# CMPE 490
# Design Principles in Engineering & Computer Engineering

## Project Design Principles & Methods

# Engineering Design

- Most engineering designs are the result of bringing together technologies to **meet human needs** or to **solve problems**.
- Design activity occurs over a period of time and requires a **step-by-step** methodology.
- The solution to a design problem is usually **open ended**, since there are many possible devices/solutions that can fulfill the needs and specs. The result or solution to a design problem is a system that possesses specified properties.
- Solving complex design problems is often an **iterative process**
  - As the solution to a design problem evolves, you find yourself **continually refining** the design. While implementing the solution to a design problem, you may discover that the solution you've developed is unsafe, too expensive, or will not work. You then "go back to the drawing board" and modify the solution until it meets your requirements.
  - For example, the Wright brothers‘ airplane did not fly perfectly the first time. They began a program for building an airplane by first conducting tests with kites and then gliders. Before attempting powered flight, they solved the essential problems of controlling a plane's motion in rising, descending, and turning. They didn't construct a powered plane until after making more than 700 successful glider flights.

# Engineering Design (cntd)

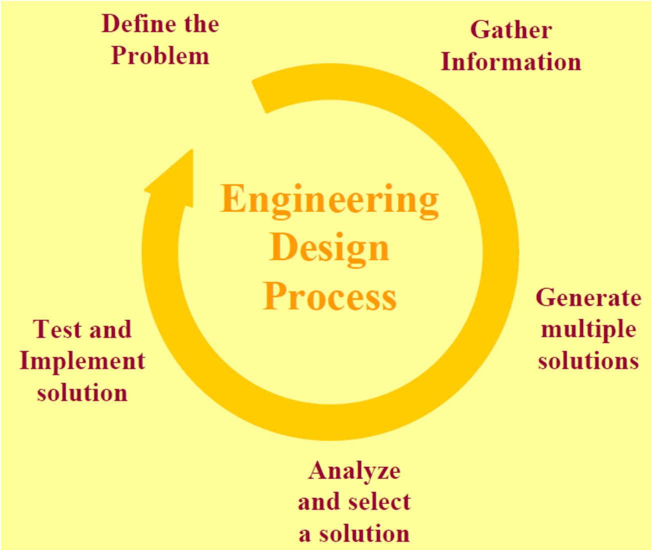
- Design activity is therefore cyclic or **iterative** in nature (whereas analysis problem solving is primarily **sequential**).
- **A good solution requires a methodology** or process.
  - There are probably as many processes of design as there are engineers.
  - Therefore, there is no rigid "cookbook" approach to design but a general application of a five-step problem-solving methodology associated with the design process can be developed for problems involving a certain amount of complexity.

# The Design Process

- Solving a complex 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 main steps** used for solving design problems are:

  1. Define the problem (w/ Realistic Constraints)
  2. Gather pertinent information
  3. Generate multiple solutions
  4. Analyze and select a solution
  5. Test and implement the solution



# 1. Define the Problem

Here, four substeps can be distinguished:

- 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, machine, or process.
- Develop a Problem Statement
  - Defining the problem is not the same as recognizing a need. The problem definition statement results from first identifying a need. The problem statement should specifically address the real need yet be broad enough not to preclude certain solutions.
- Establish Criteria for Success
  - The criteria that apply to a particular design problem are based on your background knowledge and the research that you've conducted. Since each problem or project is unique, the desirable attributes, or criteria, of **the solution are also unique**. Some criteria are **unimportant** to the success of the design. The **list of criteria** is developed by the design team. (The design team may be made up of people from various engineering backgrounds that have expertise pertinent to the problem.)
  - This team may also include people from backgrounds other than engineering, such as managers, scientists, social scientists... The design team must evaluate each criterion and decide if it is applicable to the design effort. Later in the design process, value judgments must be applied to the list of criteria.

# 1. Define the Problem (cntd)

- Identify and establish <u>a realistic set of constraints</u>
- What kind of constraints could those be?

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- Identify and establish <u>a realistic set of constraints</u>
- The realistic constraints generally include the following:
  - ❑ Engineering Codes and Standards
  - ❑ Economic Factors
  - ❑ Environmental Effects
  - ❑ Sustainability
  - ❑ Manufacturability (Constructability)
  - ❑ Ethical Considerations
  - ❑ Health and Safety Issues
  - ❑ Social Ramifications
  - ❑ Political Factors
  - ❑ Legal Issues
- The most important constraints are explained in further detail in the next few slides

# 1. Define the Problem: Key Realistic Constraints

- **Economic**: Determining whether a project should be carried out from a financial perspective. Primary considerations are the cost of making a product (including fixed and variable costs*), the pricing of a product (can it compete in the marketplace), and the cost of ownership† for both producer and consumer.
- **Environmental**: Giving consideration to the ways that a product impacts the environment, from its manufacture to its use to its disposal. Often manifested in terms of how the adoption of environmental constraints (e.g. use of only organic cotton and dyes for clothing) affects design.

* All project costs can be broken into two main categories: fixed costs and variable costs. Fixed costs are costs that are independent of output and remain constant throughout the relevant range. Fixed costs often include rent, buildings, machinery, etc. Variable costs are costs that vary with output. Generally variable costs increase at a constant rate relative to labor and capital. Variable costs may include wages, utilities, materials used in production, etc.

† Total cost of ownership (TCO) is the purchase price of an asset plus the costs of operation. When choosing among alternatives in a purchasing decision, buyers should look not just at an item's short-term price, which is its purchase price, but also at its long-term price, which is its total cost of ownership. The item with the lower total cost of ownership is the better value in the long run.

