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A mixed-integer non-linear program to model dynamic supplier selection problem

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ABSTRACT

In a highly competitive scenario, suppliers play a vital role in making a business organization successful. Business of any organization is continuous process and therefore the supplier selection is also dynamic in nature. This is quite natural as the organization's demand; supplier's capacity, quality level, lead time, unit part cost and fixed transportation cost of supplier varies with time. Therefore, supplier identified for one period may not necessarily be same for the next period to supply the same set of parts. Hence, the supplier selection problem is highly dynamic in real practice. In this paper, a mixed-integer non-linear program (MINLP) is developed to address the dynamic supplier selection problem (DSSP). To validate the proposed MINLP data are generated randomly. A numerical illustration is also provided to demonstrate the proposed MINLP using LINGO.

1. Introduction

In today's highly competitive and dynamic environment, business organizations are forced to optimize their business operations to meet the increasing customer's demand within due time keeping desired quality level in minimum cost. For any organization to remain competitive, it has to work closely with its supply chain partners i.e. suppliers. Thus, now-a-days supplier plays an important role in an organization for timely manufacturing finished good products which is directly shipped to the markets. Hence, the selection of suppliers becomes an important aspect of any business organization. In any supplier selection process, generally six main decision processes takes place viz: (1) make or buy, (2) supplier selection, (3) contract negotiation, (4) design collaboration, (5) procurement, and (6) sourcing analysis. Of these six decision process, supplier selection is one of the most vital and crucial decision which not only responsible of supplying the parts but also responsible in keeping the organization in a competitive mode. Selection of suppliers becomes more important when an organization has to select the supplier for more than one period and when the supplier's capacity, their quality level, lead time, and various cost parameters also vary. Hence, the supplier selection for multi-period, multi-parts, and multi-source is a widely occurring phenomena in a large business organization while keeping the desired quality level and least lead time. In literature it is popularly known as *Dynamic Supplier Selection Problem (DSSP)*.

In a DSSP, a set of suppliers is chosen for each period from the pool of suppliers. The main issues of DSSP are: (1) *Which part to be procured (or ordered) from which supplier(s)*? (2) *In what quantities these parts to be procured.* (3) *In which period the supplier will be selected to supply these parts*. DSSP differs from a *Traditional Supplier Selection Problem* (TSSP) where all the suppliers can fully meet the organisations' requests in terms of quantity, quality, delivery, etc. The only decision concerns the identification of the best supplier or the ranking of the suppliers. Whereas in DSSP none of the suppliers is able to satisfy the organizations' total demand due to various limitations at the supplier's end such as its capacity, quality level, delivery time, price, etc. In these circumstances the DSSP is threefold: *Supplier Selection*, *Part Quantity* and *Time Period*. Order quantities of the part and supplier choice are closely interrelated. Incorporating the decision to schedule orders over time with the supplier selection significantly reduces cost for entire planning horizon. On considering a multi-period horizon, one or more than one suppliers could be selected in each period to meet the organisation's requirement (or demand). The problem of selecting suitable suppliers is not a new problem and a great number of conceptual and empirical works have been published. Most of the models available in the literature of supplier selection deal with the case of single-period and ranking of the best supplier among the existing suppliers which is capable of meeting all the demand. In this paper, authors made an attempt to address the supplier selection in multi-period for multi-parts from multi-source. Hence, the paper propose MINLP to model DSSP.

The remainder of the paper is organized as follows: In Section 2, past work related to supplier selection problem is reviewed. In Section 3, DSSP is defined. Section 4 presents the MINLP formulation of DSSP. To demonstrate the MINLP, two illustrative examples are provided in Section 5 followed by conclusion and the directions for future research.

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2. Related work

Plethora of literatures on supplier selection or vendor selection problems are available whereas the DSSP considering multi-period multi-parts multi-source is not adequately discussed in the past. For the detailed review on supplier selection problems papers by Weber, Current, and Benton (1991), Boer, Wegen, and Telgen (1998), Wadhwa and Ravindran (2007), Chan & Chan (2004) and Ware, Singh, and Banwet (2012) can be referred. In past several methodologies have been proposed for the supplier selection problem but many of them only discusses the case of TSSP. In the TSSP, suppliers are ranked and the top ranked supplier is supposed to be same throughout the entire planning horizon unless it is re-ranked or re-assessed. The past work on supplier selection is broadly classified into two categories viz. (1) Quantitative models and (2) Qualitative models. In the category (1) numerous quantitative models such as linear programming, mixed-integer linear program, mixed-integer non-linear program, dynamic programming, multi-objective programming (Amin, Razmi, & Zhang, 2011; Dempsey 1978; Shipley, Colin, & Scott, 1991; Weber and John, 1993; Feng, Wang, & Wang, 2001; Ghodsypour & O'Brien, 2001; Masella & Rangone, 2000; Ghodsypour & O'Brien, 1998; Guneri, Yucel, & Ayyildiz, 2009, 1998; Weber and John, 1993; Demirtas & Ustun 2008; Ozgen, Onut, Gulsun, Tuzkaya, & Tuzkya, 2006; Razmi & Rafiei, 2010; Sanayei, Mousavi, Abdi, & Mohaghar, 2008; Thomas & Srinivas, 2008). Masella and Rangone (2000) proposed four different vendor selection systems depending on the timeframe (short term versus long term) and on the content (logistic versus strategic) of the co-operative customer/supplier relationships. Ding, Benyoucef, and Xie (2005) presented a Genetic Algorithm (GA) based optimization methodology for the supplier selection. Cakravastia and Takahashi (2004) proposed a multi-objective model to the process of supplier selection and negotiation that considers the effect of these decisions on the manufacturing plan. Liu, Ding, and Lall (2003) used data envelopment analysis (DEA) to compare the performance evaluation of different supplier for best selection. Aksoy and Ozturk (2011) works on supplier selection and performance evaluation in just-in-time production environments. Fuzzy DEMATEL method used for developing supplier selection criteria by Chang, Chang, and Wu (2011).

