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A two-phase algorithm for product part change utilizing AHP and PSO

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ABSTRACT

This study presents a two-phase algorithm approach to deal with the issue of product part change, and the issue of supplier selection derived from the former. In the first step, Analytical Hierarchy Process (AHP) was used on expert interview records to select the module in a product that needs to be changed with top priority. In the second step, after changing the module, the supplier selection process, including building a mathematical programming model, was initiated to select the best suppliers using Particle Swarm Optimization (PSO) algorithm. We tried to use this method to maximize the value of product updating so as to extend the product life cycle, under the conditions of limited resource, and keeping the scope of change to a minimum. Finally, we selected a switchboard manufacturer as a case study to test the proposed algorithm.

1. Introduction

At a time when the average product life cycle of a product is getting increasingly short, the significance of product part change is being recognized in stages. To maintain continuous improvement over the product line, including modifications of product weaknesses, introduction of new technologies, improvements over manufacturing processes, this optimization approach not only extends the product life cycles, but also can satisfy the needs of customers and market demand. In other words, in order to remain its product competitiveness, enterprises need a systematic approach to understand and manage the issue of product part change. Following the product part change, the supplier selection issue is another hot topic. In post-change stage, the selection of appropriate suppliers allows products of an enterprise to maintain and enhance its competitiveness in the market.

Previous studies treated related issues in a different way. Once a product was considered for internal part change, it had to go through the supplier selection process for all parts, whether the parts were changed or not. However, in actual practice, when a change of product components is considered, it is not necessary to change or redesign all components because that would set off the problem of re-selection of all suppliers. Taking a notebook computer product as an example, when a model change is needed, it may be because of improved technologies relating to core components (CPU, hard disk, memory body, etc.), leading to change of certain parts necessary in the product, while the rest of the internal parts still follow the original specifications and are obtained from the original suppliers. Therefore, this study determines to look into the supplier selection issue derived from the product part change. Researchers believe that when dealing with the issue of product part change, two questions must be considered. One of them is to identify which components need to be changed with top priority, and the other one is to find appropriate suppliers following the product part change. In other words, when faced with a need to change the product, but only limited resources available, the only way out is to change product parts. Our tasks are to find out which one part (or which group of parts) needs to be changed with top priority, or, from an alternative viewpoint, which one part (or which group of parts) will create the most additional value after the product part change. Furthermore, we need to find the most suitable suppliers for such product part change. By settling these issues over the product part change, it could help an enterprise save on unnecessary costs and increase the success rate of new product marketing.

To solve these two problems effectively, in this study, we have introduced a two-phase algorithm model to deal with the issue of product part change, and the issue of supplier selection derived from the former. Our problem-solving approach is based on AHP and PSO. Firstly, AHP analysis over expert interview records is conducted to find out which module in a selected product has to be changed with top priority. Secondly, the results of our analysis are optimized with PSO to find the most suitable supplier in line with such change. To verify the problem-solving method proposed in this study, a switchboard manufacturer is chosen for our experiment. The company's existing product line is analyzed to pick out product parts that need to be changed. By the introduction of the two-phase algorithm model, we hope to create additional values for their product after such change of product parts. Then, we try

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to find the best supplier following the change of product parts, in order to make the whole assessment model more systematic.

This study is organized in the following manner: the literature review is presented in Section 2 for understanding the issues related to product part change. Our two-phase algorithm model is introduced in Section 3. An actual case of manufactured product and related experimental results are provided in Section 4. Finally, some of the conclusions of the study are described in Section 5.

2. Literature review

In view of demands for continuous improvement, and needs for customer-oriented manufacturing environment, changes of product specs throughout the life cycle of a product are becoming quite commonplace. This kind of change is inevitable and also necessary in order to extend the product life. Many discussions by scholars and engineers have focused on the product configuration changes, dealing with the issues of management of product part change, engineering changes and design changes. In general the content of engineering change can be divided into two sub-categories, namely, design change and engineering change. The scope of engineering change involves small numbers of relevant units that belong to the same product, such as process change or change of product materials in the manufacturing process, but the changes mainly stem from the need for product quality upgrade. However, the design change relates to the architecture of a product. The content of such product change includes partial re-designing of a product or replacing of certain components for a product.

