Omega 43 (2014) 83–95

Contents lists available at ScienceDirect

Omega

journal homepage: www.elsevier.com/locate/omega

Joint supplier selection and scheduling of customer orders under disruption risks: Single vs. dual sourcing

Tadeusz Sawik*

AGH University of Science & Technology, Department of Operations Research and Information Technology, Al.Mickiewicza 30, 30-059 Kraków, Poland

ARTICLE INFO

Article history:
Received 4 January 2013
Accepted 29 June 2013
Available online 13 July 2013

Keywords:
Supplier selection
Single vs. dual sourcing
Disruption risks
Stochastic scheduling
Mixed integer programming

ABSTRACT

This paper presents a stochastic mixed integer programming approach to integrated supplier selection and customer order scheduling in the presence of supply chain disruption risks, for a single or dual sourcing strategy. The suppliers are assumed to be located in two different geographical regions: in the producer's region (domestic suppliers) and outside the producer's region (foreign suppliers). The supplies are subject to independent random local disruptions that are uniquely associated with a particular supplier and to random semi-global (regional) disruptions that may result in disruption of all suppliers in the same geographical region simultaneously. The domestic suppliers are relatively reliable but more expensive, while the foreign suppliers offer competitive prices, however material flows from these suppliers are more exposed to unexpected disruptions. Given a set of customer orders for products, the decision maker needs to decide which single supplier or which two different suppliers, one from each region, to select for purchasing parts required to complete the customer orders and how to schedule the orders over the planning horizon, to mitigate the impact of disruption risks. The problem objective is either to minimize total cost or to maximize customer service level. The obtained combinatorial stochastic optimization problem will be formulated as a mixed integer program with conditional value-at-risk as a risk measure. The risk-neutral and risk-averse solutions that optimize, respectively average and worst-case performance of a supply chain are compared for a single and dual sourcing strategy and for the two different objective functions. Numerical examples and computational results are presented and some managerial insights on the choice between the two sourcing strategies are reported.

1. Introduction

In make-to-order manufacturing, a typical customer driven supply chain consists of a number of part suppliers at different locations and one or more producers, where parts are supplied and assembled into finished products and next distributed to customers. In such supply chains, supply of parts and schedule of customer orders for finished products should be coordinated in an efficient manner to achieve a high customer service level at a low cost. The coordination is much more important in view of supply disruptions by unexpected natural or man-made disasters such as earthquakes, fires, floods, hurricanes or labor strikes, economic crisis, terrorist attack that may occur in global supply chains. The probability of such disaster events is very low, however their business impact can be very high. For example, the recent disruptions in the electronics supply chains due to the great East Japan earthquake of March 11, 2011 and then the catastrophic Thailand flooding of October 2011, where many component manufacturers were concentrated, resulted in huge losses of many Japanese companies, e.g., [1,2].

Most work on coordinated supply chain scheduling focuses on coordinating the flows of supply and demand over a supply chain network to minimize the inventory, transportation and shortage costs. For example, Chen and Vairaktarakis [3], Chen and Pundoor [4] and Pundoor and Chen [5] studied simplified models for integrated scheduling of production and distribution operations. The authors have analyzed computational complexity of various cases of the problem and have developed heuristics for NP-hard cases. Lei et al. [6] considered an integrated production, inventory and distribution routing problem involving heterogeneous transporters with non-instantaneous traveling times and many capacitated customer demand centers. A mixed programming approach combined with a heuristic routing algorithm was proposed to coordinate the production, inventory and transportation operations. Bard and Nananukul [7] developed a mixed integer programming model and a reactive tabu search-based algorithm for a transportation scheduling problem that included a single production facility, a set of customers with time-varying demand and a fleet of vehicles. Wang and Lei [8] considered the problem of operations scheduling for a capacitated multi-echelon shipping

* Tel.: +48 12 617 39 92; fax: +48 12 617 39 84.
E-mail addresses: ghsawik@cyf-kr.edu.pl, sawik@zarz.agh.edu.pl

0305-0483/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.omega.2013.06.007

network with delivery deadlines, where semi-finished goods are shipped from suppliers to customers through processing centers, with the objective of minimizing the shipping and penalty cost. The three polynomial-time solvable cases of this problem were reported: with identical order quantities; with designated suppliers; and with divisible customer order sizes. Liu and Papageorgiou [9] developed a multi-objective mixed integer programming approach to address production, distribution and capacity planning of global supply chains considering cost, responsiveness and customer service level simultaneously. An integrated approach to deterministic coordinated supply chain scheduling was proposed by Sawik [10] to simultaneously schedule manufacturing and supply of parts and assembly of finished products. Given a set of part suppliers and a set of customer orders for finished products, the problem objective was to determine which orders were provided with parts by each supplier, to schedule manufacturing of parts at each supplier and delivery of parts from each supplier to the producer, and to schedule customer orders at the producer, such that a high customer service level was achieved and the total cost was minimized. The selection of part supplier for each customer order was combined with a due date setting for some orders to maximize the number of orders that can be completed by customer requested due dates. A monolithic mixed integer programming model was presented and compared with a hierarchy of mixed integer programs for a sequential selection of suppliers and scheduling of manufacturing and delivery of parts and assembly of products. Different enhancements of the above mixed integer programming approach for the coordinated scheduling in multi-stage supply chains were presented in Sawik [11].