Wang and Chin (2008) used the advantages of Analytical Hierarchical Process (AHP) and preemptive goal programming to incorporate both quantitative and qualitative factor in supplier selection problem. For partner selection criteria in strategic alliances is explained by Wu, Shih, and Chan (2009) using the analytic network process. Application of fuzzy network process for supplier selection in a manufacturing organization discussed by Vinod, Ramiya, and Gautham (2011).

Similarly, in the category (2) many qualitative models such as AHP (Saaty, 1980, 1990; Narasimhan, 1983; Nydik & Hill, 1992), Fuzzy-AHP and weighted point method (Timmerman, 1986), matrix approach (Gregory, 1986), vendor performance matrix approach (Soukup, 1987), vendor profile analysis (Thompson, 1990), Analytical Network Process (ANP) (Bayazit, 2006; Chia-Wei and Allen, 2009; Demirtas & Ustun, 2009; Gencer and Gurpinar, 2007), TOPSIS and Fuzzy-TOPSIS (Boran, Genc, Kurt, & Diyar 2009; Shahanaghi & Yazdian, 2009; Wang, Cheng, & Chen, 2009;Kelmenis & Askounis, 2010) have been proposed by various researchers in the past to solve TSSP. Ghodsypour and O'Brine (1998) proposed integration of an AHP and linear programming to consider both tangible and intangible factors in selecting the best suppliers. Chan and Chan (2004) developed a model for TSSP applying AHP and quality management system principles. Choy, Lee, and Lo (2002) used the case based reasoning approach for efficient supplier selection to enhance the performance of the selection as compared to traditional approaches. Lee, Ha, and Kim (2001) proposed the supplier selection and management system that includes purchasing strategy system, supplier selection system and supplier management system.

Lee (2009) provides a fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks. A combined methodology for supplier selection and performance evaluation shown by Mithat, Cuneyt, and Cemal (2011).

It is observed that the TSSP is unable to capture the information of suppliers for all periods in a planning horizon. This is due the changing needs of supplier's own businesses and the supplier's own policy on quality, lead time, prices over the time. Thus, it becomes necessary to take into account such information of all suppliers before selecting the supplier for any part in every period. Also, in TSSP it is assumed that the top ranked supplier is capable to supply all parts keeping same quality norms and within the lead time. This assumption makes the TSSP limited and unpractical as far as today's business is concerned. In order to handle such dynamic situation, organization needs to develop an analytical model capable of capturing complete information of all suppliers for each period. Analytical and qualitative models developed so far are very much capable to select the best supplier in the case of single period but cannot guarantee the selected supplier to be the best supplier for the case of multi-period. As a result, supplier for one period may not be the best supplier for the next period for supplying the same part type. Hence, the need to develop a multi-objective analytical model which can provide the optimal set of suppliers for all part types in each period increasing among business organizations. The supplier selection process in the case of multiple periods entirely different from the single period case as it involves more complexity in terms of selecting the suppliers for all periods minimizing the total supplier selection cost in the shortest lead time and meeting the desired quality level for each product set by an organization. In this paper, an attempt has been made to develop a mixed-integer non-linear formulation for the DSSP.

3. Problem definition

The problem considered here pertains to a dynamic environment of a business organization where the organization has to optimize the total cost of procuring multiple parts from multiple suppliers in multiple periods. There are suppliers supplying parts with different unit price, total transportation cost, varying quality parameters and lead time. From the past evidences, organization as a buyer has historical data of each supplier such as the amount of the extra time each supplier took to deliver the parts beyond the committed lead time. Similarly, each supplier has shown different quality level for different parts. Organization has to bear the cost for late arrival of the part and poor level of quality part due to delay in the manufacturing of finished goods product. In addition, supplier's capacity also differs from time to time due to their own internal or external issues. Organizations' demand for each product also varies in different period due to fluctuating market trends. In the following section, a MINLP is proposed to select the right supplier for the right part for a given planning horizon to optimize the total cost of selecting the suppliers. The total cost consider various cost parameters such as unit price of purchasing the part from supplier, cost for any delay beyond the lead time, cost of rejecting the parts due to poor quality level and fixed cost of transportation of parts from supplier. The proposed MINLP model incorporates risk associated with fluctuating demand, supply disruption, quality failure probability and delivery delay.

4. Mathematical model for dynamic supplier selection problem

In this section, MINLP model for multi-objective DSSP that relates the unit product cost for each supplier and product, fixed