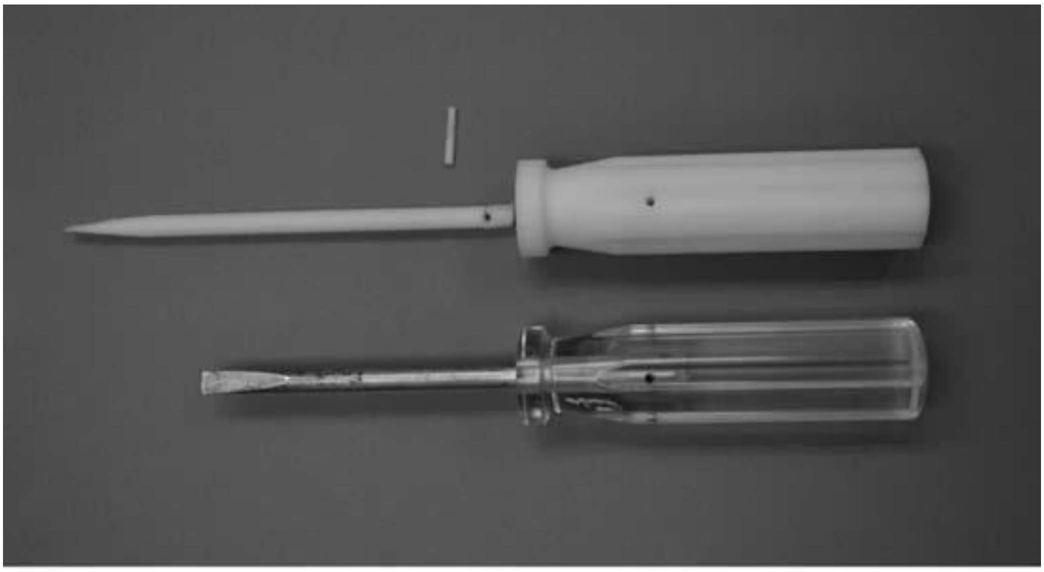
BUILDING MODELS AND PROTOTYPES

- The important questions we must ask are:
  - What do we want to learn from the model or prototype?
  - Who is going to make it?
  - What parts or components can be bought?
  - How, and from what, is it going to be made?

- How much will it cost?

BUILDING MODELS AND PROTOTYPES

- There are many options for constructing prototypes and models
  - ***Mock-ups:*** One option for making basic models or prototypes is to construct a mockup of a 3D part from 2D cutouts. These 2D parts can be made using a vinyl cutter or a laser cutter, and parts are then assembled into 3D mock-ups of a design. Materials used for these mock-ups might be foam, thin plastic, or wood.
  - ***Machining:*** We may have the option of machining parts or all of our prototypes ourselves in a machine shop.
  - ***Rapid prototyping technologies:*** Rapid prototyping technologies have emerged in recent years as relatively fast and cheap ways to fabricate prototypes that would otherwise need to be injection molded. Rapid prototyping techniques use 3D CAD models as inputs, and convert these 3D files into thin 2D layers to build the 3D part. Rapid prototyping technologies include stereo-lithography and selective laser sintering, which involve using a laser to harden either a resin bath or a polymer powder in a particular configuration to build each layer.



MODULE 4

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.

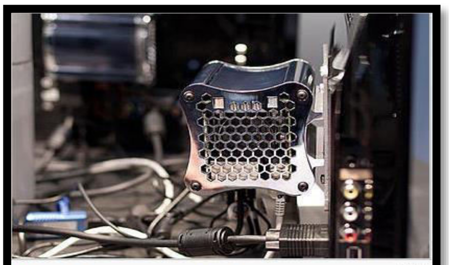
2. **Workstations**

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

Modular workstations

possible type of building using the same modular components that originally formed the office building.

3. **Computer**



Modular computer design

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,

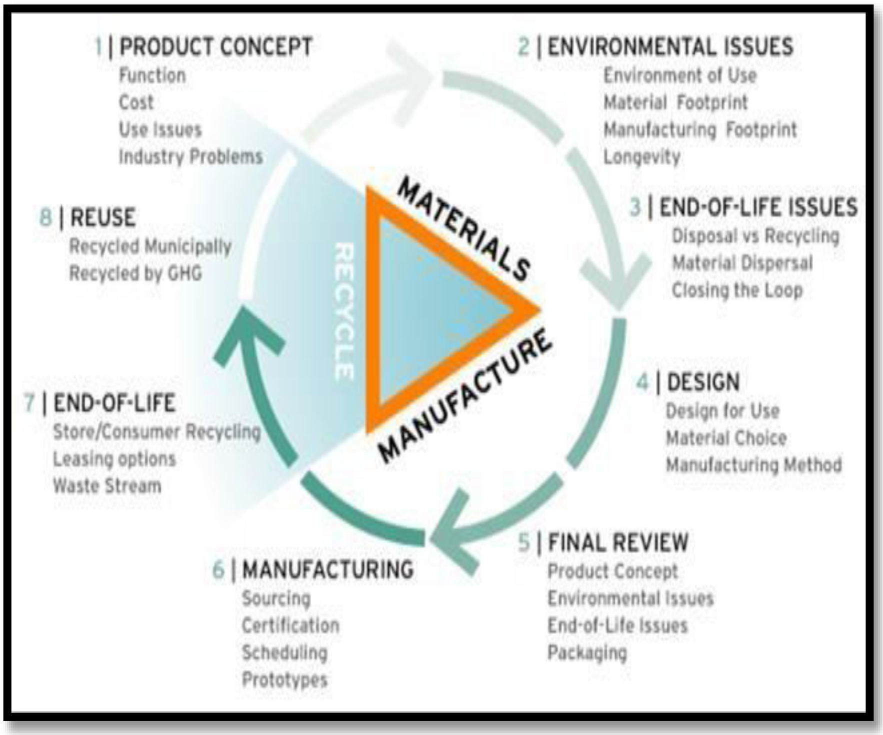
Etc. All of these parts should be easily interchangeable as long as the user uses parts that support the same standard interface as the part that was replaced. Similar to the computer's modularity, other tools have been developed to leverage modular design.

