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A new approach to solve the multi-product multi-period inventory lot sizing with supplier selection problem

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ABSTRACT

This research work deals with the multi-product multi-period inventory lot sizing with supplier selection problem. Formerly, this kind of problem was formulated and solved using an exhaustive enumeration algorithm and a heuristic algorithm. In this paper, a new algorithm based on a reduce and optimize approach and a new valid inequality is proposed to solve the multi-product multi-period inventory lot sizing with supplier selection problem. Numerical experiments ratify the success of the proposed heuristic algorithm. For the set of 150 benchmark instances, including 75 small-sized instances, 30 medium-sized instances, and 45 large-sized instances, the algorithm always obtained better solutions compared with those previously published. Furthermore, according to the computational results, the developed heuristic algorithm outperforms the CPLEX MIP solver in both solution quality and computational time.

1. Introduction

Supplier selection and lot sizing are essential activities in supply chain management. Typically, in any echelon of a supply chain it is important to select the best suppliers from which to acquire the products, the lot sizes, and the time to place the orders during a finite planning horizon.

The single-product multi-period inventory lot sizing problem has its origins at the end of the 1950s and was first proposed by Wagner and Whitin [23]. This problem can be represented as a mixed integer linear programming (MILP) model. Moreover, Zangwill [30] has shown that this problem is a fixed charge network problem. Wagner and Whitin [23] have solved this type of problem optimally with a dynamic programming algorithm. Furthermore, several dynamic lot size rules have been proposed to solve the single-product multi-period inventory lot sizing problem. For instance, see Simpson [18] who conducted a scrutinized and comprehensive study of nine well-known published rules. Since its introduction, it became one of the most studied and extended problems in inventory management. A number of excellent reviews have been published in order to provide an introduction to the lot sizing problem and its extensions. For example, De Bodt et al. [8], Bahl et al. [2], Kuik et al. [15] and Wolsey [29] are the first reviews on the history of the single product lot sizing problem. In addition to well-known heuristic rules, the lot sizing problem has been also solved using other approaches, i.e. Hop and Tabucanon [10] have developed a new and original approach to solve the lot sizing problem using an adaptive genetic algorithm. Later, Cárdenas-Barrón [4] discusses some features of the adaptive genetic algorithm in Hop and Tabucanon [10]. He concludes that it is convenient to solve the lot sizing problem with Wagner and Whitin [23] algorithm because this always obtains the optimal solution. In addition, Jans and Degraeve [11] have provided a comprehensive and complete review of metaheuristics for the lot sizing problem. One can see from the reviews mentioned above that there exist many approaches to solve the lot sizing problem that have been developed for distinct applications.

Another interesting research direction is on the inventory lot sizing with supplier selection problem which combines lot sizing and supplier choice decisions. The research works of Kasilingam and Lee [14] and Jayaraman et al. [12] address this problem. Both papers contain mixed integer programming models to select suppliers and determine the lot size of the products. Also, Dahel [7] develops a multi objective mixed integer programming approach to select the number of suppliers to use and the lot size of each product to place the orders to suppliers for a multiproduct, multi-supplier competitive sourcing environment.

Basnet and Leung [3] deal with the multi-product multi-period inventory lot sizing with supplier selection problem. First they solved the problem with an exhaustive enumerative search algorithm. Since this algorithm cannot obtain a solution within 2 h of computation for instances with 60 or more binary variables, they proposed a heuristic

