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Developing a grey-based decision-making model for supplier selection

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ABSTRACT

The purpose of this study is to develop a decision making model based on the grey relational analysis for supplier selection. Using a multi-criteria decision making approach, the grey system theory has been used to capture the complexity inherent in supplier selection process. In order to enhance the effectiveness of the proposed methodology, an integrated, two-phase model is proposed which integrates the fuzzy pairwise comparison with a grey relational analysis. In the first phase, the proposed model utilises the fuzzy pairwise comparisons technique to tackle some of the limitations in the current grey methodology. In the second phase, a method is proposed to mitigate the bias judgment and inconsistency in pairwise comparisons application in order to improve the results of the first phase. To validate the capability of the proposed model and clarify the details, suppliers of six products from a case study in the auto industry are ranked based on the proposed model, and the results are compared with outcome of the recent grey model in the literature, and the managers' ranking. The findings suggest that the proposed model provides more consistent and reliable results which are in line with managers' ranking. Implications of the study to the theory and practice and future research have been outlined.

1. Introduction

Supplier selection is widely considered to be one of the most important responsibilities of management. Having different criteria including conflicting criteria such as quality and price can create more complexity to the supplier selection decision, which is a multi-criteria decision making (MCDM) problem (Bevilacqua and Petroni, 2002). Ho et al. (2010) performed a comprehensive literature review for supplier selection and provided a classification of applied methodologies.

While there is a rich body of knowledge in supplier selection in term of the methodological approach, the effectiveness of these techniques are very limited in situation where both complete and incomplete information is present for decision making.

Deng (1982) developed the grey system theory by focusing on resolving problems with uncertainty or systems with incomplete information. Grey relational analysis (GRA) is part of grey system theory, which is suitable for solving problems with complicated interrelationships between multiple factors and variables (Moraṅ, 2006). The advantages of the GRA over traditional tools in decision making and supplier selection is related to its ability to capture, process, and integrate uncertainty in the decision making process. While several tools and methodologies such as probabilistic analysis, stochastic programming, and chance-constraint programming have been developed to address uncertainty (e.g., Kasilingam and Lee, 1996; Li and Zabinsky, 2001; Bollapragada et al., 2004; Berger and Zeng, 2006; Gutierrez and Kouvelis, 1995, Ruiz-Torres and Mahnoodi, 2007; Velarde and Laguna, 2004; Yang et al., 2007), they are not capable of handling complex problems involving both complete and incomplete information. Since GRA uses original data, the results are more relevant to practice. For these reasons, GRA has been recommended as one the best methods to be used in making decisions in the business environment (Tong and Wang, 2000; Hsu et al., 2000; Wu, 2002).

Although several decision making models have been developed based on grey relational analysis for supplier selections (Moraṅ, 2006; Li et al., 2007, Olson and Wu, 2006; Tseng, 2009), some of the models' limitations and drawbacks are present in the methodology and design structure such as weight assignment and computations, electing information from decision makers and creating a bias judgment situation. Moreover, due to the dependence of the measurement of each alternative on the other alternatives, the ranking of alternatives could change if new alternatives are added or old ones deleted. This is not part of the consideration of most of methods. We aim to fill these gaps in the literature through developing a grey-based method for supplier selection. As such, we contribute to both decision making

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theory (through resolving the inconsistencies in the existing methodologies) as well as practice (by emphasising supplier selection as one of the core management practices).

In this paper, a two-phase methodology is proposed in order to enhance the effectiveness of the current grey model application in the literature for supplier selection (Li et al., 2007). The drawbacks of the current grey model are discussed in detail. In phase one, a solution is proposed based on a fuzzy pairwise comparisons approach to enhance the weight assignment efficiency and aggregation of different decision makers' preferences. In phase 2, the inherent issues of pairwise comparisons such as bias judgment and inconsistency are discussed and a solution is proposed to enhance the accuracy of the solution developed in the phase 1. To demonstrate the sequence of the processes and improvement achieved in the proposed model, suppliers of a case study in the automotive industry are ranked based on both models (recent model in the literature and the proposed model), and the results are compared with the managers' ranking. A statistical analysis for the validation process shows that the performance of proposed model is significantly higher in comparison with the recent model in the literature.

In summary, we discuss the drawbacks of the current grey model and propose solutions accordingly. We aim at enhancing the body of knowledge by proposing a decision making model; therefore, we contribute both to the theory and practice.

