2 Axiomatic Design

2.1 Introduction

Axiomatic design is a design theory that was created and popularized by Professor Suh of the Massachusetts Institute of Technology (Suh 1990, 2000). Actually, it is a general design framework, rather than a design theory. As the word “framework” indicates, it can be applied to all design activities. It consists of two axioms. One is the Independence Axiom and the other is the Information Axiom. A good design should satisfy the two axioms while a bad design does not. It is well known that the word “axiom” originates from geometry. An axiom cannot be proved and becomes obsolete when a counterexample is validated. So far, a counterexample has not been found in axiomatic design. Instead, many useful design examples with axioms are validated.

Design is the interplay between “what we want to achieve” and “how we achieve it.” A designer tries to obtain what he/she wants to achieve through appropriate interplay between both sides. The engineering sequence can be classified into four domains as illustrated in Figure 2.1. Customer attributes (CAs) are delineated in the customer domain. In other words, CAs are the customer needs. CAs are transformed into functional requirements (FRs) in the functional domain. FRs are defined by engineering words. This is equivalent to “what we want to achieve.” FRs are satisfied by defining or selecting design parameters (DPs) in the physical domain. Mostly, this procedure is referred to as the design process. Production variables (PVs) are determined from DPs in the same manner. The aspects for the next domain are determined from the relationship between the two domains, and this process is called mapping. A good design process means an efficient mapping process.

Design axioms are defined from common principles for engineering activities as follows:

**Axiom 1: The Independence Axiom**

Maintain the independence of FRs.

*Alternate Statement 1:* An optimal design always maintains the independence of FRs.
Alternate Statement 2: In an acceptable design, DPs and FRs are related in such a way that a specific DP can be adjusted to satisfy its corresponding FR without affecting other functional requirements.

Axiom 2: The Information Axiom

Minimize the information content of the design.

Alternate Statement: The best design is a functionally uncoupled design that has minimum information content.

The axioms may look simple. However, they have significant meanings in engineering. Details of the axioms will be explained later. Axiom 1 is an expression that design engineers know consciously or subconsciously. When we design a complex system, the axiom tells us that a DP should be defined to independently satisfy its corresponding FR. In other words, the FRs of the functional domain in Figure 2.1 should be independently satisfied by DPs of the physical domain. Otherwise, the design is not suitable. When multiple designs are found from Axiom 1, the best one can be chosen based on Axiom 2. That is, the best design has minimum information content that is usually quantified by the probability of success. It also corresponds to the engineering intuition that design engineers usually have in mind. Axiom 2 is related to robust design and it will be explained later. Although the axioms are expressed simply, real application can be very difficult.

As explained earlier, axioms are defined in geometry. As in geometry, theorems and corollaries are derived from axioms (see Appendix 2.A).