European Journal of Operational Research 225 (2013) 383–392

Contents lists available at SciVerse ScienceDirect

European Journal of Operational Research

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

Production, Manufacturing and Logistics

Production and availability policies through the Markov Decision Process and myopic methods for contractual and selective orders

Gary H. Chao *

Department of Business Administration, Kutztown University, PO Box 730, Kutztown, PA 19530, USA

ARTICLE INFO

Article history:
Received 8 June 2011
Accepted 5 October 2012
Available online 22 October 2012

Keywords:
Supply chain management
Information-sharing
Markov Decision Process
Production/availability policy

ABSTRACT

In this paper, we consider a supply chain with one manufacturer, one retailer, and some online customers. In addition to supplying the retailer, manufacturers may selectively take orders from individuals online. Through the Markov Decision Process, we explore the optimal production and availability policy for a manufacturer to determine whether to produce one more unit of products and whether to indicate "in stock" or "out of stock" on website. We measure the benefits and influences of adding online customers with and without the retailer's inventory information sharing. We also simulate the production and availability policy via a myopic method, which can be implemented easily in the real world. Prediction of simple switching functions for the production and availability is proposed. We find the information sharing, production capacity and unit profit from online orders are the primary factors influencing manufacturer profits and optimal policy. The manufacturer might reserve 50% production capacity for contractual orders from the retailer and devote the remaining capacity to selective orders from spontaneous online customers.

1. Introduction

As the Internet increases information exchange and boosts product diffusion, companies can reach customers more easily and broadly; meanwhile, consumers can survey price and product information extensively and effortlessly. Companies can also benefit from automatic online transactions, which improve process accuracy and minimize resource and expenditure. This new business model, e-business, brings new opportunities and challenges to traditional brick and mortar companies. Should companies sell products through established distribution channels, online channels, or both? If they decided to sell products through both channels simultaneously, how could they manage these two channels? Especially for small and medium-sized companies, their expertise might be on product design and process control. They used to sell products through retailers who are more knowledgeable in responding to customer inquiries and needs. Do they need to establish the capacity for marketing campaigns and consumer services? There is no panacea for all companies. Manufacturers could sell products to consumers directly; however, they might differentiate orders from retailers to consumers. The manufacturer may treat retailer orders with higher priority because of stable revenue opportunities and economies of scale. If so, how should a company respond to online individual requests? How would an extra online sales channel affect the manufacturer's operating performance? Even though we are discussing the influence of the extra online sales channel in this paper, the same study can be applied to other extra sales channels with uncertain, dispersed and random demands, like outlets, or company stores.

There are many companies with on- and off-line sales channels, such as hard drivers (e.g., Seagates and Western Digital), memory modules (e.g., Kingston and Crucial), cameras (e.g., Sony and Nikon), clothing (e.g., Lands' End and L.L. Bean), and chocolate (e.g., Hershey's and Godiva). Burt's Bees sells most of its lip balms and other natural beauty and personal care products through retailers like Walmart, Walgreens, and Amazon. Consumers also can purchase the same lip balms directly from the company's website (www.burtsbees.com). Those balms are identical and sales prices are almost the same. Burt's Bees deals with retailers and online individual consumers simultaneously. Certainly, Burt's Bees can earn higher unit profits through its website than those from retailers. However, the characteristics of retailers are different from those of online consumers. Burt's Bees cannot treat online consumers the same way as it treats retailers.

The biggest difference is that there is an obligation (written or unwritten) between the manufacturer and its retailers; this is especially true when retailers have great influence over the supply chain because of reputation and size (e.g., Walmart). Contractual relationships between a manufacturer and retailers ensure product diffusion, a steady revenue stream, and efficient utilization of equipment and resources for the manufacturer. The manufacturer

* Tel.: +1 610 683 1373; fax: +1 610 983 4537.
E-mail address: chao@kutztown.edu

0377-2217/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ejor.2012.10.005

had better to fulfill orders from the retailer; if products are not available when the retailer places an order, the manufacturer may experience negative consequences. Even if there is no legal contract between the manufacturer and the retailer, opportunity costs, such as a switch to a competitor's products, the reduction of product shelf space, and the delay of revenues, could be regarded as the penalties to the manufacturer. To avoid such penalties, the manufacturer might carry more inventories, especially when order frequency is uncertain and order quantity is large. However, it is unwise to keep a high inventory level continuously because of holding cost and possible obsoleteness. Thus, it is necessary for a manufacturer to develop a policy to determine an optimal and dynamic inventory policy.

The access to retailer inventory information allows the manufacturer to carry the right amount of products at the right time. Without real end-user demand information, each player in the supply chain seeks its own local, instead the global, optimization for the entire supply chain. Insufficient or biased demand information will cause bullwhip, which consumes more cost and time in the supply chain; thus, true demand and inventory information should be disseminated throughout the supply chain. With the instantaneous retailer inventory level and end-user demands, the manufacturer could optimize its inventory level. Moreover, information technology makes the access to retailer inventory information easier, faster, cheaper, and more accurate. In this paper, we appraise how much benefit a manufacturer can obtain with retailer inventory information.

