Computers & Operations Research 39 (2012) 350–357

Contents lists available at ScienceDirect

Computers & Operations Research

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

Optimal newsvendor policies for dual-sourcing supply chains: A disruption risk management framework

Anastasios Xanthopoulos, Dimitrios Vlachos, Eleftherios Iakovou *

Industrial Management Division, Department of Mechanical Engineering, Aristotle University of Thessaloniki, P.O. Box 461, 54124 Thessaloniki, Greece

ARTICLE INFO

Available online 28 April 2011

Keywords:
Disruption management
Risk aversion
Two-echelon supply chain
Newsvendor inventory policies
Stochastic model
Service level

ABSTRACT

We propose generic single period (newsvendor-type) inventory models for capturing the trade-off between inventory policies and disruption risks in a dual-sourcing supply chain network both unconstrained and under service level constraints, where both supply channels are susceptible to disruption risks. The models are developed for both risk neutral and risk-averse decision-makers and can be applicable for different types of disruptions related among others to the supply of raw materials, the production process, and the distribution system, as well as security breaches and natural disasters. Analytical closed-form solutions are obtained and interesting managerial insights on the merit of contingency strategies in managing uncertainties and risks in dual-sourcing supply chains are discussed.

1. Introduction

As the impact of the offshoring and outsourcing practices is the continuous geographical expansion of global supply chain networks, the procurement process is becoming even more exposed to risk and disruption [1,2]. Companies throughout all industries strive for making their business processes and supply chains either more efficient or more responsive by outsourcing many core business activities, like manufacturing, transportation, warehousing, research and development, etc. [3]. Although such policies have great potential in making operations agile, leaner, and more efficient in a relatively low risk and low variability environment, at the same time they tend to increase the vulnerability of supply chains to disruptions. Recent catastrophical events, such as the recent earthquake and tsunami in Japan only underline the dramatic effect of supply chain disruptions in global organizations [4]. Such trends have placed enormous pressures on supply chains; organizations that cannot confront these challenges are facing tremendous difficulties within the confines of the new competitive environment. However, despite their significance, vulnerabilities of the supply chain are generally poorly understood and managed [5].

In general, supply chain risk management deals with the identification, assessment, and prioritization of risks followed by the coordinated and economically effective management of resources to minimize, monitor, and control the probability and impact of uncertain disruptive events [6]. Sheffi et al. [7] identified six basic supply chain disruption modes: disruptions in supply, transportation, facilities, communications and demand, as well as freight breaches. The potential economic impact of a disruption is a critical issue for supply chain management, while it increases the awareness of the significant risks posed by supply failures which highlights the need for effective disruption-management strategies [8]. Disruption risks are even more critical for "mature" stock keeping units (SKUs), which are near the end of their lifecycle, or "innovative" SKUs; for these SKUs, it is desirable to channel them into the market as quickly as possible to fill demand before their complete technological obsolescence. This is certainly true for high-tech electric and electronic products/parts with very short lifecycles (guided by the Moore's Law) as well as fashionable items.

Risk management theory and practice provide alternative ways to hedge against specific disruption risks. One of the most common policies for risk mitigation is flexible/multiple-sourcing. Firms might use multiple-sourcing choices for a variety of strategic reasons, such as hedging against supply disruptions and safeguarding against predatory monopolistic practices [9], [10]. Risk attitude is a decisive factor towards the selection of the appropriate risk mitigation strategy. Specifically, risk-averse decision-makers are more reluctant to accept a bargain with an uncertain payoff rather than another bargain with more certainty but with possibly lower expected payoff, while a risk neutral decision-maker would make his/her decision based on which option maximizes expected profit. Moreover, it is well-known that in a classical newsvendor setting, a risk-averse retailer will order a smaller quantity (i.e., the one that maximizes his expected utility) than the order quantity that maximizes his expected profit

* Corresponding author. Tel.: +30 2310 995970; fax: +30 2310 996018.
E-mail address: eiakovou@auth.gr (E. Iakovou).

0305-0548/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cor.2011.04.010

[11]. However, when managing supply chains with unreliable suppliers, it is possible for the order quantities of a risk-averse decision-maker to be very small (even zero in extreme cases) and the subsequent service levels to be very low. Thus, as the latter in practice is not acceptable, a risk-averse decision-maker should also set a lower bound on service level to ensure at least a reasonable sourcing (see also Federgruen and Yang [12]).

Kleindorfer and Saad [13] identify two general categories of risks affecting supply chain design and management: (a) risks arising from problems when coordinating supply and demand, and (b) risks arising from disruptions to normal activities (i.e. procurement of raw materials, production, distribution, etc.). In this paper, we focus mainly on the second category of risk. More specifically, generic newsvendor stochastic inventory models for risk-neutral and risk-averse decision-makers are proposed for a supply chain network of two unreliable competing supply channels and one customer (e.g. a retailer or wholesaler). The main objective of the developed models is to capture the trade-off between inventory policies and disruption risks in a dual-sourcing network under specific (or not) service level constraints, assuming that both supply channels are susceptible to disruption risks. Alternatively, the proposed models may be relevant to different types of disruptions related among others, to the supply of raw materials, the production process, the distribution system, as well as to security breaches, and natural disasters.

