



Concurrent design of product family and supply chain network considering quality and price



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ABSTRACT

We study the problem of concurrent design of a product family and its supply chain (SC) network. Inspired by a real-life case in computer industry, the impact of quality and price in SC demand is investigated. Two different models are proposed, the former maximizes the company's profit with respect to customers' priorities on quality and price; the latter is a bi-objective programming, which consider two extreme customer groups: for one group quality has the highest priority and for the other price; the intermediate groups falls between these two. The performance of the models is analyzed through a case problem.

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1. Introduction

Quality and production costs are mainly influenced by product design and the product modules selection stage. A survey by Child et al. (1991) shows that 80% of production cost, 50% of product quality and 50% of business complexity is related to product design. Any changes in the structure of the product affect product's supply chain (SC) dynamics (Verdouw et al., 2010) and consequently its quality and price which are the most important influential factor in the markets' demands.

Mass customization (MC) is a production strategy to specialize products/services through modularized product/service design, flexible processes, and integration between SC members (Fogliato et al., 2012). As in today's market by more globalization, companies look for new strategies to increase their shares or at least to capture the same shares in the market as before; they identified MC as a driver of important competitive advantage in key production sectors such as automobile, clothing, and computer manufacturing (e.g., Dell). This strategy pushes manufacturers to move from the traditional mass production systems toward MC philosophy. Flexibility of production system helps many pioneer automaker companies such as Toyota to be able to incorporate ever-changing requirements of customers in today's competitive environment and improve their market shares.

Variety of products/services improves sales as it covers the needs of wider range of customer groups; nonetheless, variety management is an issue (Child et al., 1991). Thus, a company must assess the level of variety at which customers' needs will

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be satisfied while keeping complexity in a rational level (Jiao et al., 1998). In this study, several products are considered and the modules in these products are determined to make them compatible with customers' needs.

In the literature, SC demand is normally considered as a function of price, service level, distance, and quality. Omission of product quality in the SC demand's literature is the motivation of this research. In the real-world applications, quality plays a significant role in a product/service demand. Most renowned clothing, automotive, and computer companies achieved their reputation through the quality of their products. Brand of a company is a sign of people's trust on the company's products quality. But, even well-known companies, in order to capture higher market share, need to produce products or serve services with different levels of quality and price. Consequently, consumers will trade-off on price and quality to choose the best product/service which meets their needs.

This paper focuses on a company including a SC offering a product family for different customer groups. Although we study mass customized products, we do not involve in design stage. We assume a set of available options for each module with different qualities and prices are given. It is presumed that a module with a higher quality has higher cost, which is a rational assumption. With regard to customers demand, we decide on components of a product family. We assume quality and price are two most important factors which affect the demand of the markets and customers' selection behaviors. Quality has two conflicting effects on the SCs' demands: (i) improving quality attracts the customers which are looking for high quality products, and at the same time, (ii) it causes loss of customers who are sensitive to the price increase resulted from quality improvement. This diversity in customers' expectations forces the company to supply a family of products to the markets with different qualities and prices compatible with the needs of various customer groups.

In this paper, two mathematical models are proposed for concurrent design of a product family and its SC network (SCN) with respect to modularity aspect. In the first model, with regard to customers' priority, the manufacturer decides on modules which are compatible with customers' needs in order to maximize the company's profit. The second problem is formulated and solved as a bi-objective model considering two extreme customer groups: one extreme group gives the highest priority to quality and the other gives the highest priority to price; all other intermediate groups can be positioned somewhere between these extreme cases.

Inspired by a real-life case in computer SC, we consider a two-tiered SC consisting of some available suppliers, a manufacturer and several potential retail outlets for supplying products to the available markets; this configuration applies to many other SCs like garments, oil products, pharmaceutical and automotive. The SC strategy is to develop and supply a product family with various costs and quality specifications to the markets. The developed models determine (i) which modules should be included in each product? and (ii) what should be the quality level of the selected modules? These decisions are made in a way to maximize the company's profit while considering the customers priorities on price and quality. This study investigates how product quality selection and product modularity affect the profitability of a SC; the trade-off between the positive and negative effects of the product quality on the profitability of its SC takes us to concurrent design of the product and its SC network.

The rest of this paper is organized as follows: Section 2 positions this paper in the literature and highlights the gap that is supposed to be filled by in this research. Section 3 describes the details of the problem considered in this paper; moreover, problem formulation and typology of product SC are presented. In Section 4, a bi-objective solution approach is presented. Section 5 describes the case study that was origination of this research including the used data; the computational results are provided. In Section 6, sensitivity analysis on different input parameters is performed and some managerial insights are extracted. Finally, the research is concluded in Section 7 and some future directions are proposed to cover limitations of this research.

2. Literature review

Several streams of research pertain to this paper among which, in the sequel of this section, we particularly present an overview on studies related to MC, SC demand factors and concurrent design.

2.1. Mass customization

As argued in introduction section, MC is a production strategy focusing on the broad provision of personalized products and services (Davis, 1989; Pine et al., 1993), mostly through modularized product/service design, flexible processes, and integration between SC members. Silveira et al. (2001) did an extensive review on MC; later, Fogliato et al. (2012) updated their work. Interested readers may refer to these papers for more information on MC. They introduce MC success factors as: customer demand, markets, value chain, technology, and customizable offer. The focus of this paper is on customer demand and customizable offer. Although we assume various markets with different demands, we do not extend our focus to market properties. It is worthwhile to mention that we do not study MC from product design perspective. However, we assume a set of options with different quality and cost to produce a product family. Many authors such as Agard and Bassetto (2013) study this problem at the design stage. They define quality as persisting against the failure, and try to improve it in order to capture more shares in the market.

Incentives of MC strategy are listed as providing enough variety that any customer find exactly what he/she wants with a reasonable price, allowing producers to customize products at low cost, and bringing customer specifications into the

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