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Decision Support

Maximizing revenue of end of life items in retail stores

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A R T I C L E I N F O

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A B S T R A C T

Classical and even contemporary global supply chains have been built to reduce lead times and minimize costs. That has led companies to compete on the value of their supply chains as a competitive weapon. In this new era, many enterprises are realizing that supply chains can be revenue producing and help their sustainability efforts.

In this light, we consider the discount pricing of products that are being phased-out in retail stores. The decision to replace an item triggers a time horizon for the retailer to sell the existing inventory, hence the need to develop markdown strategies to deal with the issues of how much to discount the item, when to introduce these discounts, and if inventory should be left at the end of the time horizon to sell at some salvage price to a third party wholesaler. In this paper, we develop two models. The first one is an optimal markdown strategy that maximizes revenue from the discontinued items using multi-period nonlinear programming. The mathematical properties of the model are established and a closed form optimal solution is found. The second one is a linear programming model that addresses the issues of when and for how long during the phase-out time horizon to apply prices chosen from a pre-determined price set. These models are tested with real data provided by a retailer.

1. Introduction

Inventory management is a crucial aspect of the bottom line regardless of what the business is. From accounting and financial perspective, inventory is an asset for businesses. Inventory is a buffer against uncertainty. However, inventory items have a limited life cycle. There is a window of opportunity to sell the product. Once that window closes then the sales value of it decreases and the profitability and inventory yield are not maximized. In addition to too much capital tied up, excess inventory influences service and operations. There are many reasons for excess inventory, and more often than none, the inventory buildup is not due to one reason only. Instead, multiple causes create the over-inventory situation. The multiple reasons reflect the lack of underlying priority, process and control.

In this paper, we will be addressing the excess inventory of products at the end of their life cycle, and determine the best pricing strategies for these phased-out items. Once the decision has been made to discontinue an item, the question becomes: when and by how much to markdown the item in order to deplete the given initial inventory on time. Making wrong decisions could result in a surplus of unnecessary inventory or worse, a loss in profits. In addition, we will also address the case of predetermined markdown prices, i.e. when and for how long to discount at each one of these prices. Fig. 1 below depicts the phase-out process, with an initial inventory (I) to be depleted during the phase-out time horizon (T), and either no inventory or some remaining inventory (r) at the end of the fixed phase-out time horizon is left to be sold to a third party wholesaler.

This paper was motivated by a real world problem facing a retailer, owning over 6000 stores in the U.S. A manufacturer/distributor, who supplies most of the items to the retailer, reviews all items and twice a year selects the ones to be phased-out. To retain anonymity, we will refer to them in this paper as retailer X and distributor Y. The phase-out time horizon is normally nine weeks. The items chosen for this research were taken from the cosmetic products category, which presented some of the most difficult inventory issues. The phase-out decision can be either a soft one, where there is only a change in packaging, or a hard one where the item is replaced by a different item. The replacement decision taken by the distributor can be either due to the non-sales or the short life cycle of certain products. Ineffective markdown strategies and sometimes failure to stop supplying

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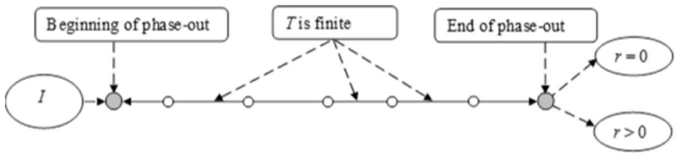

Fig. 1. Phase-out process.

the discontinued items during the phase-out time horizon, led to about dollar 10 million of total surplus inventory for retailer X.

In order to address the key problem at hand, historical sales data of the phased-out items were analyzed and a nonlinear regression model was developed to study the demand-price relationship. The model was then used to predict the behavior of an obsolete inventory item over a certain phase-out time horizon. Given an initial inventory to be depleted, the best price for each period can be determined in order to maximize revenue. In the case that the whole initial inventory is unable to be entirely depleted, and the option to sell the remaining inventory to a third party wholesaler at a particular salvage price is present, the model is modified to determine that remaining amount of inventory, and the new optimal prices for each period in order to maximize revenue.

The rest of this paper is organized as follows. Literature review is provided in Section 2. In Section 3, the price elasticity of demand and the demand-price relationship is derived from historical data followed by the development of two optimization models that maximize revenue from the discontinued items. Section 4 contains computational results and Section 5 conclusions and recommendations for future research.

