Dynamic supplier selection and lot-sizing problem considering carbon emissions in a big data environment

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A R T I C L E   I N F O

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A B S T R A C T

Selection of the right suppliers with a view of overall reduction in the procurement cost as well as carbon emissions is an important task for the buyers to sustain in the fierce competitive environment. The rising concerns about carbon emissions due to severe climatic changes globally have forced supply chain managers to re-strategize about controlling their carbon emissions. This paper proposes a dynamic supplier selection model incorporating the carbon emissions under the carbon cap-and-trade scenario. Carbon emissions caused due to ordering, holding the inventory, production and handling and transportation have been considered in the paper. The proposed mathematical model is a mixed-integer-non-linear-program (MINLP). Validation of the proposed MINLP has been done using two randomly generated datasets having the essential parameters of Big Data, i.e. volume, velocity, and variety.

1. Introduction

Multi-period lot-sizing and supplier selection decisions hold great importance in supply chain decision making process from a buyer’s perspective. Due to the increased focus on quality and cost competitiveness, buyers tend to look for suppliers who can offer them the least product prices while simultaneously being able to meet other requirements. It may not be possible for any one of the supplier to meet all the buyer requirements. The buyers may be tempted to procure some part of their product demand from one supplier while fulfilling the remaining demand from other suppliers. It is in this context that dynamic supplier selection problem assumes importance over the traditional supplier selection problem where all the suppliers are supposed to meet all the buyer’s requirements. The cost of raw materials and component parts constitute almost 70% of the product costs in most of the organizations (Ghobadian et al., 1993). Hence, supplier selection can have huge impact on the organizations efficiency and effectiveness in terms of increased profitability by reduction in procurement prices and continuity of production processes by ensuring smooth flow of raw material. In addition to the focus on reduction in procurement cost, carbon emissions in supply chain are also an important area of concern. The various supply chain activities involving the movement of raw and finished goods, manufacturing processes and storage of in-process as well as inventory items require critical measures of energy and cause a lot of emissions from transportation, and storage warehouses. Organizations are increasingly recognizing the need to reduce their carbon emissions due to the concerns raised by their customers and shareholders. This had led them to make efforts to reduce carbon footprint by adopting more energy efficient equipments and redesigning their production processes. Due to this, Innovation in green technologies is becoming increasingly necessary to enhance the working conditions and productivity of industries (Song and Wang, 2018). However, operational adjustments, too, can have a significant impact on reducing carbon emissions without increasing the costs remarkably. Due to the potential impact of operational decisions on the carbon footprint of a firm, there is a need for incorporating them in the quantitative models which typically focus on either minimizing cost or maximizing profit (Benjaafar et al., 2013). Benjaafar et al. (2013) illustrated how carbon emissions can be integrated into procurement, production, and inventory management decisions. They examined distinctive emission regulations including strict emission caps, taxes on emissions, cap-and-offset, and cap-and-trade. They concluded that supply chain collaboration and operational/structural adjustments are modest basic drivers for reducing the supply chain carbon footprint. The increased carbon emissions, on account of manufacturing, transportation, and storage of various products, have led to global warming being seen as one of the topmost environmental concerns being faced worldwide today. Accordingly, high energy consumption countries like China and India, ought to dedicate serious attention to improve their environmental efficiency alongside sustaining their economic development (Song et al., 2018). The amount of carbon emissions associated with various supply chain processes vary, however, procurement and
logistics activities are major contributors of carbon emissions in a supply chain (Kaur and Singh, 2018). Transportation activities alone are estimated to account for nearly 14% of total CO2 emissions globally (Dekker et al., 2012). Consumers are becoming increasingly environmentally conscious and laying more emphasis on low-carbon purchases. A survey has highlighted that almost 83% consumers worldwide want organizations to implement programs to safeguard environment (Nielsen, 2011). The same survey, however, revealed that only 22% of consumers are ready to pay more for environment friendly products. This underlines a serious need for organizations to control their carbon footprints while remaining cost effective. This cannot be achieved just by employing extensive technology to curb excess carbon emissions rather operational adjustments can prove to be equally beneficial. Papers by Luo et al. (2017) and Han et al. (2017) can be referred for more details on carbon emissions in supply chains.

In addition to the concerns related to carbon emission in various processes of supply chain management, another huge challenge being faced today is to utilize the massive amount of data being generated in supply chain activities owing to the increased use of sophisticated technologies like ERP, barcodes, RFID devices etc. This kind of data which is referred as “Big Data” is generated both in structured and unstructured formats and primarily has three characteristics i.e. volume, velocity and variety (Chen et al., 2012; Kwon et al., 2014; Kwon and Sim, 2013; McAleee et al., 2012; Russom, 2011). Big data is believed to provide critical insights that can transform the business processes by way of well informed decisions resulting in both tangible and intangible benefits like increased profitability, defect reduction and enhanced customer satisfaction (Dubey and Gunasekaran, 2015; Huang and Handfield, 2015; Wailer and Fawcett, 2013).