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algorithm to solve the problem in a reasonable computational time. On the other hand, Moghadam et al. [16] propose a new mathematical formulation for the multi-period inventory lot sizing problem with supplier selection and solve it using a hybrid intelligent algorithm based on fuzzy neural networks and genetic algorithms. Aissaoui et al. [1] present an excellent and comprehensive review on supplier selection and lot sizing. They mainly focus on papers that deal with the determination of the best combination of suppliers and allocation of the orders in order to cover different purchasing requirements. In the same year, Wadhwa and Ravindran [22] model the supplier selection problem as a multi-objective optimization problem in which one or more purchasers order multiple products from different suppliers in a multiple sourcing network. Later, Ustun and Demirtas [21] propose a model that integrates the well-known analytic network process (ANP) and achievement scalarizing functions to select the best suppliers and establish the optimal lot sizes between the chosen suppliers by considering tangible–intangible criteria and time horizon. Afterwards, Ho et al. [9] review the literature related to the multi-criteria decision making approaches for supplier selection and evaluation. Tsai et al. [20] develop an attribute-based ant colony system (AACS) which is a framework to study the critical factors to select the best suppliers for purchasing decisions. Ware et al. [24] present an exhaustive and well documented state of the art literature review. Basically, Ware et al. [24] critique the papers that deal with the supplier selection problem. Afterwards, Ruiz-Torres et al. [17] propose a mathematical optimization model to determine the optimal demand allocation over a set of suppliers considering the risk of supplier failures. Ware et al. [25] study the interrelationship of supplier selection criteria using the interpretive structural modeling (ISM) approach. Choudhary and Shankar [5] propose an integer linear programming optimization model to jointly determine the timing of procurement, lot-sizes, and the selection of suppliers and carriers in order to minimize the total cost thru a finite planning horizon. In a subsequent paper, Choudhary and Shankar [6] develop a multi-objective integer linear programming model to make the best decisions on inventory lot-sizing, supplier selection, and carrier selection. Ware et al. [26] propose a methodology for the flexible supplier selection problem in which both qualitative and quantitative factors are considered jointly. They use the analytical hierarchy process (AHP) and interpretive ranking process (IRP) for the qualitative model, and a mixed non-integer linear programming problem for the quantitative model. In the same year, Ware et al. [27] analyze the impact of demand variation on a multi-product, multi-source, multi-period model for the supplier selection problem. Ware et al. [28] develop a mixed-integer non-linear program to address the dynamic supplier selection problem. More recently, Karsak and Dursun [13] present a fuzzy multi-criteria group decision making methodology which uses the well-known quality function deployment (QFD), and a fusion of fuzzy information and a 2-tuple linguistic representation model for supplier selection.

This research paper mainly improves the work of Basnet and Leung [3]. It is of fundamental importance to mention that the inventory lot sizing with supplier selection problem in Basnet and Leung [3] is a complex combinatorial NP hard optimization problem. Heuristics or approximation algorithms play a vital role in solving NP hard problems with the hope that a near optimal solution in a short amount of time can be found. Consequently, this research presents a heuristic algorithm that provides a quality solution for the multi-product multi-period inventory lot sizing with supplier selection problem in a reasonable amount of computational time.

Basnet and Leung [3] have left as a fertile area for future research the improvement of their solutions. Therefore the main goal of this research paper is to propose a new approach to solve the multi-product multi-period inventory lot sizing with supplier selection problem heuristically. This new approach is based on the reduce and optimize approach (ROA). It is possible to accelerate the solution process of an optimization problem by solving it on a small set of variables. Within this context, the ROA approach always solves the problem over a small feasible space that contains a near optimal solution. Treviño-Garza [19] has proved that the ROA is capable of solving other types of binary integer problems (i.e. single machine total weighted tardiness problem, set covering problem and set partitioning problem) in a reasonable time. The noteworthy results achieved by Treviño-Garza [19] have encouraged us to apply ROA to multi-product multi-period inventory lot sizing with supplier selection problem in the present research article.

The rest of this paper is organized as follows. Section 2 presents the formal definition of the multi-product multi-period inventory lot sizing with supplier selection problem and its mathematical formulation. Section 3 proposes a heuristic algorithm to solve the multi-product multi-period inventory lot sizing with the supplier selection problem and also provides the results of the extensive computational experiments. Finally, Section 4 gives some conclusions and future research directions.

2. The multi-product multi-period inventory lot sizing with supplier selection problem

2.1. Problem definition

Basnet and Leung [3] formally define the multi-product multi-period inventory lot sizing with supplier selection problem as follows. Consider the situation where the deterministic demand of multiple discrete products is known over a given finite planning horizon. Each product can be supplied from a set of suppliers, for example one or more suppliers could be chosen in each period for the procurement of a product. There is a supplier ordering cost that is incurred in each period when an order is placed to the supplier. Also, there is a product holding cost per period that applies to each product in inventory when it is carried through a period in the finite planning horizon. There are no capacity constraints and shortages are not allowed. The decision maker (manager) seeks to decide what products to buy in what lot sizes from which suppliers and in which periods to place the orders. Basically, Basnet and Leung [3] propose a mixed integer linear programming (MILP) formulation which is presented in Section 2.2.

2.2. Mixed integer linear programing model (MILP) for the multi-product multi-period inventory lot sizing with supplier selection problem

Basnet and Leung [3] propose the following MILP formulation for the multi-product multi-period inventory lot sizing with supplier selection problem (the notation and the mathematical model are placed here just for self-completeness of this paper).

Indices

- $i=1,2,3,\ldots, I$ index for products.
- $j=1,2,3,\ldots, J$ index for suppliers.
- $t=1,2,3,\ldots, T$ index for periods.

Parameters

- D_{it} = demand for product i in period t.
- P_{ij} = purchase price for product i from supplier j.
- H_i = holding cost for product i per period.
- O_j = ordering cost for supplier j.

Decision variables

- $Xijt$ = lot size for product i ordered from supplier j in period t.
- Yjt = 1 if an order is placed to supplier j in period t, 0 otherwise.