Computers & Industrial Engineering 125 (2018) 451–466

Contents lists available at ScienceDirect

Computers & Industrial Engineering

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

Single-period ordering and pricing policies with markdown, multivariate demand and customer price sensitivity

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ARTICLE INFO

Keywords:
Single-period problem
Short lifecycle products
Multivariate demand
Promotional markdown
Customer segments

ABSTRACT

This paper studies single-period ordering and markdown pricing policies for short lifecycle products (SLP) by considering differing customer price and time sensitivities. The SLP is assumed to have declining customer valuation (and price) over the selling season and multivariate demand, which is a function of the inventory level, price and time. Promotional markdown (in contrast to clearance markdown) becomes an indispensable part of a pricing policy in view of stock-dependent demand and isused as a mechanism for customer segmentation and price discrimination over time. To offer a realistic pricing, we consider the impact of highly price-sensitive customers who value the price of the product over its innovativeness and who act strategically by purchasing only during a'sale' at a markdown price.

In this context, single-period inventory models are formulated to include markdown under two market scenarios, namely the homogenous market and thetwo-segment market – *a price insensitive (PI) segment, and a price-sensitive (PS) segment*. The assumption of non-overlapping segments is relaxed later, and PI customers are allowed to buy later on at a markdown price. The proposed profit-maximising models determine the optimal order size, initial price, markdown time, and price. The solution methods along with the optimality conditions are specified in detail. The results are discussed by using numerical examples, and model behavior with respect to parameters is presented along with the sensitivity analysis.The study reveals the benefits of market segmentation and markdown pricing which recognise high price-sensitive 'bargain hunter' customers and offers deeper discounts that yield greater profits. It also demonstrates the superiority of a markdown policy to a single pricing policy, and the benefits of considering the demand stimulating-effect of inventory.

1. Introduction

Currently, markets are flourishing with short lifecycle products (SLP) such as fashion goods, sports goods, consumer electronics (for example, mobile phones), video games, seasonal merchandise that is associated with holidays/special events and the like. Moreover, the proportion of these products in the retailer's merchandise is increasing with the shortening life cycles of traditional products such as telephones and computers (Fisher & Raman, 1999). The important characteristics of the SLP include a short selling season, single pre-season purchase order, uncertain demand, and low salvage value. The ordering problem of SLP is studied extensively as a newsvendor problem/single-period inventory model (SPIM) (Choi, 2012; Gallego & Moon, 1993; Kalpana & Kaur, 2012; Khouja, 1999; Qin, Wang, Vakharia, Chen, & Seref, 2011). The SPIM, in general, is probabilistic and presumes demand as an exogenous random variable with known distribution. However, in reality, demand is a result of the simultaneous acts of a multitude of factors such as price, inventory level, promotional efforts (for example, advertising, more display space) and the like. Notably, some of these factors can be manipulated by a retailer firm. Though the impact of these individual variables has been considered in formulating inventory models, only a few SPIMs have considered the simultaneous influence of these variables on the demand. Therefore, our study considers demand as being a result of many factors, by using a multivariate function of *price, time and inventory level*.

Though a SPIM is essentially probabilistic, a case of deterministic stock-dependent demand is studied as a SPIM, because there is, essentially, a loss of demand (sale) with the decline in the inventory level. An order size that is just equal to the demand leaves no inventory at the end of the season. However, there would be lost sales from the diminished demand, which in turn is a result of the relatively low inventory level. Therefore, it would be more profitable to carry a higher level of inventory, which results in higher demand even though some unsold units need to be salvaged at the end of the season (Urban & Baker, 1997).

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https://doi.org/10.1016/j.cie.2018.09.004
Received 3 November 2016; Received in revised form 31 August 2018; Accepted 4 September 2018
Available online 06 September 2018
0360-8352/

It is generally observed that, for a certain type of products (for example, fashion apparel), a higher level of inventory leads to more sales. This demand-stimulating effect of the inventory is often referred to as the "billboard effect" (Xue, Ozgun, Chen, & Yi, 2017). The effect may be explained in terms of increased visibility and availability, the perception of the product's popularity, high quality, and so on. The greater stock levels provide a wider choice to the buyers and, therefore, the increased probability of sale. Conversely, lower stock levels of certain goods (for example, donuts) may raise a perception of lower quality of products (Balakrishnan, Pangburn, & Stavrulaki, 2004). Researchers have found a positive relationship between inventory and sale for style merchandise such as women's dresses, sports apparel, magazines, and such others (Koschat,2008; Levin & McLaughlin, 1972; Silver & Peterson,1985; Whitin,1957; Wolfe, 1968). The minimum display inventory that is needed to stimulate the demand has been termed variably as 'psychic stock' (Larson & DeMarais, 1990) and 'fixture fill' (Smith & Achbal, 1999). Many retailers take advantage of the demand-stimulating effect and stock more inventory than necessary, which leads to the phenomenon of 'stack them high, let'em fly' (Balakrishnan et al., 2004). An inventory problem that considers stock-dependent demand has been investigated extensively (Urban, 2005). Thus, besides providing a high level of service, inventory plays a promotional role in stimulating the demand. Therefore, it is important for the retailers to consider the endogenous demand effect of the inventory while developing profitable inventory management strategies.