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 & 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.

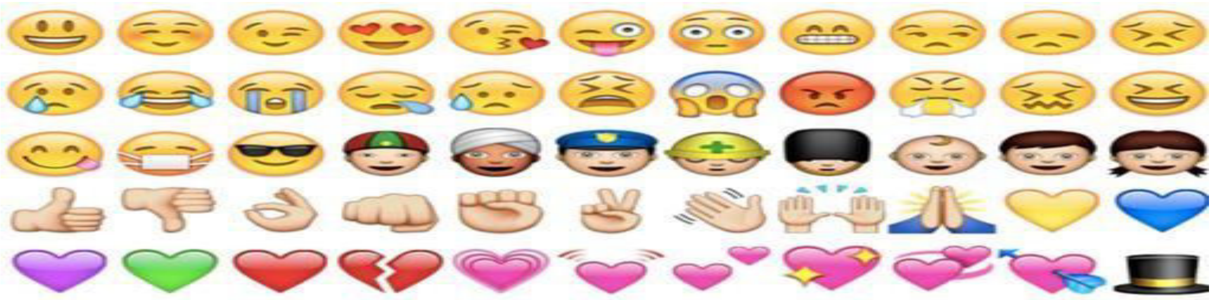
Human factors and engineering psychologists study how people interact with machines and technology. They use psychological science to guide the design of products, systems and devices we use every day. They often focus on performance and safety.

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

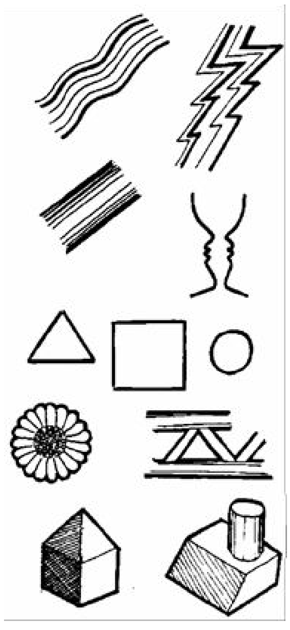
There is no better approach for improving your design than gaining a better understanding of the people you are designing for. There is little practicality in dissecting every psychological principle relevant to design, but understanding a handful of key concepts can be a powerful gateway into designing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

Aesthetics & Ergonomics

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.

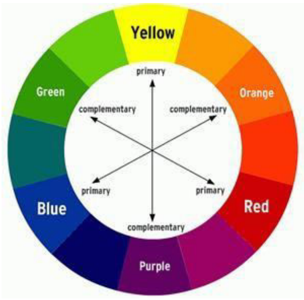
Size and proportion: The size of an object is found by measuring its length, width, and height. These are known as linear dimensions. Proportion is the relationship between an object's heights compared to its width.

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 McIntosh'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:-

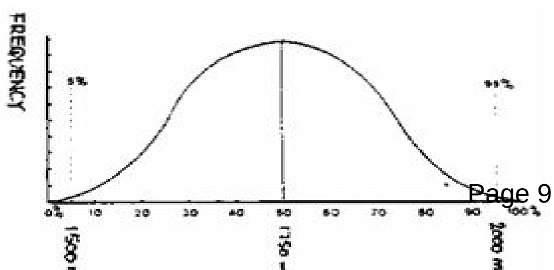
1. Begin by looking closely at how the product will be used, decide on the characteristics of the user and the product and the relationship between them.
2. Consider the factors which will ensure health, safety, convenience and comfort of the user.
3. Compare your design ideas with what you find in 1 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.



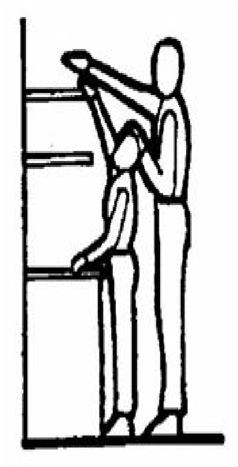
You will see that few men are very small i.e. 1500 mm. Few men are very tall i.e. 2000 mm. However there are large numbers of men who are around average height i.e. 1750 mm.