Barzizza (2001) believes that changes in market competition and consumption patterns often set a trend of increasingly short product life cycle, giving rise to frequent change of product configuration and change of product components. As Li, Chen, Huang, and Zhong (2006) mentioned, product configuration is more complicated than other issues during the manufacturing process, thus it needs a systematic and effective decision-making system to solve the problems in a rapid manner. Rouibah and Caskey (2003) points out that by effective handling of product part change during its product life cycle could allow an enterprise to lower its production costs, shorten development time, and improve its product quality so as to enhance its competitive edge on the market. Jonghoon and Lee (2002) refer to the fact that the model design of a product often has to go through frequent modifications in the production process. Once parts change is made, it could affect subsequent manufacturing processes, as well as related production costs and time. Wright (1997) indicates that the product configuration is a special design activity. The designers have to select components with given component properties, as well as the assembly of components in accordance with the customers' needs.

Because the effect of product part change and the scope of change are very extensive, an efficient method or system is needed to solve these issues. Wang and Che (2007a),Wang and Che (2007b) proposes a method to process product part change of TFT-LCD, using the fuzzy theory, T-score technology, and genetic algorithms, so as to select suitable suppliers for each component after the design change. Zhang, Wang, Wan, and Zhong (2005) propose the application of knowledge management and configuration-oriented modeling to integrate the product information and to manage complex product-related matters. Wang and Liu (2005) classify the restrictions for re-assembly of component into two types: (i) restrictions on pure re-assembly, and (ii) restrictions on complex re-assembly. A heuristic algorithm is used to develop the best combination policy for re-assembly of components. Wang et al. (2008) utilizes value engineering, fuzzy theory, and genetic algorithms to tackle the issue of supplier selection following the product part change.

From the above-mentioned literature, in view of increasingly short product life cycle, we can see that product part change is inevitable. For example, the product life cycle of today's notebook computers and mobile phones may be only about six months. The following task of supplier selection is also a hot issue. Therefore, the question on how to establish a systematic way to deal with the whole change process in an efficient and prompt manner has become a common topic for many research works. However, when dealing with the issue of supplier selection that follows a product part change, most of the previous studies had assumed that all components of the products need to be changed, but this study rejects the previous assumption. The previous studies failed to meet the actual demand in the real world, thus we propose a two-phase algorithm model to deal with product part change and its related selection of component suppliers. The problem-solving method is based on AHP and PSO.

3. Proposed two-phase algorithm

The study can be separated into two parts. The first part is to use AHP to confirm that some components in a product need to be changed, in order to meet the minimum customer requirements for a product. In other words, the product needs to be able to maintain its basic operations and functions. Therefore, expert interviews are used to analyze the product and to find out which module has caused most frequent failures, and also to confirm which module change could create the greatest benefits under limited resources available. The second part follows the product part change, which is to set up the parameters for developing a supplier selection model, and to develop an optimization algorithm based on PSO, hoping to utilize the outstanding performance of PSO to help identify the best supplier package and the allocation amount in quick and accurate manner. This information will be given to policy makers for their reference use in decision making. The structure of this study is shown in Fig. 1.

3.1. Analytic hierarchy process

AHP is a multi-attribute decision-making model (MADM) (Srdjevic, 2005) proposed by Saaty (1980). Since this method has the advantages of structural integrity, simple theory, and easy operation, it is often used in situations with uncertainty and problems involving multiple assessment criteria (Scholl, Manthey, Helm, & Steiner, 2005). for policy makers, the hierarchical structure can put the problem that needs to be solved into proper perspective, but when it is faced with "selection of appropriate policy," the assessment of various alternatives shall be based on certain benchmarks in order to determine the priorities and advantages of alternatives, and then to pick out the most suitable policy. AHP provides a framework for analysis by cutting complex and non-structural circumstances into "hierarchical" moments. Each moment is given subjective value for its importance, and these values are then added to determine the extent of advantage that can be derived from these moments, and it will also be used as moment weights when analyzing the problem.

Saaty (1990) mentioned that AHP is a powerful auxiliary tool for generating set of alternatives, choosing best policy alternatives, and determining requirements for dealing with 12 types of problems. Önüt and Soner (2008) used AHP to generate relative weight, and in the selection of factory site. Lee, Chen, and Chang (2006) used AHP to assess the performance in order to make the performance evaluation of IT manufacturing sector more convincing and standardized. Feng, Chen, and Jiang (2005) used AHP for selection of supplier groups. Chiang (2005) believed that AHP is a dynamic problem-solving method. It can be effectively used to