



A decision support system for procurement risk management in the presence of spot market

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ABSTRACT

In the presence of spot market, this paper presents a decision support system to model risks for procurement processes and to design a robust purchasing plan, including supplier selection and order allocation. Taking advantages of contract supplier and spot market, the buyer can better meet business requirements in this dynamic business environment. However, there are limitations of existing methods for modeling multiple correlated risks to support decision makers for allocating orders among multiple suppliers in the presence of spot market. Therefore, Monte Carlo simulation algorithm termed as Expected Profit–Supply at Risk (A-EPSaR) is proposed to quantify each supplier's risk so as to let decision maker realize the trade-off between profit and risk. The goal programming model helps to allocate orders among the supplier pool and the contract-spot allocation model can assign orders between the spot market and the supplier pool, respectively. The significance of this paper is to propose a novel decision support framework which helps the buyer to make optimal and robust procurement decision including supplier selection and order allocation among multiple supplier sources in the existence of correlated demand, yield and spot price uncertainties. A case study is used to illustrate the performance of the proposed framework and the proposed methods show the promising result.

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1. Introduction

Procurement risk management is of great importance and is crucial to the success of supply management [25,34]. With the popularity of outsourcing from 1980s, many companies outsource the business which is not their core competency [15]. For example, Dell outsources the manufacturing of computer components to other companies and focuses on assembling each ordered unit according to a selection of custom options. Outsourcing becomes a business strategy for Dell and other business partners, so enterprises can focus on its core technology and enhance their competency. But this brings a great challenge for procurement. Indeed, procurement is becoming more and more demanding in this dynamic market environment in terms of supplier risk management [20,22,24]. Nowadays the majority of raw materials and components are manufactured in countries where costs are lower. Many of the business partners and component producers are overseas and difficult to be monitored. Therefore, supply from these contract suppliers is hard to be controlled and has different extents of uncertainty. In fact, there are many uncertainties that existed in procurement [5,11,19], such as variable lead time and uncertain demand. Since the

lead times of these contracts are usually quite long, the buyer doesn't have enough time to place a second order when the uncertain demand or uncertain yield is realized. Or when the supply is affected by nature disasters, part or all of suppliers' production capability is halted. More and more companies have already realized the importance of managing procurement risk. For example, HP has formed a Procurement Risk Management (PRM) team and enabled \$100 million dollars in accumulative savings over the past 5 years according to [25].

The incorporation of a reactive supply channel in procurement is advocated by many scholars. These reactive supply channels can be spot market [29], option contracts [30] or a back up supplier [31]. Utilizing the short lead time advantage of spot market, Seifert et al. [29] figure out the optimal order allocation among the single contract supplier and the spot market under demand uncertainty. Haksöz and Kadam [13] provide a tool to assess the effects of contract breaches in the presence of demand and spot price risks. A new term Supply at Risk (SaR), which returns the worst loss that will not be exceeded with a given level of confidence, is introduced by Haksöz and Kadam [13] to evaluate supply risk. Indeed, SaR is a similar concept akin to the Value at Risk (VaR) statistic in finance [18]. A portfolio of contracts are evaluated and SaR is obtained to find out the optimal supplier portfolio according to [13].

As the shortcomings from contract supplier can be made up and compensated by the reactive supply, therefore, to deal with the procurement risk management, it is essential to utilize both supply sources and take related risk factors into consideration. At the beginning of every

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procurement period, the buyer will place orders on the supplier pool of long term contract suppliers. Because of the uncertain yield from these contract suppliers and unstable demand, spot market with negligible lead time is adopted as the reactive supply source to meet unexpected demand or sell extra stock. The price from spot market changes continuously and is higher compared with the long term contract suppliers. Indeed, these uncertain factors are not independent and can affect one another. In this paper, the most general case of a completely correlated demand, spot price and uncertain supply is considered. The risk attitude of a buyer is also taken into consideration as it affects the procurement decision. In addition, the following factors are also studied: procurement cost, minimal order and maximal order proportion assigned to a single supplier and fixed cost of adding one more supplier. In order to assist decision making in formulating the management plan, a novel PRM framework is proposed. The proposed framework helps to generate a procurement plan which includes 1) the selection of appropriate suppliers; 2) the order allocation for the respective supplier; 3) the aggregate order to be purchased from the selected supplier pool; and 4) the total order amount purchased from spot market.

This paper is organized as follows: Section 2 describes the related research work and the gaps in these areas. Section 3 presents the integrated framework from supply risk identification to risk monitoring. Section 4 illustrates the framework with a case study. In Section 5, conclusions are drawn and future research directions are stated.