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:

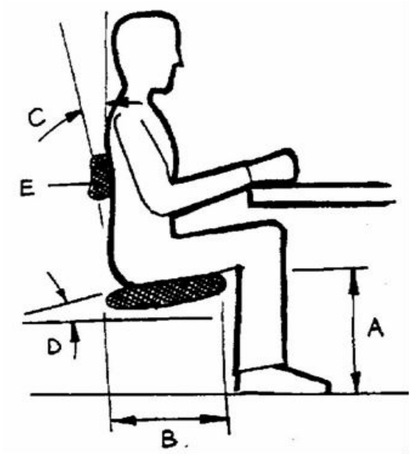
1. **Door Design**



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



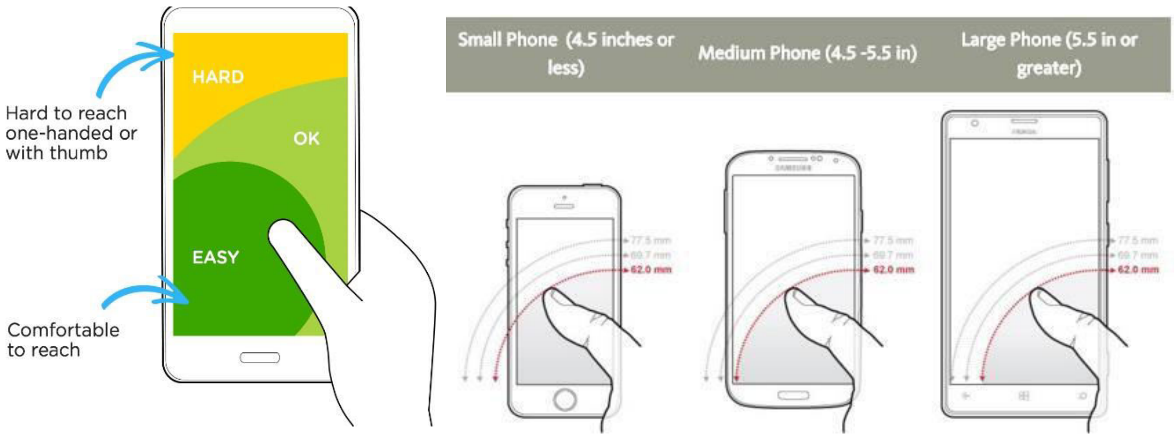
Seats are used for a variety of activities and each activity will require a different design of chair. The design of a chair to be used at a desk will be very different from the design of an easy chair!

Measurements and considerations in chair design are:-

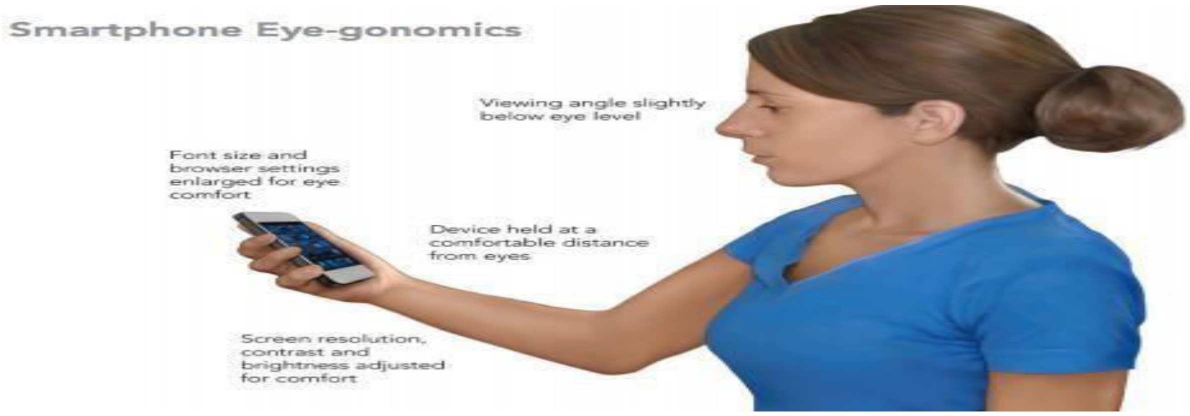
- Seat height A suited to work level. Seat depth B to provide clearance.
- Seat back and angle C should support the natural curve of the spine.
- Seat angle D should be horizontal or sloping back.
- Back rest E should be adjustable for a work chair and should also allow free movement of the shoulders.
- 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.

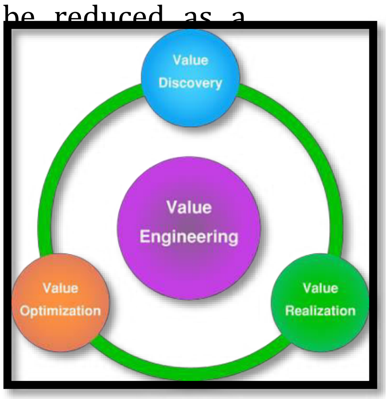


This figure representing choosing better screen size for a smartphone that being handles on palms.



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

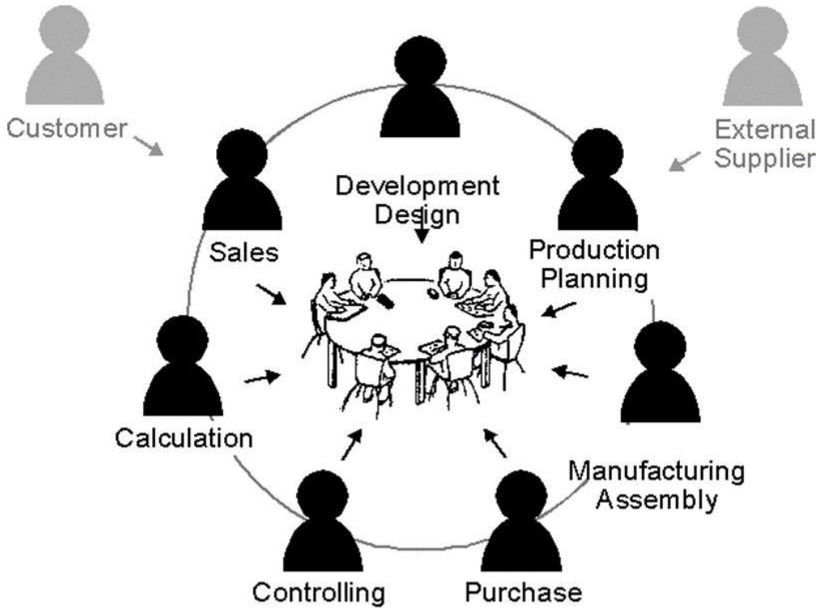
$$\textbf{Value} = \frac{\textbf{Worth}}{\textbf{Cost}} = \frac{\textbf{Function(Utility)}}{\textbf{Cost}}$$