Retailers generally use a pricing strategy to spur demand for their merchandise. Knowledge of demand (quantity demanded at a specific price) is critical in making optimal pricing and ordering decisions. A demand function specifies a relationship between demand and price and is typically a decreasing function of its price. Moreover, the demand rate of SLP may vary across the selling season—selling more at the beginning of the season or at the end of the season. For example, fashion apparels, topical books, toys, and video game DVDs are expected to sell more at the start of the selling season, whereas holiday greeting cards are expected sell better at the end of the season, as the holidays approach. For the simplicity of exposition, we consider SLP, the demand for which declines over their selling season and a power functional form is used to include this time diminishing demand. The demand function is discussed in detail in Section 3.3.

With a consideration of a stock-dependent demand, a retailer is likely to order more to stimulate demand and would prefer a profitable in-season price markdown to salvaging at the end of the selling season. Secondly, retailers are increasingly using markdown as a mechanism for customer segmentation and price discrimination. They consider differences in customer valuation (reservation price/willingness to pay) and the timing of a purchase while pricing a product. New products are offered initially at a premium price; subsequently, the price is reduced in the latter part of a selling season. High-valuation customers buy early at higher prices, whereas low-valuation customers purchase at 'sale' prices later in the season (Kalish, 1983). Thirdly, customer valuation of a product decreases over time because of the time of its use (more utility of early purchase), deterioration, and obsolescence (Philips, 2005). For example, consumers' valuation of fashion and seasonal items (Desiraju & Shugan, 1999) or high technology products such as the iPad (Du, Zhang, & Hua, 2015) is the highest at the start of the selling season and declines thereafter. The declining valuation necessitates a price markdown that would generate consumer surplus and persuade potential customers to buy. The study has considered SLP, the valuations and prices of which decline over their selling period.

Broadly, two types of pricing policies are studied in the literature: pre-announced fixed pricing policy and inventory contingent pricing policy. In the pre-announced pricing policy, prices are predetermined and announced before the start of the selling season. A well-known example of the policy is Filene's Basement, where unsold items after 2, 4 and 6 weeks are sold with a markdown of 25%, 50%, and 75%, respectively. In contrast, the inventory contingent pricing policy is a reactive response to clear off the leftovers, and markdown prices are dependent on the leftover inventory level. The pre-announced strategy is meant to segment customers that differ in their valuations, so that high- (low-) valuation customers will purchase the product at the regular (markdown) price. Thus, in our case, the price markdown is pre-announced, deliberate, proactive, planned and promotional and a retailer has a single opportunity to markdown the product at a predetermined time of the season. While multiple markdowns may be more beneficial to a retailer, our assumption prevails in settings in which frequent price changes are inconvenient or difficult because of the cost and short duration of the selling season.

Differences among customers, with regard to product valuation, price sensitivity, innovation (or fashion) consciousness, purchase timing and the like need to be considered while formulating a realistic retail pricingpolicy. Customers' valuation of a product is highly subjective and dependent on factors such as disposable income, desire for the product, and so on. Price sensitivity refers to a weight assigned to a product price relative to other attributes and to the extent to which individuals respond to changes in its price. Price sensitivity is an *individual difference variable* and has two important dimensions: price importance and the willingness to pay (Kalra & Goodstein, 1998). Fashion-sensitive customers, who look for fashion content, tend to be less price-sensitive (willing to pay more) than economical bargain hunters. On the other hand, highly price-sensitive and forward-looking customers defer their purchases in expectation of future markdowns. An important measure of price sensitivity is the price elasticity of the demand, which describes an *aggregate response* of a market segment to price levels. To study the impact of differing customer prices and time sensitivities, we consider a two-segment market: the price-insensitive (PI) segment and the price-sensitive (PS) segment. The customers of the PI segment are price-insensitive (within a price band) and value product innovativeness (including fashion content, novelty, features, technological superiority, and such others) over its price. These high-valuation customers buy early and at a premium price, without considering the future price path (myopic behaviour). This buying behaviour can be attributed to their desire to derive greater consumption utility from an early purchase or to avoid a risk of non-availability in the future (Du et al., 2015). In contrast, customers of the PS segment have low product valuation and value price over its innovativeness. They are willing to forgo the utility of an early purchase and buy the product only when its price is marked down sufficiently below their valuation. This behaviour and customer segmentation is discussed in detail in Section 4.2. These two segments are similar to the PI and PS segments of Desiraju and Shugan (1999); the myopic and bargain hunting segments of Cachon and Swinney (2009); the myopic and strategic customers of Elmaghraby and Keskinocak (2003) and Du et al. (2015). Initially, these segments are assumed *non-overlapping*, implying that PI customers would not buy at a discounted price during the markdown period. However, this assumption is relaxed later on (Section 4.4). Thus, this paper studies the impact of differing price and time sensitivities on ordering and markdown pricing under two market scenarios: the homogenous market and the two-segment market, which is similar to the study by Li and Yu (2017). In all, we formulate four inventory models, as shown in Fig. 1.

The present study is inspired by Urban and Baker (1997) and carries a similar theme, but with significant departures. Our work makes manifold contributions and goes beyond determining the order size and the markdown price in the homogenous market. Firstly, to the best of our knowledge, we are the first to study the impact of price and time sensitivities of customers on ordering and markdown pricing, by using a two-segment market. It demonstrates the benefits of markdown pricing and market segmentation, which are larger profit and order size, over single pricing and a homogenous market. Second, to make the pricing more realistic, we generalise the situation by allowing a high-valuation and price-insensitive customer to buy at discounted prices during the markdown period. The study reveals that it results in a larger profit and