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Novel fuzzy hybrid multi-criteria group decision making approaches for the strategic supplier selection problem

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ABSTRACT

The current complexity of supply chains (SC) activities requires the need for coordination between supply chains partners to maximize the efficiency. Considered by practitioners as one of the main SC coordination problems, this paper considers the strategic supplier selection problem. Fuzzy set is used in order to address the imprecision of supply chain partners in formulating the preferences values of various selection criteria. The problem is formulated as a multi-stakeholder multi-criteria (MSMC) decision making problem and solved using two novel approaches. The first hybrid approach combines the fuzzy consensus-based possibility measure and fuzzy TOPSIS method. The second hybrid approach combines the fuzzy consensus-based neat OWA and goal programming model where, the inclusion and participation of stakeholders in the decision-making process is explicit. For each approach, the correlation coefficient and standard deviation (CCSD) based objective weight determination model is used to compute the criteria weights. To demonstrate the applicability of the proposed approaches, a simple example of strategic supplier selection problem is presented and the numerical results analyzed. Moreover, for each approach, the deviations between individual solutions and collective solution are evaluated using the Levenshtein distance. Finally, the advantages and disadvantages of each approach are listed.

1. Introduction

In aggressively competitive international industrial and economic environments, supply chain coordination (SCC) can be seen as one of the active research topics in production and operation management (POM). The literature is very rich with studies dedicated to SCC such as production and distribution coordination (Kim, Hong, & Lee, 2005), procurement and production coordination (Munson & Rosenblatt, 2001), production and inventory coordination (Grubbstrm & Wang, 2003) and distribution and inventory coordination (Yokoyama, 2002). According to Malone and Crowston (1994) *"coordination is the act of managing dependencies between entities and the joint effort of entities working together towards mutually defined goals"*.

Several researchers (Arshinder & Deshmukh, 2008; Arshinder, Kanda, & Deshmukh, 2011; Cárdenas-Barrón, 2007; Piplani & Fu, 2005, etc.) realized the need to develop new approaches for supply chain coordination problems. Some existing approaches shared costs and price information (Yao & Chiou, 2004), where other have set up networks of inventory management information systems (Verwijmeren, van der Vlist, & van Donselaar, 1996) to coordinate efficiently supply chain activities.

More and more, supply chain stakeholders collectively make a number of tactical and strategic decisions to achieve mutually defined goals. Some of these decisions are for selection problems *i.e.,* selection of machine tools, selection of supply chain partners, selection of suppliers–suppliers, selection of transportation system, etc., which require the consideration of several evaluation criteria. Due to this reason, the supply chain coordination problem is considered as a multi-stakeholder multi-criteria (MSMC) decision making problem in this research work.

The strategic selection problem, considered as one of the main SCC problems by practitioners, is addressed by Singh and Benyoucef (2013). The problem is formulated as a fuzzy MSMC decision making problem and solved using *fuzzy consensus-based neat OWA and technique for order performance by similarity to ideal solution (TOPSIS) methodology*. Moreover, correlation coefficient and standard deviation (CCSD) based objective weight determination model is used to compute the weights of the criteria for fuzzy TOPSIS. However, for the problem of similar nature, Igoulalene and Benyoucef (2013a, 2013b, 2014) proposed new hybrid approaches. More specifically, Igoulalene and Benyoucef (2013a) developed a new *fuzzy consensus-based possibility measure and goal program-*

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ming approach for manufacturing strategy selection problem. Igoulalene and Benyoucef (2013b) presented a *new fuzzy consensus-based neat OWA and goal programming approach* for information system selection problem. Recently, Igoulalene and Benyoucef (2014) proposed a new *fuzzy consensus-based possibility measure and TOPSIS approach* dedicated to the plant selection problem.

This paper presents two *new* fuzzy hybrid approaches for the *strategic supplier selection* problem. It is formulated as a fuzzy MSMC decision making problem. The first approach combines the *fuzzy consensus-based possibility measure and TOPSIS method*. Where the second approach combines the *fuzzy consensus-based neat OWA and goal programming model*. For each approach, we use a CCSD model to compute the criteria weights. To demonstrate the applicability of the proposed approaches, a simple example, of a strategic supplier selection problem, is used and the numerical results are analyzed. Furthermore, for each approach, we show how the Levenshtein distance is used to compute the deviations between individual solutions and collective solution. In order to help potentials users, we highlight the advantages and disadvantages of each approach.

The rest of the paper is organized as follows: Section 2 provides a brief literature review on strategic supplier selection, consensus based group decision making, fuzzy TOPSIS applications and goal programming applications. Section 3 describes the problem environment. Section 4 presents the theoretical background. Section 5 details the two proposed hybrid approaches. Section 6 illustrates the applicability of the two approaches using a simple example of supplier selection problem. Section 7 concludes the paper with some future research directions.