Biscuit
Pocket

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:

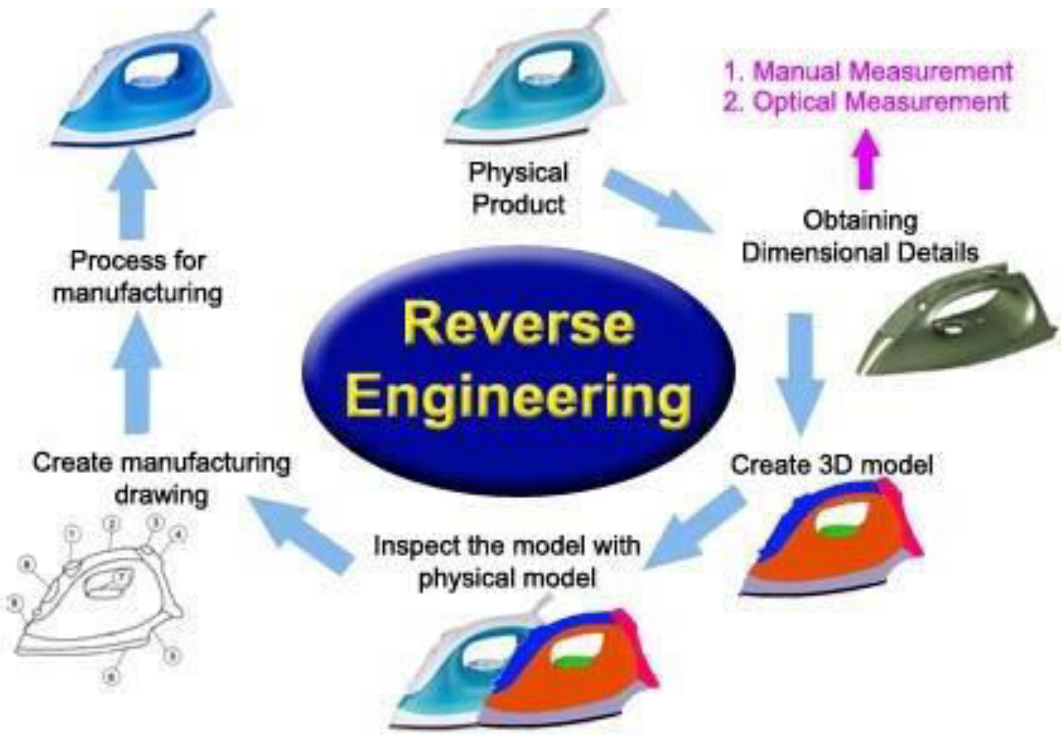
1. Competitive Advantage- reduction in time to market means that businesses gain an edge over their competitors.
2. Enhanced Productivity- earlier discoveries of design problems means potential issues can be corrected soon, rather than at a later stage in the development process.
3. Decrease Design and 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

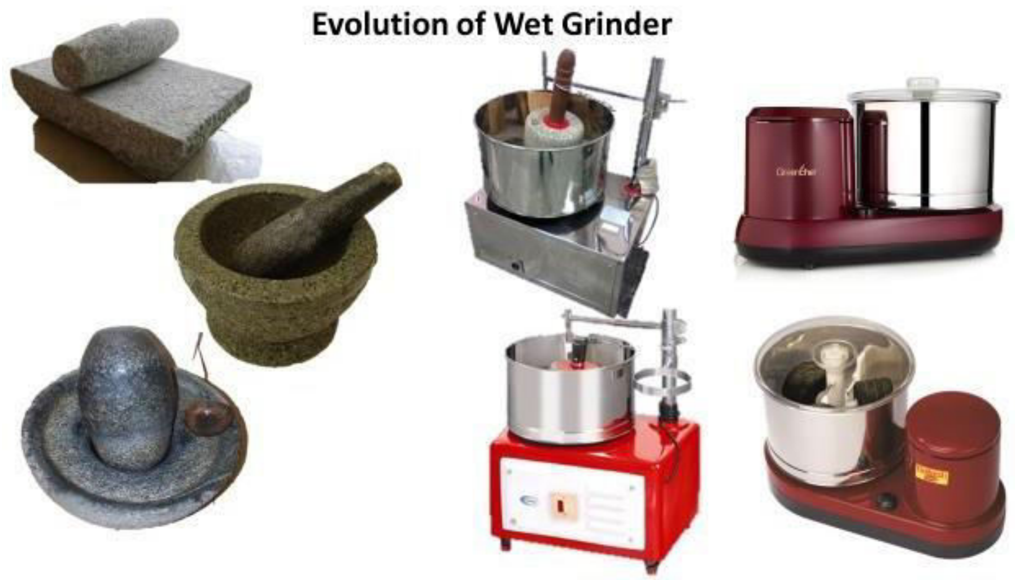
Increasing globalization has led to product manufacturers seeking cooperation with other companies at an international level, not only for production but also for product development. In such cooperation engineering designers from different cultural backgrounds participate in the design process. Their 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.