2. Literature review

Supply and procurement risk management are part of the supply chain risk management [33]. Haksöz et al. [11] mentioned that the top three risks in procurement are demand, price and breach of contract risks. The aim of risk management in supply chain is to identify the potential risks and implement the risk management technique to reduce the impact and probability of occurrence of risks in supply chain. In fact, the utilization of a pool of suppliers to diversify risks is quite common and effective in the industry especially when the suppliers are not reliable [1]. Spot market is also adopted as a reactive supply source as it has the advantage of short lead time, i.e., the extra demand can be met by spot market within a negligible time [29]. In addition, the prediction market is an effective approach to manage demand uncertainty [10].

In the area of utilizing multiple suppliers under yield uncertainty, Agrawal and Nahmias [1] derived the optimal number of suppliers and the corresponding lot sizes. They have studied both the following two cases: identical suppliers and non-identical suppliers. They discover that the expected profit is strictly concave with the order quantity and the number of suppliers. Another observation is that the ratio of optimal order size is inversely proportional to the yield variance. If suppliers want to increase their shares of the total order, they have to improve their yield performances. Federgruen and Yang [6] proposed a model to configure the supply base in the presence of yield and demand uncertainties under a single period setting. The generated optimal procurement plan includes the optimal set of suppliers to be chosen and the optimal orders to be assigned to each supplier. If there is no reactive supply after the uncertain demand or yield is realized, the unmet demand is usually penalized at a certain value; and the extra products are also salvaged.

The other alternative to solve the procurement problem is to adopt spot market as a reactive supply channel. In fact, spot market is studied by many economists for pricing and hedging of commodities [3,28,32]. But there are still a lot of researches that can be done such as investigating the effect of spot market on supply chain and the trade-offs between the spot market and contract suppliers [24]. Haksöz and Seshadri [12] have done a comprehensive literature review regarding the study of spot market in supply chain operations. It is mentioned that these works can be divided into two categories: optimal procurement strategy and the valuation of procurement contracts. Under the assumption of demand uncertainty, Seifert et al. [29]

quantify the benefits of using spot market from a buyer's perspective. They develop and solve mathematical models that determine the optimal amount of orders to be purchased via forward contract and spot market, respectively. Also under the assumption of uncertain demand, Chen and Liu [4] quantify the benefits of using spot market from both the buyer's and the supplier's perspective. The optimal order size is obtained under uniformly distributed demand and spot price. Apart from the spot market, procurement using option contract can also be a reactive supply channel. It gives buyers the right, but not the obligation to purchase at the exercise price from the seller within a pre-specified time period. In order to gain the option right, buyers have to pay an option price to reserve the capacity. If buyers don't want to execute the contract, the payment would not be refunded. This kind of contract ensures a buyer's flexibility to respond to the actual demand. At the same time, it also provides a certain amount of compensation for the supplier in the form of option price. Fu et al. [7] derive the optimal number of option contracts and the corresponding lot sizes from option contracts and spot market under uncertain demand. The results show that the adoption of both option contracts and spot market can help control the supply risk.

In addition, adoption of prediction market is proved to be quite effective in supply chain risk management by providing an accurate demand forecast and promoting channel coordination. Guo et al. [10] designs macro prediction market analogy to a real money futures market where a retail index with a payoff depends on the future realization of uncertain macroeconomic factor. By the adoption of this prediction market approach, useful information is shared and market participants are motivated to produce a reliable forecast. Therefore, the incorporation of prediction market approach into supply chain management helps to achieve accurate demand forecast sharing; reduce the order variance and improve the expected supply chain profit. With the popularity of social network (e.g. Twitter), the simulation result of a Twitter-based prediction market shows that the price dispersion is small as agents acquire more information in the network. Network based prediction market has a better prediction and the finding gives insight about how social network affects information acquired by agents so as to affect the overall market performance [27]. The similarity between the spot market trading approach and the prediction market approach is that they can be both used for managing demand uncertainty. The difference is that the spot market trading approach tries to minimize risk impacts after risk events happen, while the prediction market approach can help to reduce the uncertainty of risk factor before risk events happen. In addition, the spot market trading approach can also be used to manage uncertain yield which is hard to predict for individual suppliers.

Based on the literature review, the above researchers have already extensively studied both the effectiveness of supplier diversification to reduce supply volatility as well as applying spot market to manage demand uncertainty. However, limited research works have been carried out by adopting both reactive supply and multiple contract suppliers for yield uncertainty management. The incorporation of yield uncertainty into procurement decision making makes the supply more reliable and effective. Taking the advantages of both risk diversifications from a supplier portfolio and spot market, this paper manages to solve the problem of order allocation among multiple suppliers in the presence of spot market. Uncertain demand, volatiles spot price and unreliable supply are considered in the problem formulation. Moreover, the risk attitude of the buyer is also incorporated in the proposed model. Generally, two broad areas are related to our research: supplier diversification under yield uncertainty and procurement in the presence of spot market.

In addition, there is a lack of method to quantify the multiple dimensional and correlated risks when selecting suppliers. Some paper suggests using Analytic Hierarchy Process (AHP) to model the multiple dimensions of supply risks [8,21]. But AHP fails to express the correlation among risks which actually exist in the industry. For

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