Various perspectives on supply chain coordination issues were reported and reviewed by Arshinder et al. [12] and the gaps existing in the literature were identified. Li and Wang [13] reviewed coordination mechanisms of supply chain systems in a framework that was based on supply chain decision structure and nature of demand. A review of methods and literature on supply chain coordination through contracts was provided by Hezarkhani and Kubiak [14].

The supplier selection and order quantity allocation problem is a complex stochastic optimization problem, however the research on supplier selection under disruption risks is very limited. For example, risks associated with a supplier network was studied by Berger et al. [15], who considered catastrophic super events that affect all suppliers, as well as unique events that impact only one single supplier, and then a decision-tree based model was presented to help determine the optimal number of suppliers needed for the buying firm. Ruiz-Torres and Mahmoodi [16] considered unequal failure probabilities for all the suppliers. Berger and Zeng [17] studied the optimal supply size in a single or multiple sourcing strategy context, under a number of scenarios that are determined by various financial loss functions, the operating cost functions and the probabilities of all the suppliers being down. Yu et al. [18] considered the impacts of supply disruption risks on the choice between the single and dual sourcing methods in a two-stage supply chain with a non-stationary and price-sensitive demand. Yue et al. [19] introduced frontier sourcing portfolios to support manufacturers sourcing decisions, which consider the cost and probability of finishing the order on time. Ravindran et al. [20] developed multi-criteria supplier selection models incorporating supplier risks. In the multi-objective formulation, price, lead-time, disruption risk due to natural event and quality risk are explicitly considered as four conflicting objectives that have to be minimized simultaneously. Four different variants of goal programming were used to solve the multi-objective optimization problem. Xanthopoulos et al. [21] developed newsvendor-type inventory models for capturing the trade-off between inventory policies and disruption risks in a dual-sourcing supply chain network, where both supply channels are subject to disruption risks. The models were developed for both risk neutral and risk-averse decision-making. Sawik [22,23] proposed a portfolio approach for the supplier selection and order quantity allocation under disruption risks and applied the two popular in financial engineering percentile measures of risk, value-at-risk (VaR) and conditional value-at-risk (CVaR) (e.g., Sarykalin et al. [24], Yao et al. [25]) for managing the risk of supply disruptions. The two different types of disruption scenarios were considered: scenarios with independent local disruptions of each supplier and scenarios with local and global disruptions that may result in all suppliers disruption simultaneously. The resulting scenario-based optimization problem under uncertainty was formulated as a single- or bi-objective mixed integer program.

In view of the recent trend of outsourcing and globalization, coordinated selection of part suppliers and allocation of order quantities and scheduling of customer orders may significantly improve performance of a multi-stage supply chain under disruption risks. However, the research on quantitative approaches to the coordinated supplier selection and customer order scheduling in the presence of supply chain disruption risks has not been reported in the literature. In a make-to-order environment, the supplier selection and order quantity allocation are a medium- to short-term decision, driven by the time-varying customer demand. Thus, the scheduling horizon for supplies of parts coincides with the scheduling horizon for customer orders and to achieve the best results the supplier selection and order quantity allocation decisions should also be made for the same time horizon. The advantage of a joint decision making can be shown especially in the presence of supply chain disruption risks. The major contribution of this paper is that it proposes a new stochastic mixed integer programming approach to integrated supplier selection and customer order scheduling in the presence of supply chain disruption risks, for a single or dual sourcing strategy. The suppliers are assumed to be located in two different geographical regions: in the producer's region (domestic suppliers) and outside the producer's region (foreign suppliers). The supplies are subject to independent random local disruptions that are uniquely associated with a particular supplier and to random semi-global (regional) disruptions that may result in disruption of all suppliers in the same geographical region simultaneously. The domestic suppliers are relatively reliable but more expensive, while the foreign suppliers offer competitive prices. However the foreign suppliers are more prone to breakdowns and material flows from these suppliers are more exposed to unexpected disruptions due to natural or man made disasters and longer shipping times and distance. Given a set of customer orders for products, the decision maker needs to decide which single supplier or which two different suppliers, one from each region, to select for purchasing parts required to complete the customer orders and how to schedule the orders over the planning horizon, to mitigate the impact of disruption risks. The problem objective is either to minimize total cost of ordering and purchasing of parts plus penalty cost of delayed and unfulfilled customer orders due to the parts shortages or to maximize customer service level, i.e., the fraction of customer orders filled on or before their due dates. The resulting allocation of total demand for parts among the selected suppliers and the schedule of customer orders for every potential disruption scenario should be determined ahead of time, either to minimize the average or worst-case cost or to maximize the average or worst-case customer service level. The obtained combinatorial stochastic optimization problem will be formulated as a mixed integer program with conditional value-at-risk as a risk measure. The risk-neutral and risk-averse solutions that optimize, respectively average and worst-case performance of a supply chain are compared for a single or dual sourcing strategy