2. Literature review

Nowadays, from the companies' point of view, customers turn out to be increasingly influential in terms of purchasing and bargaining power. In this scenario, companies have to cooperate or interact with suppliers to maximize the productivity at the smallest cost while satisfying customer requirements in terms of quality, price, delivery, innovation, flexibility, risk, etc. Further, the participation of a large number of stakeholders regarding negotiations, financing, distribution, procurement and product quality assurance at the source implies the significance and long lasting impacts of suppliers selection on sourcing. As a result, strategic supplier selection approaches require collaboration in sharing costs, benefits, expertise, and in attempting to understand one another's strength and weaknesses, which in turn leads to single sourcing and long-term partnerships (Bhutta & Huq, 2002). In the following, we concentrate our efforts to review some recent works according to the four aspects 1 – strategic supplier selection, 2 – consensus based group decision making, 3 – fuzzy TOPSIS applications and 4 – fuzzy goal programming applications respectively.

2.1. Strategic supplier selection

During recent years, the supplier selection process has received considerable attention in the supply chain management literature. A supplier selection decision inherently is a multi-criteria decision making (MCDM) problem and of strategic importance to companies. The nature of this decision usually is complex and unstructured. Many researchers proposed several approaches to deal with this selection problem. Most recent published studies use techniques and methods such as analytic hierarchy process (AHP), analytic network process (ANP), artificial intelligence (AI), TOPSIS, potential support vector machine (P-SVM), preference programming (PP), fuzzy set, case-based reasoning (CBR), mathematical programming (MP),. . ., etc.

You, You, Liu, and Zhen (2015) proposed an extended VIKOR method for the group multi-criteria supplier selection problem with interval 2-tuple linguistic information (ITL-VICOR). By using three realistic supplier selection examples, the feasibility and practicability of the proposed ITL-VIKOR method are demonstrated and comparisons with the existing approaches are realized. The experimental results showed that the ITL-VIKOR method is more suitable and effective to handle the supplier selection problem under vague, uncertain and incomplete information environment.

Yu and Wong (2015) developed an agent-based negotiation model to automate the supplier selection process involving a bundle of products with synergy effect. The negotiation proposal, negotiation protocol, negotiation strategies, and decision making methods involving in the negotiation model are elaborated for the multi-product supplier selection environment. The purchasing company and suppliers can reach agreements on the details of products simultaneously and exploit the synergy effect between products. Finally, to demonstrate the applicability d and effectiveness of the negotiation model for multi-product supplier selection, illustrative examples are conducted.

Rezaei, Fahim, and Tavasszy (2014) investigated the supplier selection problem in the airline retail industry and discussed a number of issues that make airline retail complex and distinguish it from conventional retail. They developed a two-phased methodology. In the first phase, a conjunctive screening method is used, which aims to reduce the initial set of potential suppliers prior to the comprehensive final choice phase. In the second phase, a fuzzy AHP is used, in which suppliers are evaluated against the main criteria and sub-criteria. A real life case study from the Royal Dutch Airlines (KLM) is presented and the numerical results are discussed extensively.

Ware, Singh, and Banwet (2014) developed a mixed-integer non-linear program (MINLP) to address the supplier selection problem. To validate the proposed MINLP data are generated randomly. To demonstrate the efficiency of the proposed MINLP, several numerical results are provided using LINGO.

Kar (2014) proposed an approach for group decision support for the supplier selection problem. The approach integrates fuzzy AHP for group decision making and fuzzy GP for discriminant analysis. In the first step, the fuzzy AHP with the geometric mean method are used to prioritize and aggregate the preferences of the group of decision makers. Then using the ordinal consensus improvement approach consensus is realized to aggregate priorities. In the second step, the consensual priorities of the group of decision makers are integrated with fuzzy goal programming for discriminant analysis to provide predictive decision support. The numerical results showed through a case study how the developed approach is more effective compared to an existing approach for group decision making using only AHP.

Chai, Liu, and Ngai (2013) presented a rich literature review on research works published from 2008 to 2012 on the application of decision making techniques for supplier selection problem. They selected, reviewed and classified 123 journal articles in four aspects including decision problems, decision makers, decision environments, and decision approaches. Under such classification, 26 decision making techniques are identified from three perspectives: (1) MCDM techniques, (2) MP techniques, and (3) AI techniques. Furthermore, they provided some recommendations for future concerning the application of decision making techniques in supplier selection.

Arikan (2013) addressed the multiple sourcing supplier selection problem as a multi-objective linear programming problem where three objective functions are considered respectively minimization of costs, maximization of quality and maximization of on-time delivery. He developed a fuzzy mathematical model and