An Improved Hybrid Model for Order Quantity Allocation and Supplier Risk Exposure

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ABSTRACT
This paper investigates the risk exposure arising from the supplier evaluation criteria of cost, quality, delivery, and flexibility. An integrated method of Fuzzy Decision Making Trial and Evaluation Laboratory (FDEMATEL) and Fuzzy Analytical Network Process (FANP), which is able to address interaction and feedback effects between the criteria and subjectivity in the decision rating, is used to generate the importance weights of the objectives for a network relationship problem. Different weights of the objectives are then incorporated into a Fuzzy Multi-Objective Programming (FMOP) model for determining the optimal order quantity allocated to the suppliers. The proposed method provides a more realistic decision making scenario by considering different importance weights of criteria from individual priority. Therefore, it provides a practical method to solve the real world problems. The validity of the proposed method is illustrated by a case study from a trading company.

KEYWORDS
Fuzzy Analytic Network Process (FANP), Fuzzy Decision Making Trial and Evaluation Laboratory (FDEMATEL), Fuzzy Multi-Objective Programming (FMOP), Quality Allocation, Supplier Risk Assessment

1. INTRODUCTION
Evidence suggests that more than 60 percent of a firm’s total expenses are related to purchases in raw materials and/or component parts and services (Krajewski and Ritzman, 2002). These purchases are important for firms in the manufacturing and high-technology industries (Ghodsypour and O’Brien, 1988; Weber et al., 1991). Reliance on third party suppliers and merchants exposes the firm to risks, i.e., supply chain risk. Supply chain risk can be classified as either operational or disruption risks (Tang, 2006) or internal risks and external risks (Goh et al., 2007). Operational risks are associated with the uncertainties in the coordination of supply and demand, while disruption risks refer to the major disruption incidents such as tsunamis, terrorist attacks, and economic crises (Tang, 2006). Internal risks arise within a supply chain network while external risks exist between a supply chain network and the environment (Goh et al., 2007). The more a firm relies on external sources, the more it is exposed to the outcomes of the other firms and the environment (Kull and Talluri, 2008). Supply chain risk is usually assessed based on how they impact the performance variables such as cost, quality, delivery lead time, health, safety (Norrman and Jansson, 2004), information and cash flow (Chopra and Sodhi, 2004). In a broader context, supply chain risk is associated with equity risk.
and may have a negative impact on the long-term stock price and financial performance of a firm (Hendricks and Singhal, 2005).

One way to mitigate the risk in the supply chain is to manage the supplier evaluation and selection process. Selecting the appropriate suppliers can lower the risk of a supply chain disruption as wastage is reduced, quality failure is minimized, and lead times and flexibility are improved (Kumar et al., 2004; Phusavat et al., 2015). Therefore, it is necessary to evaluate suppliers along the supply chain in terms of their risk exposures.

As the evaluation of risks involves capturing data across various stages in the supply chain, there is a need to select a method that can adapt to the supplier assessment process. There is also a need to allow the flexibility of using quantitative and qualitative measures that may interact and possess feedback effects. In doing so, one can holistically represent the risk exposure of suppliers.

In practice, feedback and interactions between the criteria are common (Tzeng et al., 2007). Risks can be influenced by these interrelationships through factors such as flexibility, economic environment and supplier confidence level in the delivery process (Kull and Talluri, 2008; Wu et al., 2010). For instance, high quality products lead to high purchasing cost, or higher levels of supplier flexibility increase the supplier’s standing as a dominant player in the industry. To obtain an accurate supplier analysis for achieving maximum profit, it is essential to consider all the network effects, both independent and dependent relationships among the criteria in the evaluation process. Techniques such as the Decision Making Trial and Evaluation Laboratory (DEMATEL) as proposed by Gabus and Fontela (1972) and the Analytic Network Process (ANP) by Saaty (1996) have been developed to handle problems with the inter-related factors.

However, only a few papers incorporated risk in the assessment in the literature (Hsu et al., 2013). In most studies on supply chain risk, supplier evaluation objectives are considered independently along with a set of constraints (see Kull and Talluri, 2008; Wu et al., 2010; Wu et al., 2013). If the factors are interdependent, one has to consider the method of integrating the quantitative and qualitative data. In some cases, the context drives the choice of the method. Using single method may require decision makers to restrict their preferences, even to alter their data collection procedure.

On the other hand, a variety of risk measures may be considered in supplier selection. This increases the complexity and relationships of the supply chain risk factors. By understanding the variety and interconnected supply chain risks, effective mitigation strategies can be implemented (Chopra and Sodhi, 2004). Therefore, the interaction and interdependence relationships among the evaluation criteria are crucial for the evaluation process. This study focuses on four aspects of risk exposure, i.e., cost, quality, delivery and flexibility, in supplier evaluation for the following reasons: 1) All of these risk exposure criteria are the main competitive priorities in the purchasing function (Krause et al., 2001), 2) They persist in the supply chain literature (Tang and Tomlin, 2008), and 3) They are often cited as root causes of uncertainty from the perspective of customer demand (Trkman and McCormack, 2009). Table 1 shows the competitive priority criteria given by Krause et al. (2001). We relate the supply risk exposures to each purchasing criterion.

In the literature of the supplier evaluation based on risk and uncertainty, various methods have been proposed. For example, Talluri et al. (2006) proposed a chance constrained data envelopment analysis (CCDEA) approach for vendor selection under supply risk. Ross et al. (in press) extended the CCDEA approach in evaluating the supplier performance risk by considering the buyer’s information sharing factors and on-time delivery disruption scenarios. However, CCDEA may cause sub-optimal solutions since only a single objective function was considered (Wu et al., 2013). Therefore, DEA approaches are still limited when evaluating the imprecise and ambiguity of the risk measures. To improve the performance of dealing with imprecise and vague data, a conceptual framework such as the fuzzy set analysis proposed by Zadeh (1965) has been employed in risk evaluation (Kangari...