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Activity-based divergent supply chain planning for competitive advantage in the risky global environment: A DEMATEL-ANP fuzzy goal programming approach

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ABSTRACT

Supply chain management allows modern enterprises to relax their own capacities and produce in a more flexible manner for diversified consumer demands. However, for an enterprise with divergent supply chain (DSC) and multiple product lines, to plan the production allocation for higher competitive advantage in the risky global market is a challenging problem. The existing literature still has not address this problem very well. This paper is aimed to treat this problem by using an integrated approach of activity based costing (ABC) and management, five forces analysis, risk and value-at-risk analysis, decision making trial and evaluation laboratory (DEMATEL), analytic network process (ANP), and fuzzy goal programming (FGP). The proposed model can effectively incorporate the key factors of precise costing, managerial constraints, competitive advantage analysis, and risk management into DSC forecasting and multi-objective production planning. A case study of a consumer-oriented cell phone DSC is also presented. The sensitivity analysis shows that identifying and relaxing crucial constraints can play an important role in DSC planning for higher competitive advantage and lower risk.

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1. Introduction

Supply chain (SC) operations enable producers to break through their limits of production with much more flexibility and thus they can focus on consumers' demands. In order to satisfy the diversified demands of consumers, manufacturers might produce various products in which some products may need common components for cost reduction, and form so-called divergent supply chain (DSC); for example, cell phone manufacturers might change the appearances and styles of their cell phones, and maintain the same basic inner-components (Fig. 1).

A SC may be viewed as a DSC if a SC node has one predecessor, but more than one successors (Beamon & Chen, 2001). Mineral industries and consumer-oriented industries often form such type of SC. This type of SC is opposite to a convergent supply chain (CSC). In a DSC, the critical issues of product mix planning, supply chain constraints, forecasting and risk management, and competitive advantage may have relationships with each other. For instance, over production of high risk and low competitiveness products, which may be caused by lack of suitable measurement or not suitably relaxing constraints, could result in ineffectiveness and low capacity efficiency. Especially in today's highly risky global market, how to address these issues and meanwhile achieve high cost-benefit performance has become an important research topic (Syntetos & Boylan, 2006). Fig. 2 shows the external environment and internal constraints for a supply chain (Robbins & Coulter, 2001). We can see that successful supply chain management relies on employing internal resources, finance, and strategy to achieve higher competitive advantage, avoid higher risk, and prepare for potential opportunity.

In the literature of supply chain management, the planning of supply chain is frequently discussed, whereas the integration of precise costing, SC constraints, competitive advantage, and risk management for a DSC still has not been deeply explored. How these elements could be included in DSC planning remains a problem to be solved.

To fill this gap, this research integrates activity based costing (ABC) and management, five forces analysis, risk and value-at-risk analysis, decision making trial and evaluation laboratory (DEMATEL), analytic network process (ANP), and fuzzy goal programming (FGP) for the DSC planning problem. This paper uses cost drivers at various levels (unit, batch, product, facility, supply chain) to measure activity amounts and costs, and identify the constraints of each activity in the supply chain. In measuring respectively the competitive advantage and risk of a product supply chain, DEMATEL is first used to analyze and determine the interdependence relationships between the criteria. Next, ANP evaluates the weights of the alternatives. Value-at-risk (VaR) is also used to measure the potential largest loss. Finally, FGP is used to obtain the optimal product mix and the worst profit. We found that this research

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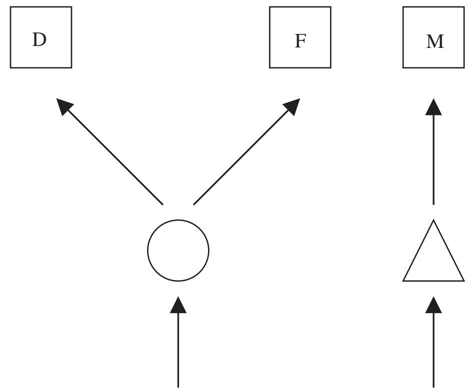

Fig. 1. A divergent supply chain (D, F) and a general supply chain (M).