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.

MODULE 5

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

Bike engine casing act as heat dissipater

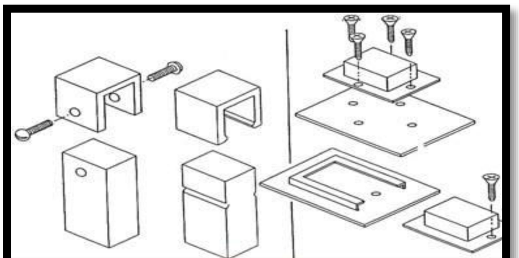
multi-use. For example, all the parts used in the firm (purchased or made) can be sorted into two groups: the first containing all the parts that are used commonly in all products. Then, part families are created by defining categories of similar parts in each group. The goal is to minimize the number 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.

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**

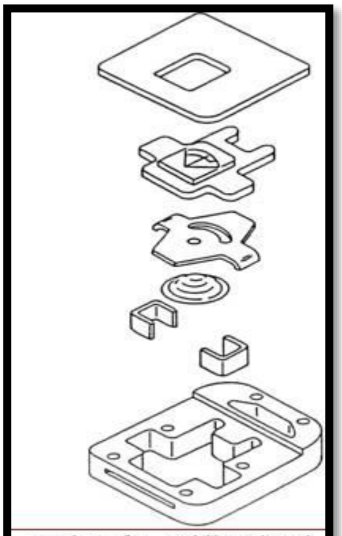


Avoid separate fasteners: design the fastening functions into the parts.

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.

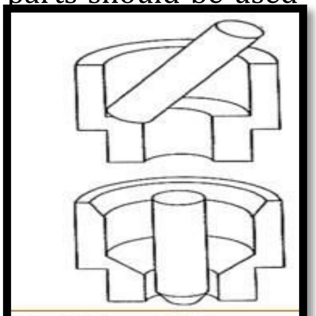
Unidirectional assembly become more crucial when manufacturing done by automated robotic arm, by reducing the assembly direction we can reduce the unnecessary movements of robotic arms. It will reduce the assembly time as well as programming time.

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

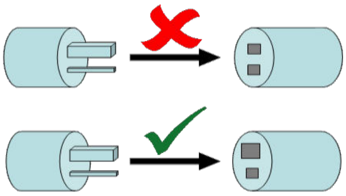
4. **Minimize the part count**

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:



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

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

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

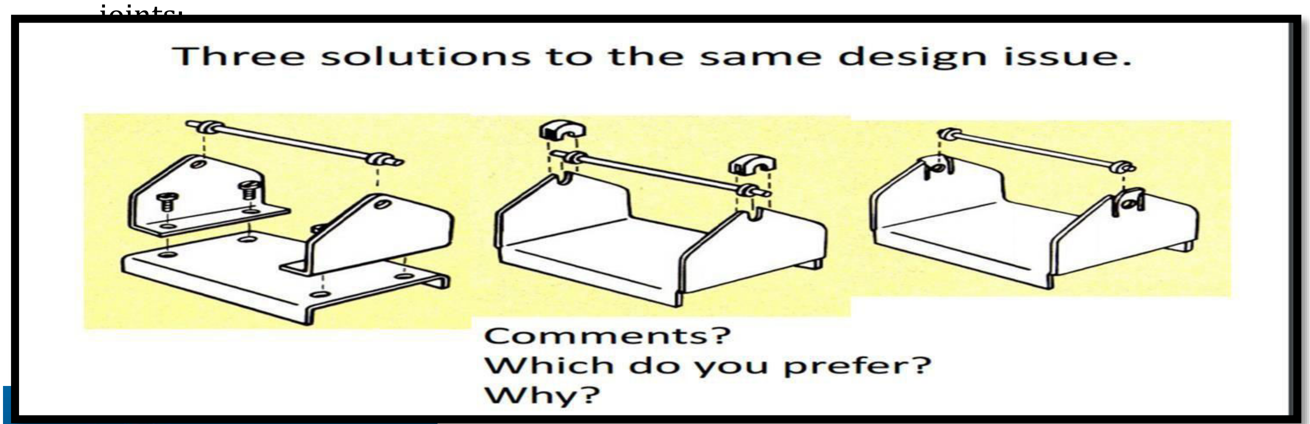
in either of two states: (1) it already has occurred, calling for defect detection, or (2) is about to occur, calling for defect prediction. Poka-yoke has three basic functions to use against defects: shutdown, control, and warning. The

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:

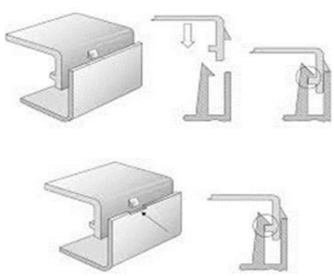
Snap joints are a very simple, economical and rapid way of joining two different components.