2. Case study

We used the data from a company in the automotive industry to apply the proposed model and recent model for further analysis and discussion. This company manages parts preparation for a car manufacturer, and it is responsible for dealing with suppliers where it handles quality evaluation, planning and scheduling for parts delivery. In this study, data from suppliers producing the products (plastic parts) was used. We considered suppliers of six products. The defined criteria are delivery, quality, price, transportation cost, technology, and production system flexibility. More information about these criteria is provided below:

Delivery: Quantity and delay in delivery are the two parameters of suppliers' performance selected since they have a major impact on the total cost of production. Poor performance in these areas can increase inventory and warehousing cost, and create disorder in buyer scheduling. Therefore, punctuality and quantity of the products delivered are indicators of supplier performance.

Quality: To measure supplier's quality performance, the quality of the suppliers' product is evaluated.

Transportation cost: The distance of a supplier from its buyer can have a great impact on the total cost.

Price: As one of the main and tangible factors, it is considered in the modelling.

Technology: The product technology level such as design, functionality, and materials of a supplier is a key element used by the buyer. Since new markets have strong effects on supplier products, more advanced technology can provide better quality, and enhance customer satisfaction.

Production System flexibility: The supplier's ability to be flexible in production is an important factor for the buyer. Having an effective scheduling system and an flexible production system to produce different products are important to the buyer.

There are several studies about the most important criteria in the literature in supplier selection and evaluation (Ellram, 1990; Kannen and Tan, 2003). Although the results and rank of preferred criteria varied based on the particular industry, the selected criteria in our study have high priority in most industries.

3. Grey relational analysis: recent model

A very brief review of grey relational analysis is presented and the recent model in the literature is implemented for the case study data. Our objective here is to implement and examine the robustness of the recent model in grey analysis. This enables us to assess the effectiveness of the proposed model in comparison with the existing grey model for supplier selection in the literature.

3.1. Grey relational analysis

A summary of the GRA steps is as follows: The first step of GRA is to make the performance of alternatives comparable by sequence, which is called grey relational generating. As a result, a reference sequence is defined for comparison. The next step is to compute the grey relational coefficients between all comparability sequences and the reference sequence. At the end of this process, the grey relational grade between the reference sequence and every comparability sequence is calculated. If a comparability sequence translated from an alternative has the highest grey relational grade between the reference sequence and itself, that alternative will be the best choice (Kuo et al., 2008).

A grey set G of x where $x \in [0,1]$ has two parts, lower level membership $\underline{\mu_G}(x)$ and upper level membership $\overline{\mu_G}(x)$, shown as $\otimes G = [\underline{G},\overline{G}] = [\underline{\mu_G}(x),\overline{\mu_G}(x)]$. Grey number operation is an operation defined on sets of intervals, rather than real numbers. A couple of the definitions are as shown below:

$$\otimes G1 + \otimes G2 = [\underline{G_1} + \underline{G_2}, \overline{G_1} + \overline{G_2}] \quad (1)$$

$$\otimes G1 - \otimes G2 = [\underline{G_1} - \overline{G_2}, \overline{G_1} - \underline{G_2}] \quad (2)$$

More details (proof and other definitions) can be found in Deng (1982) and Li et al. (2007).

In order to demonstrate how the proposed model performs, and compare it to the recent model in the literature (Li et al., 2007), we implemented both models for suppliers of a product as described in the case study (Section 2)

3.2. Grey implementation: the recent approach

The recent model in the literature for supplier selection by grey approach (Li et al., 2007) is implemented step by step for one of the products (N) of the case study to clarify its drawbacks. In the validation section, all products will be taken into consideration for both models (the recent and proposed model).

The criterion weights and ratings of suppliers are considered as linguistic variables based on the recent grey method. These linguistic variables are expressed in grey numbers as shown in Table 1. The criteria ratings $\otimes G$ which are expressed in grey numbers are shown in Table 2.

The case study data was applied through the procedure summarised in the following steps:

Table 1
The scale of criteria weights $\otimes$W-designed based on the recent model.

Scale	$\otimes$W
Very low (VL)	[0.0, 0.1]
Low (L)	[0.1, 0.3]
Medium low (ML)	[0.3, 0.4]
Medium (M)	[0.4, 0.5]
Medium high (MH)	[0.5, 0.6]
High (H)	[0.6, 0.9]
Very high (VH)	[0.9, 1.0]