Although the traditional yield management literature investigates several system settings, this work is one of the first attempts jointly tackling supply chain disruption management and risk aversion issues for supply chain procurement. We model disruption events as potential incidents that inhibit an order from being a perfect one (i.e. an order that is delivered on time, complete, and damage-free). Moreover, risk aversion is implicitly taken into account through the consideration of the appropriate service level constraints. Constraints which capture Types I and II (fill rate) service levels are analytically considered [14]. In each case, the selection of the appropriate service level goal depends on the attitude of each decision-maker towards risk.

The consideration of two suppliers with different procurement prices, disruption probabilities and consequences (order yield), differentiates this work from the existing literature for dual-sourcing supply chains, which generally allows for one reliable and one unreliable supplier. Finally, closed-form analytical solutions are obtained for the determination of the optimal expected total profit of the retailer/wholesaler, providing important managerial insights on the merit of contingency strategies in managing uncertainties in dual-sourcing supply chain disruption management systems.

The remainder of the paper is organized as follows. In the following section, we provide an up-to-date literature review on yield management and disruption supply chain models, focusing mainly on procurement issues under general supply risks. In the third section, the problem and the network under study are defined. In the fourth section the proposed quantitative models are formulated and solved, while the main results and relevant managerial implications are thoroughly discussed. Finally, in the last section conclusions and directions for further research are provided.

2. Literature background

Supply chain disruptions have been proven to have both short- and long-term negative impact on corporate profitability and shareholder value [15]. As corporations have expanded their supply chains globally they are even more exposed to disruption risks. Thus, it is imperative that they first analyze and understand these risks and then they develop solutions to mitigate their impact [16]. Clearly, the design and execution of appropriate methodological approaches can play a critical role in handling risks and disruptions for various operational settings. Towards this direction, the literature dealing with the joint tackling of yield/inventory and risk management appears to be growing during the last decade. Below, we categorize the relevant research works into single- and multiple-sourcing efforts.

2.1. Single-sourcing

Henig and Gerchak [17] developed a periodic review production/inventory model with random supply yield. Moinzadeh and Aggarwal [18] consider an (s,S) inventory policy for a constant production and demand rate system with random disruptions at a bottleneck production facility, in which supply could be randomly disrupted and the disruption lasts for a random period of time. Near-optimal production policies are obtained via a heuristic procedure. Parlar [19] considers random supply disruptions with stochastic demand and lead-time in a continuous review inventory system, while supplier availability is modeled as a semi-Markov process. Ferrer [20] developed a newsvendor single-sourcing model for a remanufacturing network, in order to estimate the merit of a priori information regarding the quality of a single end-of-life part and the impact of the quality of the returned products on remanufacturing yield. Xia et al. [21] developed a deterministic Economic Order Quantity-type inventory model for a two-stage supply chain that is susceptible to production-rate disruptions. The authors investigate two classes of problems, one with fixed setup periods and another with flexible setup periods. More recently, Xiao and Qi [22] study a supply chain with one supplier and two competing retailers that is subject to production disruptions during a single period. Two coordination mechanisms are considered, an all-unit quantity discount and an incremental quantity discount. Finally, Keren [23] presents an interesting single period inventory problem considering known demand and stochastic supply yield.

2.2. Multiple-sourcing

Two significant research contributions in the field of yield inventory management for a dual-sourcing network are those of Parlar and Perry [24] and Gurler and Parlar [25]. Both research efforts consider a firm that faces constant demand and sources from two identical-cost capacitated suppliers which are subject to production failures. Interfailure and repair times are exponentially distributed for both suppliers in Parlar and Perry [24], while in Gurler and Parlar [25] they follow an Erlang distribution. Anupindi and Akella [26] propose a dual-sourcing model with stochastic demand, in which the order lead-time for supplier i is a discrete random variable that takes values of one or two periods. Agrawal and Nahmias [27] developed a multiple-sourcing deterministic demand model to determine the optimal lot sizes and number of suppliers, when the supply yield from each supplier is random and fixed costs are associated with each supplier. Tomlin and Wang [28] developed a single period dual-sourcing model with yield uncertainty. By considering one unreliable and one reliable (and thus more expensive) supplier, they focus on inventory and sourcing mitigation. In the same context, Tomlin [29] proposes a Markov chain single product model by considering capacity constraints for both suppliers and order quantity flexibility for the reliable vendor, while Chopra et al. [30] considers the unreliable supplier to be subject to both recurrent and disruption uncertainties. Further, Federgruen and Yang [12] and Dada et al. [31] consider Type I service level-related constraints in their yield management models, while Yang et al. [32] propose an interesting analytical approach on the multiple-sourcing random yield problem.

In conclusion, there is a variety of research methodological approaches regarding the yield inventory management processes