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:



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

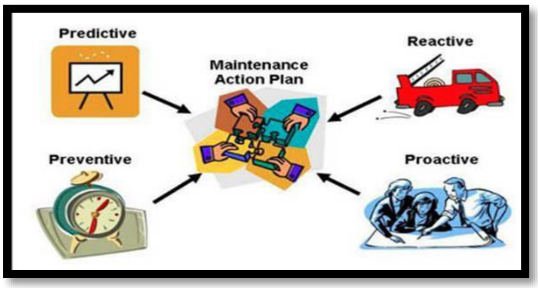
6. Controlling the significant and critical factors using SPC (statistical process control) where applicable
7. Tracking all yield and defect rates from both in-house and external suppliers and developing strategies to address them

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.

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.

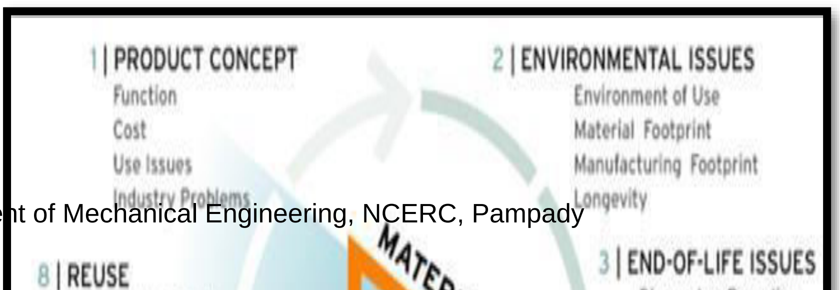
3. Design for disposal or reuse: The end-of-life of a product is very important, because some products emit dangerous chemicals into the air, ground and water after they are disposed of in a landfill. Planning for the reuse or refurbishing of a product will change the types of materials that would be 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



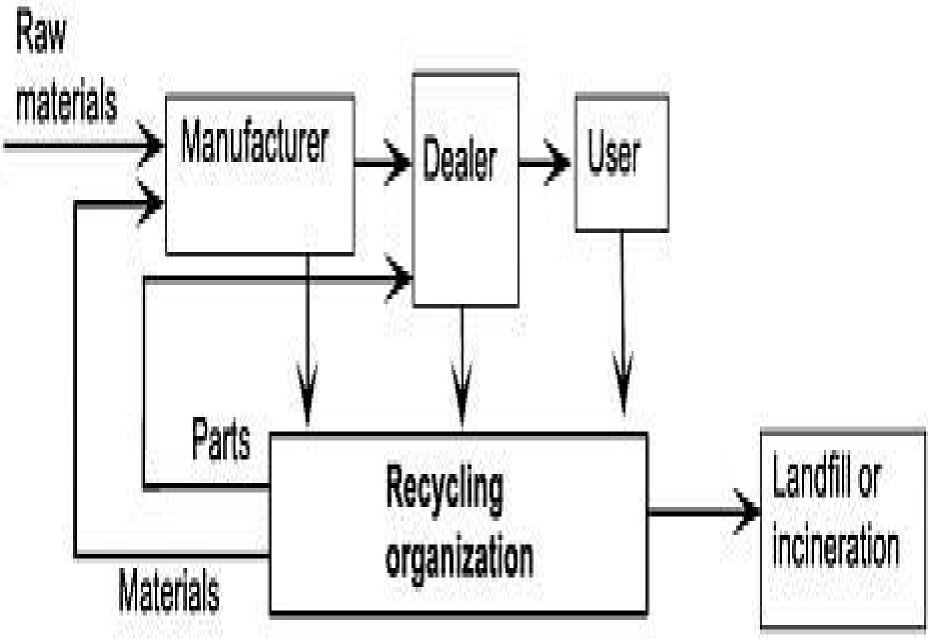
life cycles going on at the same time. These parallel life cycles are initiated when the need for the product is first recognized.

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

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.

What is Intellectual Property Rights?

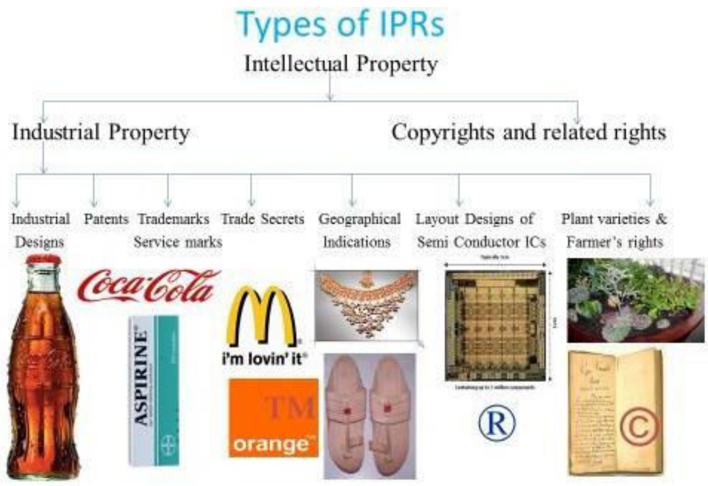
Intellectual property rights (IPR) can be defined as the rights given to people over the creation of their minds. They usually give the creator an exclusive right over the use of his/her creations for a certain period of time.

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. Aninvention 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.

