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An integrated acquisition policy for supplier selection and lot sizing considering total quantity discounts and a quality constraint

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ABSTRACT

We consider a two-stage supply chain where a buyer purchases a product from multiple capacitated suppliers to satisfy a constant demand rate over a finite planning horizon. Suppliers have different perfect rates and offer total quantity discounts. The buyer selects suppliers and allocates orders to them that satisfy a minimum average quality level. A mathematical model is proposed with the objective on minimizing the total cost per time unit. The model is solved by dualizing the quality constraint. The relaxed model is solved by an efficient dynamic programming algorithm. The subgradient method is used to solve the dual problem.

1. Introduction

In many industries, purchased materials contribute a major portion of a company's total cost. According to a study by Van Weele (2009), in industries like computer and automotive, the costs associated with purchased materials account for up to 80% of the total product cost, as shown in Table 1. As a result, whether a company can effectively control its cost greatly depends on the successfulness of its procurement policy. In the past decades, as globalization opened a broader scope for supplier search, multi-sourcing has become a trend. It allows companies to take advantage of differentials in various factors such as price, quality, lead-time, and transportation, and helps them reduce underlying risks due to uncertainties in political and economic environments. In addition, when a single supplier's capacity cannot satisfy the demand, for the buyer, multiple sourcing becomes the only solution. Therefore, most business areas are now dominated by dual or multiple sourcing (Shin et al., 2000), especially for multinational companies. In this paper, we aim at addressing the acquisition problem that arises with multiple candidate suppliers.

The use of a multi-sourcing procurement strategy however, implies a great deal of coordination among the selected vendors and the buyer firms. This is particularly important in supply chains with a decentralized control system, being the ones under which retailers, wholesalers and producers purchase their stock from external partner companies, without control integration. When each entity strives to optimize its own costs, the performance of the entire supply chain, and in most cases the individual performance of the companies involved, can be diminished. One common result is the lack of coordination in inventory policies, where each firm determines their own policy without considering for example, the production capabilities of their partners or their corresponding costs. A well-known practice is the use of quantity discounts from suppliers to incentive higher order quantities from their buyers.

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Table 1
Cost associated with purchased materials and services as a percentage of total product cost (Van Weele, 2009).

Industry	Retailers	Computer	Consumer electronics	Automotive	Pharmaceutical	Service industry
%	60–86	60–80	50–70	60–80	25–50	10–40

Most of the literature (see Sarmah et al. (2006)), is focused on quantity discounts on individual orders, i.e. single-order quantity discount (SQD).

An SQD agreement is a coordination contract that stablishes the pricing scheme of a supplier given an order from the buyer. The actual discount schedule can be of different types, being the most common all-unit discounts and incremental discounts. Although these contracts are of interest for vendors and buyers as it motivates the latter to purchase larger quantities, thus reducing the purchasing cost, it poses several disadvantages. On the side of the buyer, a lower purchasing cost will inevitably promote the purchasing of large orders, but more sporadically. This could end up increasing the inventory cost, as capital will remain idle in the warehouse for longer periods of time. In the case of the supplier, larger individual orders do not guarantee an overall increase on the total amount purchased by the buyer. Hence, the large orders may only stretch the production capability of the vendor and might result in additional costs such as overtime to meet the procurement commitments, without experiencing any increase in their business with the buyer. Moreover, this kind of agreement could result in the supplier not having the capacity to offer other business partners similar deals, as his capacity is occupied with only one buyer. Given these issues, the problem considered in this paper uses a different discount-based coordination mechanism, i.e., a total quantity discount (TQD) agreement. This means that the suppliers offer a discount over the entire amount purchased in a fixed period, as opposed to offering a price reduction to individual orders. This provides overall, all the advantages of an SQD agreement, without the associated drawbacks.

This research explores a supplier selection problem with one buyer and a pool of potential suppliers. Buyer and suppliers trade a single product that experiences a deterministic constant demand rate over a finite planning horizon to ensure a finite reorder cycle time. These suppliers are capacitated, meaning that they can only sell a certain amount per time unit. Following Adeinat and Ventura (2015), and Mendoza and Ventura (2008), the model considers a minimum quality requirement on the side of the buyer. Given these limitations, our model allows for multi-sourcing to occur as several suppliers may be needed to meet both the total demand requirement and the average quality level, thus eliminating trivial solutions. As mentioned before, instead of using an SQD agreement between suppliers and buyer, the problem presented considers a total quantity discount (TQD) agreement between partners. This is a particularly efficient setup not only for the reasons listed above, but also because it can help in mitigating risks associated with purchasing in more scatter and larger installments. These risks might include holding on to excess inventory of products that are updated regularly or, in more extreme scenarios, may be subject to recalls. Moreover, although not the subject of our research, we do note that a TQD agreement is also a desirable alternative for products that are perishable, as it allows the buyer to purchase an overall larger amount of product to lower the procurement cost, without increasing the risk of spoilage (Goossens et al., 2007).

In addition to the above, our problem considers that orders issued to the selected vendors can be continuous or integer. In both cases, we evaluate whether properties known for infinite planning horizon models are applicable in this setup. In doing so, we introduce an algorithm based on dynamic programming and Lagrangean relaxation to solve the discretized version of the model under both lot sizing requirements.

The rest of the paper is organized as follows. In Section 2, we review related work present in the existing literature. In Section 3, the problem statement and formulation are presented. The algorithm to solve the problem is introduced in Section 4. A case study and numerical experiments are used to illustrate the algorithm and analyze its performance in Section 5. Conclusions and future research directions are given in Section 6.

2. Literature review

Purchasing is one of the most important strategic decisions of a company. In this paper we consider the problem of developing a procurement policy for a single product considering the selection of external suppliers and the allocation of orders to each selected supplier within a finite time horizon. Due to their critical roles in practice, the supplier selection and lot sizing problems have been studied extensively over the past two decades. We refer the reader to Chai et al. (2013), Aissaoui et al. (2007), and Glock (2012) for a thorough review of these studies. A short review of the literature closely related to our research is provided below.

Supplier selection and lot sizing are highly interrelated, mainly because factors such as cost, capacity or quality affect both of these decisions. The main factor to consider in the majority of industries is the cost associated with the procurement process. Thus, when evaluating suppliers, it is necessary to know the corresponding minimum cost under the optimal lot sizing policy. Due to the latter, supplier selection and lot sizing should be analyzed simultaneously. Rosenblatt et al. (1998) perform such a study for a single-product supply chain over an infinite planning horizon with a constant demand rate. They proposed a mixed-integer nonlinear programming (MINLP) model to determine the preferred set of suppliers and the corresponding order quantities. However, considering our case, when the planning horizon is finite, their model does not guarantee an integer number of orders for the suppliers. To surpass this hurdle, they present an approximation scheme addressing this issue. Dai and Qi (2007) improved on Rosenblatt et al.'s model by taking the number of orders as an integer variable. They derived an exact algorithm based on dynamic programming (DP) and a scatter search algorithm to solve the problem. Following that line of research, Mendoza and Ventura (2008) considered an acquisition problem where a cyclic order schedule is applied. Under the cyclic order policy, the entire planning horizon is divided