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A group decision-making method based on intuitionistic fuzzy set in the three dimensional concurrent engineering environment: a multi-objective programming approach

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Abstract

This paper proposes a group decision-making process by using multi-objective programming to address three-dimensional concurrent engineering (3D-CE) problems involving product, process and supply chain design. This paper uses opinion of decision makers to evaluate of the candidate suppliers and to determine importance of criteria by considering lack knowledge/information in the early design stages. For identifying impact of the lack knowledge/information on selecting the best configuration of product design, assembly/manufacturing process and suppliers of components, a numerical example is represented for two states of intuitionistic fuzzy and fuzzy. The evaluation showed that the configuration selected for two states are completely different.

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Keywords: New product development; Three-Dimensional Concurrent Engineering; Multi-objective programming model; Intuitionistic fuzzy set.

1. Introduction

NPD process is a series of necessary activities for developing a new product that it is including of the growth of its idea, production and introduction into the market. The product design is one of the most important activities in developing new product. A good design process should guarantee both the fulfilment of customer needs and business goals. So, evaluation of product design plays a critical role in the early phase of product development. It can save both cost and time in product development by decreasing the risk of re-design of new product. It is widely accepted that more than 70% of the total product development costs are committed by decisions taken at the early stages of design [1]. The subject is more important when to know that much information about criteria in the early stages of design is not available or is uncertain.

Today, considering of simultaneous different criteria from diverse areas in the early stages of design is inevitable. Fine [2] introduced the term "Three-Dimensional Concurrent Engineering (3D-CE)" that consider, simultaneously, different aspects of the design, process and supply chain in the early stages of the product development.

Selecting of design alternatives is a multi-criteria decision-making process which involves many factors of both customer needs and business constraints. In the early design stages, evaluation of design alternatives is difficult to precisely express by crisp data because the information available is usually imprecise, incomplete or subjective. So, an effective method to evaluate design alternatives in the early stage of design process is inevitable.

In real life, however, the information of an object corresponding to a fuzzy concept may be incomplete; a decision maker (DM) may have a hesitation or uncertainty about the membership degree. Atanassov [3] introduced the concept of intuitionistic fuzzy set (IFS) to deal with this challenge. Expression of hesitation is particularly helpful for decision makers (DMs) when they need to select suppliers in a highly uncertain supply network such as a design product [4]. An IFS-based

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method can be applied to derive the most appropriate suppliers that its output can be further utilized by a multi-objective optimization model to determine the most appropriate design alternatives.

The paper is organized as follows: section 2 review literature related to 3D-CE. Section 3 describes the basic concepts used in the paper. Section 4 represents the proposed method to choice the best configuration of product design, assembly/manufacturing process and suppliers of components. Section 5 expresses a numerical example to show efficiency of the method. Section 4 represents conclusion and future research.

2. Literature

In the recent years, some papers have argued impact of product design, process and supply chain design on NPD process. Ellram et al. [5] surveyed literature related to mutual fields of 3D-CE (product/process, product/supply chain, and process/supply chain) and done a good review of the 3D-CE. Huang et al. [6] integrated platform product decisions, manufacturing process decisions, and supply sourcing decisions by developing a mathematical model to quantify the relationships among various design decisions. Petersen et al. [7] explained how to integrate suppliers into the new product development process and showed their impacts on process design and supply chain decisions. Fine et al. [8] proposed a goal-programming model to address three-dimensional concurrent engineering (3D-CE) and surveyed relationship between product and supply chain structure. Wang et al. [9] described relation of product characteristics to supply chain strategy and developed an integrated analytic hierarchy process (AHP) and preemptive goal programming (PGP) methodology. Fixon [10] developed a multi-dimensional framework as a coordination mechanism that builds on existing product characteristic such as component commonality, product platforms, and product modularity. Nepal et al. [11] proposed a method based on fuzzy logic to model both product structure and supply chain based on experts` information. Gehin et al. [12] presented a method to support designers in the definition of the product lifecycle scenario, including component lifecycle scenarios, when designing the elements of the structure of the product. Blackhurst et al. [13] used a short network approach to develop the Product Chain Decision Model (PCDM) for considering decisions related to product design and manufacturing process and the impact of such decisions on the supply chain. Ellram and Stanley [14] used the 3D-CE to integrate environmentally responsible manufacturing (ERM) and NPD and surveyed its benefit. Shahrokhi et al. [15] proposed hybrid method by integrating multi-objective programming and fuzzy AHP to address CE problem to select processes and suppliers in an uncertain environment. Shidpour et al. [16] developed a multi-objective linear programming (MOLP) model integrated to TOPSIS method to determine the best configuration product design, assembly process and suppliers by considering qualitative and quantitative criteria in early stages of new product development (NPD) process.

This paper proposes a group decision-making process by using multi-objective programming model to select the best configuration of product design, assembly/manufacturing (A/M) process and suppliers of components. Since in the early design stages much information about criteria is uncertain, we develop a new method based on group decision-making process and intuitionistic fuzzy set. We use opinion of decision makers to construct intuitionistic fuzzy decision matrices by considering lack knowledge/information. These intuitionistic-based decision matrices are used to early evaluate of the candidate supplier and to provide the final set of suppliers as well as to determine importance of criteria. For identifying impact of the lack knowledge / information on selecting the best configuration, a numerical example is represented for two states of intuitionistic fuzzy set and fuzzy set. Results of the evaluation showed that the best configuration for two states is completely different.

3. Background

In this section, we present the basic concepts used in our method.

3.1. Intuitionistic fuzzy sets

Intuitionistic fuzzy sets (IFSs) that are recognized as a generalization of fuzzy set theory is characterized by a membership function and a non-membership function. Let X be a universe of discourse, then a intuitionistic fuzzy set B is defined as:

$$B = \{\langle x, \mu_B(x), \nu_B(x)\rangle | x \in X\} \quad (1)$$

$$0 \le \mu_B(x) + \nu_B(x) \le 1 \quad \forall x \in X \quad (2)$$

where $\mu_B : X \to [0,1]$ and $\nu_B : X \to [0,1]$ are membership and non membership functions, respectively. The hesitation degree is calculated as:

$$\pi_B = 1 - \mu_B(x) - \nu_B(x) \quad (3)$$

If U and V be two intuitionistic fuzzy numbers (IFN), then [3]:

$$U + V = \{\mu_u(x) + \mu_v(x) - \mu_u(x).\mu_v(x), \upsilon_u(x).\upsilon_v(x) \mid x \in X\} \quad (4)$$

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