In addition to retailers, the manufacturer can directly sell products to online customers to collect extra profits. Compared with retail orders, online orders are usually smaller and dispersed, but the unit profit is more attractive. Online orders could help Burt's Bees increase profits and inventory turnover. Moreover, since there is no contractual relationship between Burt's Bees and individual consumers, it does not have to satisfy each online request. Burt's Bees can place "sold out" or "out of stock" messages on the website if there is no enough inventory or there is a need to reserve products for incoming retailer orders. Thus, Burt's Bees needs to set up an availability policy to optimize online transactions without endangering the promised supply to retailers.

In this paper, we build a capacitated supply chain model with one manufacturer, one retailer, and individual online customers. There is a contract between the manufacturer and the retailer and the manufacturer has an obligation to fulfill each order from the retailer. The manufacturer needs to determine the optimal production schedule and to figure out whether it can sell products online or not; it needs to set up an optimal production and availability policy. In the following sections, we review relevant literature in the next section. Then we apply the Markov Decision Process (MDP) and the myopic method to help the manufacturer develop an optimal policy to maximize expected operating profit. We also evaluate the value of the retailer's inventory information, the benefit of adding an online sales channel, and the difference between the MDP and myopic models. Finally, we predict the switching functions of production and availability to help the manufacturer construct an easily implemented optimal policy for daily operation.

2. Literature

One of the most distinguished examples of the implementation of information sharing is Campbell Soup's Continuous-Replenishment Program (Cachon and Fisher, 1997; Fisher, 1997). In the traditional Electronic Data Interchange (EDI) ordering system, EDI increased the order delivery process, but nothing about the inventory or market information was shared with members in the supply chain. Many papers studied the benefits of information sharing with partners in the same supply chain. Cachon and Fisher (2000) discussed the effects of lead and batch size without production capacity constraints. Chen (1998) considered a serial multi-stage supply chain with (R,nQ) order policy. Chen (2011) studied a monopolist selling a single product to heterogeneous market segments differentiated by price-delay combinations. Gavirneni et al. (1999) explored partial and complete information sharing in a supplier–retailer setting under different distribution patterns, production capacity, and holding costs. Simchi-Levi and Zhao (2000) investigated information sharing savings under varying production capacities and penalty costs, and how and when shared information is valuable to a manufacturer. Those papers suggested that information sharing helps members of the supply chain shrink total inventories, allocate inventories properly, maintain or enhance service levels, and increase operating profits throughout the chain. Lee and Whang (1998) found that when aligning incentives of different partners, confidentiality of shared information, regulation, and technology issues prohibit information sharing prevalence. Most papers focused on one supplier and one or many independent and identical retailers. Li (2002) took another view on the impact of horizontal competition among retailers; the effect of vertical information sharing on competition is remarkable by wholesale pricing and information leakage under assumptions of demand or cost uncertainty. In addition to inventory information from the direct retailer, the supplier could also look at cumulative end-customer demand. Gavirneni (2002) found the model works well, especially under high production capacity, low ordering costs, low penalty cost, and low demand variance.

Some researchers studied supply chains with more than one retailer. Huang and Iravani (2005) discussed the values of differing amount of information sharing within a supply chain with one supplier and two retailers; they use the MDP to choose optimal production control policies. Huang and Iravani (2006) showed that the optimal production and stock rationing policy generated from MDP is superior to first come, first served and modified echelon-stock rationing policies. Huang and Iravani (2008) continued their study on optimal production and rationing policies under the influence of customer classes and batch order quantity. Garyon et al. (2009) studied optimal production policy for a make-to-stock supplier that receives orders from different customer classes; they propose that it is beneficial to the supplier if advanced demand information (ADI) was provided by the customer. However, ADI may cause fill-rate reduction for some customers because the supplier uses ADI to reduce inventory costs. Ren et al. (2010), Chen (2011), and Guan and Zhao (2010) also examined how the retailer information affect benefits a supply chain.

Switching functions help a manufacturer define the optimal operating policies. Huang and Iravani (2003) used the MDP to demonstrate that switching functions behave like a monotone base-stock policy. Carr and Duenyas (2000) addressed the problem of admission control and sequencing in a production system that produces two product classes, one make-to-stock (with penalty for failure to fulfill orders) and the other make-to-order. They found the switching curve for optimal production is a decreasing function, and the curve for acceptance of make-to-stock is an increasing function. Although sharing information is always beneficial to the manufacturer in a decentralized supply chain, it is not necessary and economical for manufacturers to require all retailers or customers to share information. Huang and Iravani (2003) suggested the supplier offer selective information to retailers with the lowest operating costs. In reality, it is common for manufacturers to treat retailers and individual customers differently in terms of order priority. That is, if there is not enough product on hand, the manufacturer prefers to fulfill the retailer order first and the manufacturer may show "out of stock" to online individual customers. Here, we