# 1. Define the Problem: Key Realistic Constraints

- **Health and Safety**
  - Engineering is about application of knowledge for the improvement of humanity. Products should be designed such that their everyday use does not cause harm. Indeed, engineers have literally helped improve the lives of thousands, even millions, through their designs.
  - Designing a “safe” product does not mean that it cannot fail or that we cannot get hurt or killed by the product; it means that the degree of risk is considered to be acceptable.
  - Finally, designers must acknowledge that all products have lifetimes, and therefore modes of failure (material fatigue, poor design, environmental degradation, and/or human error), associated with them.

# 1. Define the Problem: Key Realistic Constraints (cntd)

- **Manufacturability**: Concerned with designing a product in such a way that it can be "manufactured" (e.g. parts made and then assembled into the product) efficiently, reliably and within acceptable costs. This can include redesigning a product to reduce the number of parts, simplify fabrication, or utilize common parts and materials.

- **Sustainability**: The process of developing engineering devices, products, and systems that use the resources available to it to meet the needs of the present without compromising the ability of future generations to also meet their own needs.
  - Does the manufacture and/or use of the product employ renewable resources?
  - In what ways can the product be reused and/or recycled at the end of its lifetime?

# 1. Define the Problem: Key Realistic Constraints (cntd)

- **Social**: Developing projects that are designed to meet human needs and/or to address social issues. What human needs?
  - There is arguably a hierarchical structure to human needs where the higher needs come into focus only when the lower needs are met. In ascending order:

    **Physiological**: includes basic human needs such as breathing, drinking, eating.
    Safety: includes mechanisms that provide for a predictable, orderly world: shelter from the elements, personal security from crime, financial security, health maintenance, etc.

    **Love/Companionship**: humans need to feel a sense of belonging and acceptance; we like to have friends, belong to groups, join clubs, organizations, churches, etc.

    **Esteem**: comes from a human need to be respected and to respect both oneself and others. Feeling good about what we have accomplished in life is a driving force–we also feel good if others appreciate our contributions.

    **Self-actualization**: developing a sense of fulfillment in one's life through building upon strengths, overcoming weaknesses, and growing in skills and knowledge.

# 1. Define the Problem: Key Realistic Constraints (cntd)

- **Political**: One needs to understand how engineering and political activities interact, and how to work effectively in this environment. Key points to examine are:

  Government as a regulator.
  Government as a customer.

- **Ethical**: Engineers need to be aware of codes of conduct that provide standards of proper behavior in our interactions with others, both inside and outside of the profession.
  - Engineering ethics is the field of applied ethics and system of **moral principles** that apply to the practice of engineering. The field examines and sets the obligations by engineers to society, to their clients, and to the profession.
    - ✓ Hold paramount the safety, health, and welfare of the public.
    - ✓ Perform services only in areas of their competence.
    - ✓ Issue public statements only in an objective and truthful manner.
    - ✓ Act for each employer or client as faithful agents or trustees.
    - ✓ Avoid deceptive acts.
    - ✓ Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

# 2. Gather Pertinent Information

- Before you can go further in the design process, you need to collect all the information available that relates to the problem.
  - 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 offer 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)?
- Search for information resources
  - Scientific publications and technical handbooks.
  - Electronic catalogs.
  - Indexes.
  - The Internet.
  - Advisors.

# 3. Generate Multiple Solutions

- 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 a totally unique solution to the problem. This process is called synthesis.

- You can improve your creative ability by choosing to develop these characteristics in yourself:
  - Curiosity and tolerance of the unknown.
  - Openness to new experiences.
  - Willingness to take risks.
  - Ability to observe details and see the whole picture.
  - No fear of problems.
  - Ability to concentrate and focus on the problem until it's solved.

# 4. Analyze and Select a Solution

- Analyze each alternative solution against the selection criteria defined in Step 1:
  - ✓ Functional analysis
  - ✓ Industrial design/Ergonomics
  - ✓ Manufacturability/Testability
  - ✓ Code complexity/Implementability
  - ✓ Product safety and liability
  - ✓ Economic and market analysis
  - ✓ Regulatory and Compliance

# 4. Analyze and Select a Solution (cntd)

- The decision process
  - After analyzing your alternative solutions, you need to decide and document which design solution
  - The first step in creating a decision matrix is for you (or the design team) to rank, in order of importance, the desirable attributes or criteria for the design solution. These attributes can include factors such as safety, manufacturing considerations, the ease of fabrication and assembly, cost, portability, compliance with government regulations, etc. You then assign to each attribute or criteria a value factor related to the relative importance of that attribute.
  - Next you evaluate each design alternative against the stated criteria. A rating factor is assigned to each solution, based on how well that solution satisfies the given criterion. For example the rating factor can be on a scale of 0 to 10, with 10 representing a solution that satisfies the given criterion the best.

# 5. Test and Implement the Solution

- The final phase of the design process is implementation, which refers to the realization (perhaps construction as well as manufacturing) and testing of the solution to the design problem.
- You must consider several methods of implementation:
  - Prototyping
  - 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 (implement parallel design and analysis in which safety, manufacturability, serviceability, marketability, and compliance issues are considered early on and during the process). It decreases product development time and also the time to market, leading to improved productivity and reduced costs.

# 5. Test and Implement the Solution (cntd)

- 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.

- Applying for Patents

- Testing and Verification

  Testing and verification are important parts of the design process. At all 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.

# References


Khandani, S, *Engineering Design Process*, August 2005.

Dym, G. L., *Engineering Design a Project-based Introduction*, Wiley, 4ed, 2014.

Pahl G., Beitz. W., *Engineering Design A Systematic Approach*, Springer-Verlag, 2007

Ertas, A., Jones, J. C., *The Engineering Design Process*, John Wiley and Sons, New York, 1996.

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