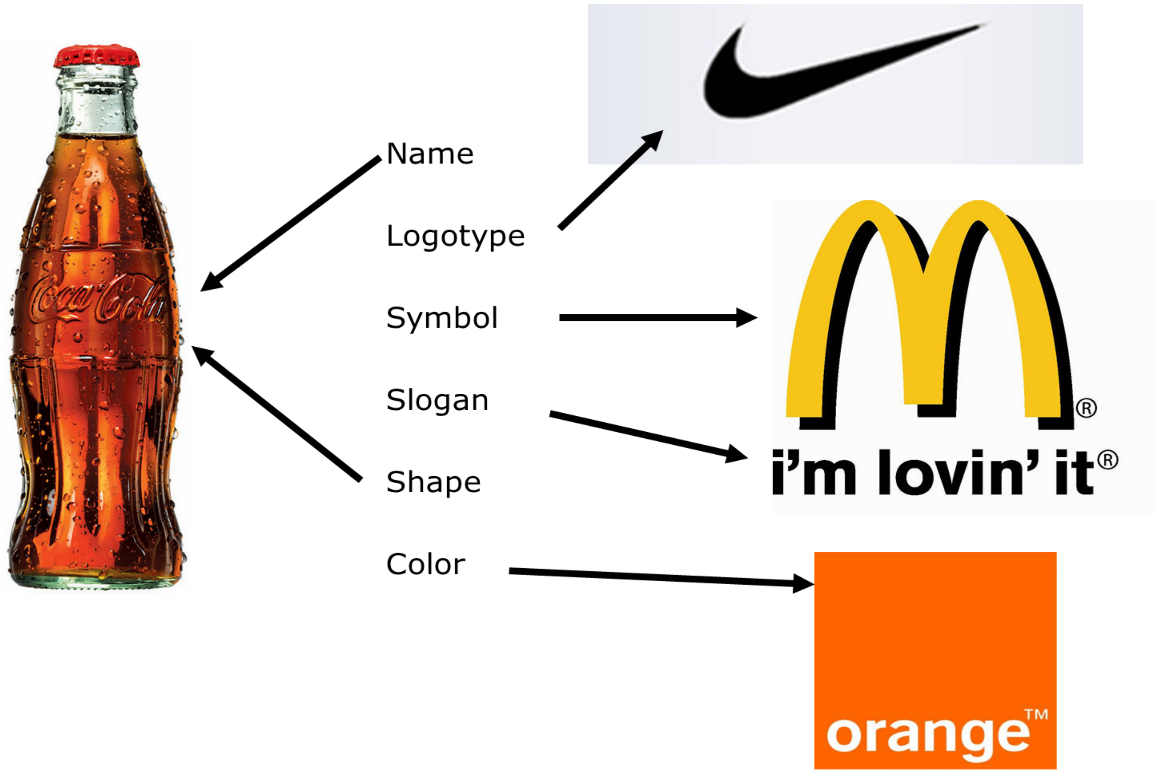
It is a monopoly right granted to a person, who invented a new product or process of making an article, for 20years under the Indian Patens Act, 1970, and can be renewed after expiration of period.

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. Theexclusive 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.



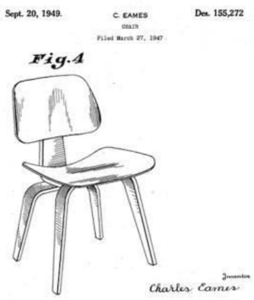
The owner of a trademark may pursue legal action against trademark infringement. Most countries require formal registration of a trademark as a precondition for pursuing this type of action. The United States, Canada and other countries also recognize common law trademark rights, which means action can 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.

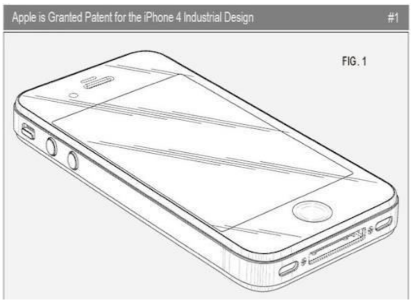
A trademark may be designated by the following symbols:

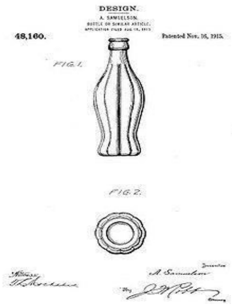
- ™ (the "trademark symbol", which is the letters "TM" in superscript, for an unregistered trademark, a mark used to promote or brand goods)
- SM (which is the letters "SM" in superscript, for an unregistered service mark, a mark used to promote or brand services)
- ® (the letter "R" surrounded by a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


Aranmula Kannadi from Kerala

certification that the product possesses certain qualities, is made according to traditional methods, or enjoys a certain reputation, due to its geographical origin.

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.

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.

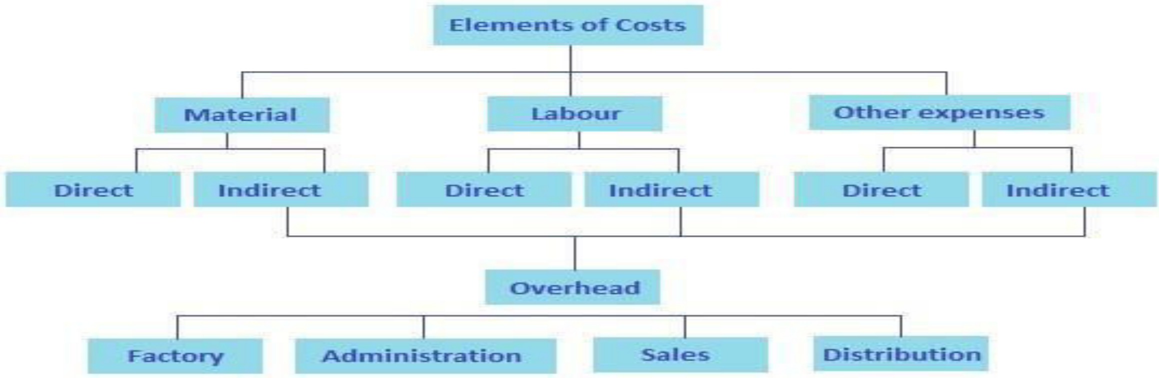
Cost estimates are used in the following ways:

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 inthe 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 fi rst 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.