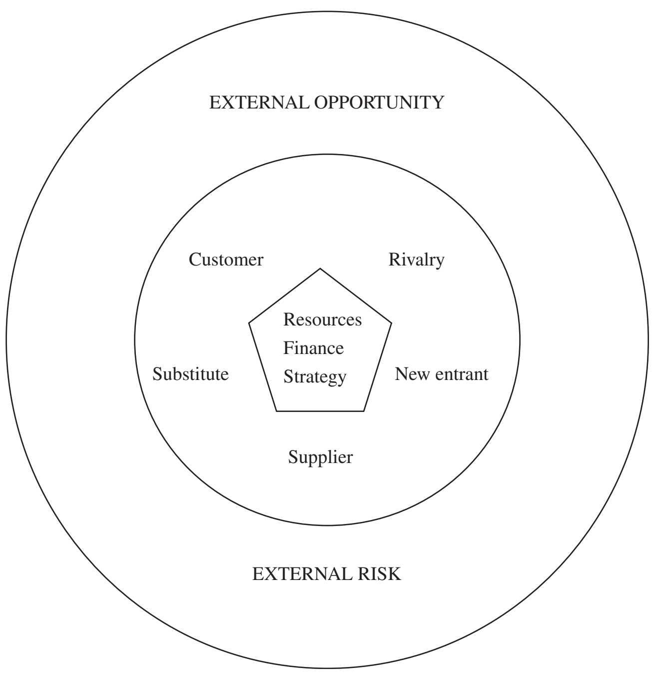

Fig. 2. The external environment and internal constraints for a supply chain.

develops a new approach that can not only improve DSC production planning, but also can efficiently strengthen DSC competitive advantage and risk management.

In the sensitivity analysis of the case study, this paper shows that identifying and relaxing crucial constraints can effectively improve DSC planning for higher competitive advantage and lower risk. In this case, supply chain management time is more crucial than common component capacity constraint. When only the common component constraint is relaxed, the overall planning of product mix is not affected. However, if the supply chain management time is first relaxed, it will increase the production of the higher competitive advantage and lower risk products, meanwhile relaxing common component constraint will also come into effect. Hence, identifying and relaxing crucial constraint is a step with priority in DSC planning. This paper provides a fine application of ABC and DEMATEL-ANP-FGP model in a DSC, and also assists SC managers in making appropriate decisions to decrease the revenue risks of their product mix and raise the overall competitive advantage at the same time.

The rest of this paper is organized as follows: Section 2 presents the literature review. Section 3 discusses the proposed DEMATEL-ANP-FGP model followed by a case study in Section 4. Section 5 concludes this study.

2. Literature review

Multi-product SC planning problems under uncertainty have been discussed by several papers. Mitra, Gudi, Patwardhan, and Sardar (2009) adopted a fuzzy mathematical programming approach to address the multi-site, multi-product, multi-period supply chain planning problem under uncertainty. The slot-based planning model results are obtained for different uncertain scenarios. This model does not require the knowledge of distributions associated with the uncertain parameters. Peidro, Mula, Poler, and Verdegay (2009) proposed a fuzzy mixed-integer linear programming model which considers supply, demand and process uncertainties in supply chain planning. They suggested that the fuzzy formulation is more suitable than deterministic methods in dealing with SC planning which is difficult to obtain precise or certain information, and needed to be modeled by triangular fuzzy numbers. Liang and Cheng (2009) addressed an integrating manufacturing/distribution planning decision (MDPD) problem with multi-product and multi-time period in supply chains by using a fuzzy multi-objective linear programming model (FMOLP) with the consideration of time value of money for each of the operating cost categories in an uncertain environment. Their method aims at minimizing total costs and total delivery time in association with inventory levels, available machine capacity and labor levels at each source, market demand and available warehouse space at each destination, and total budget constraints. Cakır (2009) discussed the problem involving multi-commodity, multi-mode distribution planning by applying the Benders decomposition which is suitable to addressing outsized distribution planning problems characterized with a large commodity set and many transportation mode options. To solve such problems that have an abundant number of discrete variables, the Benders method is efficient enough to isolate a group of decision variables and investigating the problem partially. Vila, Martel, and Beauregard (2006) proposed a mixed integer programming model which maps the industry manufacturing process onto potential production–distribution facility locations and capacity options production–distribution network of divergent process industry companies in a multinational context.

There are also some other papers investigating SC problems under uncertainty. Al-Othman, Lababidi, Alatiqi, and Al-Shayji (2008) adopted a multi-period optimization model to study the effect of uncertainties in market prices and demands on the supply chain of a petroleum organization in an oil producing country. They showed that in the situation with an appropriate balance between crude exports and processing capacities, impacts of economic uncertainties may be tolerated. It is essential that petroleum organization develop resilient production plans for the allocation of the produced crude between direct exports and local processing in an uncertain economic environment. Knemeyer, Zinn, and Eroglu (2009) develops a model that can proactively plan for catastrophic risk events, which specifically builds on existing risk analysis that is often implemented by the insurance industry to quantify the risk of multiple types of catastrophic events on key supply chain locations. The method also provides information to help managers with the generation and selection of appropriate countermeasures and thus mitigate the potential effect of catastrophic events on supply chains. The results reveal that this method is a systematic approach to estimate both the probability of occurrence and the financial impact of potential catastrophic events of those targeted locations with higher risk. Leung, Wu, and Lai (2006) presented a stochastic programming approach to evaluate optimal medium-term production loading plans under an uncertain environment

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