10 Design

Chapter Overview

Design is a core activity of engineering; it transforms amorphous needs and wants into tangible products or defined processes. In this chapter, we will examine a formal design process that is broadly applicable to different industries, disciplines, and projects. This process consists of three phases: [1] the recognition of need, want, or opportunity, [2] the creation of a number of design options, and [3] the selection of an optimal option via assessment. The second and third phases occur in iterative cycles.

As a professional engineer or an engineering organization, it is important to consider four things before involving ourselves in a design project: mission, expertise, resources, and reputation. We will get involved in a project only if [1] the project is aligned with our mission, [2] we are able to add value to the project through our expertise, [3] we have the resources to invest in the project, and [4] our involvement has a desirable impact on our reputation.

Once we have decided to pursue a design project, we will start by gaining an understanding of the need, want, opportunity, or some combination of these three. Needs and wants arise from the community that will be impacted by the product of the design process. Opportunity can arise from "technological push" or "consumer pull", the latter being much more preferable. Once we have recognized the needs, wants, and opportunities, we will gather information from the project stakeholders and develop an understanding of the desired qualities of the engineering solution. There is a tendency in our profession to jump into the creation phase without developing this understanding, which can lead to the creation of products and processes that satisfies our assumptions but not the real stakeholders. The final result of this information gathering phase is the development of a list of objectives and constraints that define the design problem.

During the creation phase, we will generate a list of solutions or ideas that satisfies the con-

straints. If no solution can be found to satisfy all constraints, we may need to relax the less important constraints. During the assessment phase, we will ideally eliminate all solutions except the best one that satisfies the project constraints and optimizes the project objectives. Because different stakeholders may hold conflicting desires, certain trade-offs may be required. One approach to handle the trade-off is to create a single objective as a weighted sum of different objectives associated with the projects. The weights will reflect both our values and the values of the stakeholders. Typically, the two phases occur in iterative fashion. In the beginning, we may create a number of broad design paths and eliminate the obvious "bad" designs. As the process progresses, we will create and assess designs with increasing levels of details.

The design process can be aided with mathematical tools such as linear programming or calculus, with calculations carried out by computers. Here, the design problem is stated mathematically, and a computational algorithm will search for the set of parameters that optimizes the objective function while satisfying the constraints. In addition, the design process is enhanced by prototyping, where designs are tested in normal and extreme conditions. Once an optimal design or a shortlist of designs is selected, it is a good idea for this design or shortlist to be reviewed by those who are concerned with the outcome of the project but are not intimately involved in it. They may introduce perspectives that you have not considered. Finally, fine details such as the drawing of solutions and bill of materials are created, and the design is communicated to the customer and stakeholders.

Design is a fundamental competency of all engineers. It is both logical and intuitive at the same time, and you will become better at design through practice.

Learning Objectives

In this chapter, you will learn about a design process that can be applied to different projects ranging from consumer widget to a process with no tangible result. Specifically, you will:

- learn to determine if an opportunity should be pursued or not;
- learn to sense need/want/opportunity;
- learn to create alternative designs and solutions; and
- learn to select optimal designs and solutions.