In view of the above discussion, the paper is guided by the following objectives:

1. To propose a supplier selection and order allocation model in dynamic setting having multi-products, multi-periods and, multi-suppliers.
2. To integrate carbon emissions arising due to procurement, inventory holding, ordering and transportation in the model under carbon cap-and-trade policy.
3. To map the parameters used in the proposed model to the dimensions of Big Data.
4. To numerically illustrate the prosed model using two randomly generated datasets having the characteristics of Big Data.

The remainder of the paper is organized as follows. Section 2 reviews the extant literature on supplier selection and lot-sizing and big data in the context of supply chain management. Section 3 discusses the proposed mixed-integer non-linear program for modeling the dynamic supplier selection and lot-sizing problem. Section 4 demonstrates the application of the proposed MINLP through two numerical illustrations. Results of the numerical illustrations are discussed in section 5 followed by concluding remarks and future research directions presented in Section 6.

2. Literature review

This section briefly discusses the extant literature on supplier selection and lot-sizing and integration of big data in supply chain management.

2.1. Supplier selection and lot-sizing

Inventory lot-sizing and supplier selection problems have appeared in literature dating back to almost six decades. In one of the very early work, Wagner and Whitin (1958) presented a dynamic programming solution algorithm for inventory lot sizing problem of a single product over multi-periods. Over the years many articles have published in literature addressing the supplier selection problems from different perspectives like considering quantity discounts, shortages and late deliveries, rejections due to defects, service level, etc. However, more often than not, the focus has been on selection of the best suppliers from a pool of suppliers for a single product over a single period time horizon. Various qualitative and quantitative models have been used in the past to address the supplier selection problem. Some authors have also integrated qualitative and quantitative methods. Various quantitative models such as linear programming, mixed- integer linear program mixed-integer non-linear program, dynamic programming, multi-objective programming, goal programming have been used in past works (Aggarwal and Singh, 2015; Ayhan and Kilic, 2015; Ghodsypour and O’Brien, 1998; Kaur et al., 2014; Mafakhare et al., 2011; Nazari-Shirkouhi et al., 2013; Rezaei and Davoodi, 2011; Singh, 2014; Ustun and Demi, 2008; Ware et al., 2014a, 2014b, 2014c). Ghodsypour and O’Brien (1998) presented a decision support system for supplier selection by integrating analytic hierarchy process and linear programming. They first calculated the weights for each supplier using AHP on various qualitative aspects namely, price, quality and service and then used these weights in the objective function to maximize the total value of purchasing (TVP) which they expressed as product of rating and lot-size of ith supplier. Ghodsypour and O’Brien (2001) also examined the supplier selection problem for a single product, single period, and multi-sourcing environment considering capacity constraints. They used a MINLP to determine the optimum allocation to different suppliers so as to minimize the total cost of purchasing. Verma and Pullman (1998) conducted an empirical study to differentiate between the managers’ rating of the perceived importance of various supplier selection parameters such as quality, price, flexibility, and delivery performance and their actual choice of suppliers. They used Likert’s scale to determine the importance of supplier attributes and employed discrete choice analysis (DCA) experiment, to examine the final choice of suppliers. They noted that while quality was the topmost attribute for supplier selection, cost and delivery performance were the dominant factors governing the final selection of suppliers. Ustun and Demi (2008) integrated analytic network process (ANP) and multi-objective mixed integer linear programming (MOMILP) for a single-item, multi-periods, multi-sourcing problem to include both tangible and intangible factors for selection of best supplier. Çebi and Bayraktar (2003) investigated the supplier selection problem by integrating lexicographic goal programming (LGP) and analytic hierarchy process (AHP) model including both quantitative and qualitative conflicting factors. Selçuk (2006) used AHP and preemptive goal programming (PGP) to model the supplier selection problem. Rezaei and Davoodi (2011) presented two multi-objective mixed integer non-linear models for multi-period lot-sizing problem involving multiple products and multiple suppliers. Each model was constructed on the basis of three objective functions pertaining to cost, quality and service level. The first model was without shortages while in second model shortages and back ordering were allowed. They proposed a genetic algorithm to solve the models. Quantity discounts too have been widely used to address supplier selection problem. Zhang and Chen (2013) investigated the supplier selection problem using a mixed integer programming approach. Their model included stochastic demands and quantity discounts. In one of the recent works, Aggarwal et al. (2018) have proposed a non-preemptive goal programming (GP) and weighted sum aggregate objective function (AOF) technique to solve a vendor selection and order allocation problem for time dependent stochastic data subject to a set of demand, capacity and quantity discount based constraints. They have used chance constraint approach to handle the uncertainty related to lead times.

In addition to the considering various cost parameters in supplier selection and order allocation models, authors have also attempted to address the issue of carbon emissions owing to increasing concerns about global warming and suspended particulate matter (PM) in the environment. In this direction, many models have appeared in
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