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A decision support system for product design in concurrent engineering

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Abstract

Compared with the traditional sequential design method, concurrent engineering is a systematic approach to integrate concurrent design of products and their related processes. One of the key factors to successfully implement concurrent engineering is information technology. In order to design a product and its manufacturing process simultaneously, information on product features, manufacturing requirements, and customer demands must be processed while the design is concurrently going on. There is an increased understanding of the importance of the correct decisions being made at the conceptual design and development stages that involve many complex evaluation and decision-making tasks. In order to promote the efficiency in concurrent product development, appropriate evaluation and decision tools need to be provided. In this paper, the characteristics of fuzzy, multi-stage evaluation and decision making in concurrent product development process are analyzed and a decision support system for product design in concurrent engineering is presented. An example is given to illustrate the application of the system.

Keywords: Decision support systems; Concurrent engineering; Concurrent product development; Fuzzy sets

1. Introduction

The manufacturing environment has dramatically changed in the last few years. Worldwide competition among manufacturers and the development of new manufacturing technologies have contributed to today's competitive situations in manufacturing industries [13]. Such competition has stimulated rapid changes in manufacturing industries, causing a significant shift in how products are designed, manufactured, and delivered. Customers demand products of higher quality, lower price, and better performance in an ever-shorter delivery time. Competition in the marketplace for new products is

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forcing changes in the way product designers and manufacturing engineers develop products. In conventional product development, conceptual design, detailed design, process planning, prototype manufacturing, and testing are considered as sequential processes. Compared with the traditional sequential method, concurrent engineering is a systematic approach to integrate the concurrent design of products and their related processes. Concurrent engineering is intended to stimulate product designers/developers to consider all elements of the product life cycle in the early stage of product development.

In order to improve product quality, lower cost, shorten the product development cycle, and fulfill customers' requirements, concurrent engineering requires product designers to take all the factors involved in the life cycle of a product into consideration. As a result, quite a few related concepts have been proposed such as design for assembly (DFA), design for manufacturability (DFM), design for serviceability (DFS), and design for environment (DFE) [9,11]. Concurrent engineering requires designers to take all stages in the life cycle of a product into account when making decisions. Manufacturing, assembling, maintenance, and environmental protection are typical stages of the life cycle of a product. DFA, DFM, DFS, and DFE reflect different aspects of product design. It is obvious that the over-emphasis of one stage over another may not be a good choice; therefore, it is suggested that designers should take all stages such as DFA, DFM, DFS, and DFE as well as related methods into consideration [12,25].

Concurrent product design stages can be classified into stages such as initiation, DFA, DFM, DFS, and DFE. Careful evaluation and appropriate decisions regarding design alternatives must be made at each stage [25]. From a systems point of view, product design is considered as a process characterized by "design-evaluation-redesign" [13,14,21]. Such an evaluation process is a complicated one for a number of reasons: (1) it is necessary to take all design objectives into account. However, some objectives conflict with one another such as precision versus manufacturing cost, material performance versus material cost, and so forth; (2) in the design stage, especially the early development stage, it is difficult to quantify and weigh design objectives precisely due to lack of information or vague objectives; (3) designers' subjective preference makes the evaluation more complicated. However, proper decisions are needed for product design in concurrent engineering.

To cope with this, utility theory or fuzzy sets theory can be employed to evaluate and select design alternatives. With utility theory, design alternatives can be evaluated if numerical data is available. Since the information available in the early design stage is most likely imprecise and fuzzy, and decision problems in concurrent engineering are generally difficult to define and structure, it is proper to apply the fuzzy sets approach to the process [10]. As mentioned above, all design factors including assembling, manufacturing, and maintenance, which affect the product design in the life cycle of a product, should be taken into account in concurrent design. A concurrent design process can be classified into several stages in which both evaluation and decision are needed. Each stage can be considered as a subsystem for decision making; subsystems together form a multi-stage fuzzy decision system.

Many complex decisions need to be made in the concurrent product development process [27]. As a result, complex concurrent engineering design problems require decision aids such as decision support systems. Given the nature of decision support problems, the research emphasis of decision support systems development has been focused on modeling issues [4]. In this paper, fuzzy sets theory is used to evaluate design alternatives and facilitate decision making. With comprehensive evaluation models based on fuzzy sets theory and dynamic programming, a decision support system is developed in this study to provide support for multi-stage decision making in concurrent engineering design and selecting best design alternatives. The overall objective of this research is to develop a decision support system for helping project managers and design/development engineers in their decision-making activities within a concurrent engineering environment.

2. Fuzzy evaluation

Numerous studies characterize concurrent product design processes as a fuzzy process, especially early