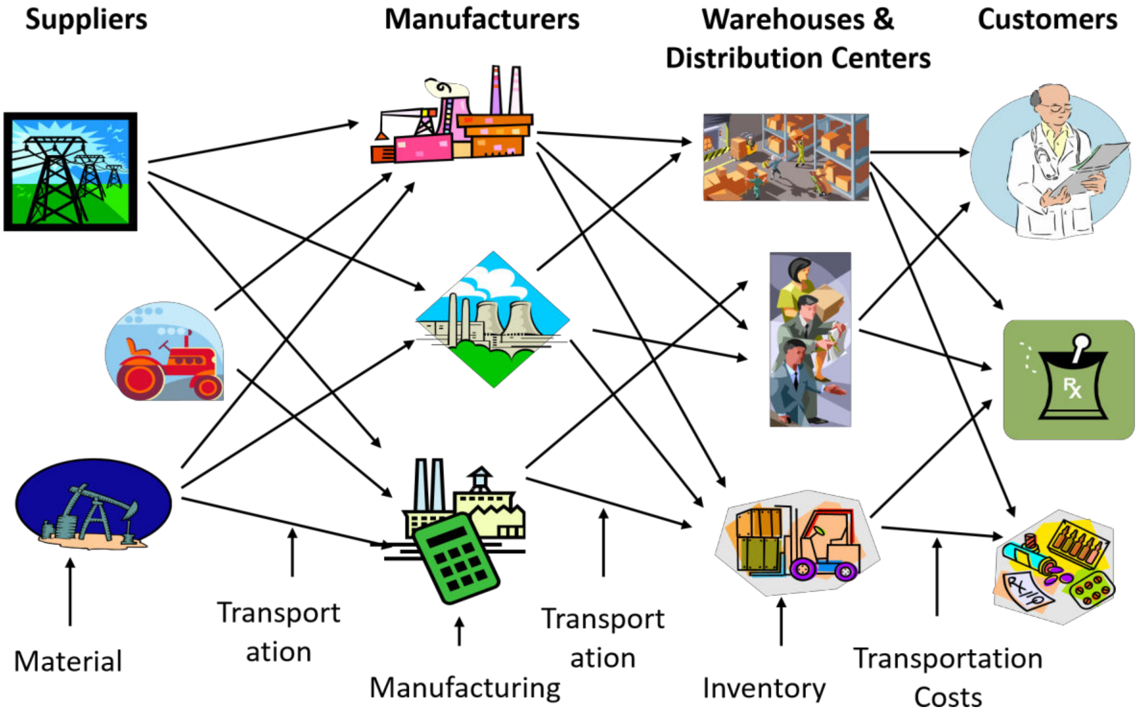
Batch production scheduling is the practice of planning and scheduling of batch manufacturing processes. Although scheduling may apply to traditionally continuous processes such as refining, it is especially important for batch processes such as those for pharmaceutical active ingredients, biotechnology 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**

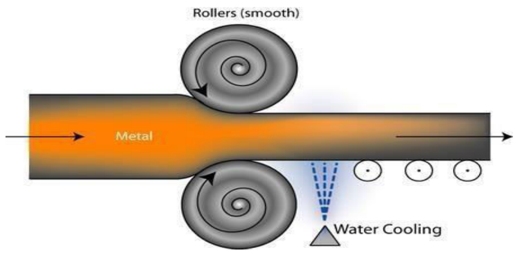
1. Primary shaping process

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.

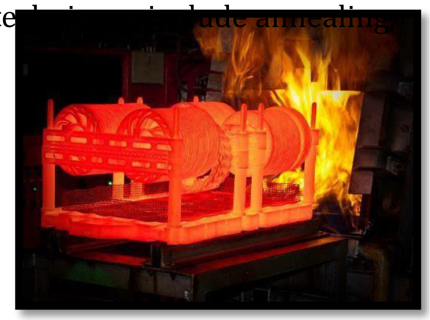
- **Buffing**

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.

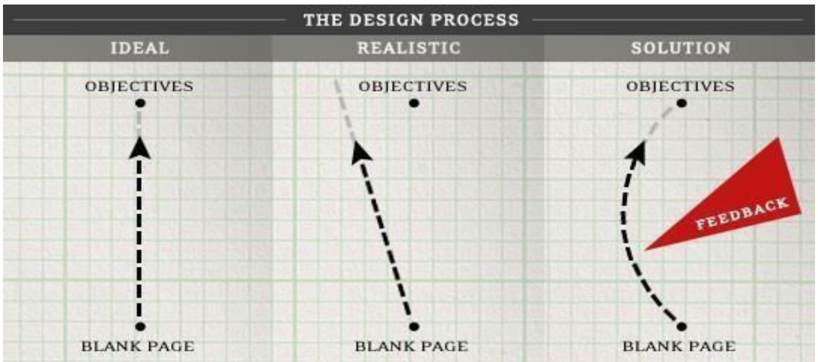
Feedback on Design

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