Most often markdown prices in retail stores are not arbitrary but are selected from a set of predetermined prices. For example, if the regular price of an item is dollar 9.99, likely discount prices are dollar 8.99, dollar 7.99 and dollar 6.99. A second model is presented in this paper to determine the number of periods at which each predetermined markdown price is set during the phase-out time horizon in order to maximize total revenue from the phased-out items.

2. Literature review

Inelastic demand allows a producer to raise prices without much affecting demand for the product, whereas elastic demand exists when consumers are sensitive to the price at which a product is sold and will not buy if the price rises by what they consider excessive.

There has been an increasing adoption of dynamic pricing strategies and their further development in retail and other industries (Coy, 2000). Three factors contributed to this phenomenon: an increased availability of demand data, an ease of changing prices due to new technologies, and an availability of decision-support tools for analyzing demand data and for dynamic pricing.

Companies must be aware of their own operating costs and availability of supply, and they must have a good understanding of the customer's reservation price as well as the projection of future demand. Past research tried to address inventory problems, such as Whitin (1955) who was one of the first to highlight the fundamental connection between price theory and inventory control; Scarf (1960) who addressed optimal policies for multi-echelon inventory; and Porteus (1971) who examined a standard inventory model with a concave increasing ordering cost function. However, today, new technologies allow retailers to collect information not only about the sales, but also about demographic data and customer preferences (Elmaghraby & Keskinocak, 2003). Despite significant improvements in reducing supply chain costs via improved inventory management, a large portion of retailers still lose millions annually as a result of lost sales and excess inventory. Pourakbar, Frenk, and Dekker (2010) addressed the end of life inventory decisions for electronics service parts, and adopted an alternative policy to meet demands for service by offering customers a replacement of the defective product with a new one or giving a discount on the next generation of the product. Furthermore, Pourakbar, Van Der Laan, and Dekker (2012) presented a finite horizon Markov decision process to characterize the structure of the optimal inventory control policy. Continuing the work, Pourakbar, Van Der Laan, and Dekker (2014) addressed the returns of phase-out items, where a non-stationary demand arrival process is assumed. The structure of the optimal policy in the final phase is characterized and is shown that the optimal policy is a time-varying decision.

Other worthy literature in the inventory planning of old and new generations of the product together with the timing of the release of the product is mentioned in Li, Graves, and Rosenfield (2010). Furthermore, worthy literature that deals with service parts are mentioned by Hong, Koo, Lee, and Ahn (2008), Inderfurth and Kleber (2013), and Kleber, Schulz, and Voigt (2012).

According to Elmaghraby and Keskinocak (2003), there are three main characteristics of a market environment that influence the type of dynamic pricing problem a retailer faces: replenishment vs. no replenishment of inventory (R/NR), dependent vs. independent demand over time (D/I), and myopic vs. strategic customers (M/S). Based on different combinations of the 3 above-mentioned characteristics, different categories can be formed.

Analytical models by Zhao and Zheng (2000) study how pricing decisions should be made in NR-I markets have the following common assumptions: the firm operates in a market with imperfect competition, the selling horizon T is finite, the firm has a finite stock of n items and no replenishment option, investment made in inventory is sunk cost, demand decreases in price P, and unsold items have a salvage value. Pricing decisions in such markets are mainly influenced by demand, and how it changes when prices change along with other factors (*elasticity of demand*). In particular, pricing decisions need to look at the arrival process of customers and the changes in the customer's willingness to pay over time.

Caro and Gallien (2010) presented a cost driven model where lacking service is translated into backorders and penalties, by using generic LTB and control policies. Feng and Chen (2003) considered a joint pricing and inventory control problem with setup costs and uncertain demand. Specifically, they developed an infinite horizon model that integrated pricing and inventory replenishment in a distribution environment, where they allowed for dynamically varying prices in response to changes in inventory levels by taking advantage of price-sensitive demand. In contrast, Zhao and Zheng (2000) modeled the demand as a non-homogenous Poisson process with rate λ_t and allowed the probability distribution of the reservation price ($F_t(P)$) to change over time.

Polatoglu and Sahin (2000) studied a periodic-review inventory model where, in addition to the procurement quantity, price is also a decision variable. They developed a model where demand in each period is a random variable having a price and, possibly, period-dependent probability distribution, with the expected demand decreasing in price.

When dealing with inventory replenishment, an eye must be kept on the effects of setting the price too low or too high. If it is too low, it could risk stock-outs and lost sales while waiting for replenishment. And if set too high, it could lead to excess inventory and high holding costs.

Chen and Simchi-levi (2002, 2003, 2004), Chan, Simchi-Levi, and Swann (2001) and Chan, Muriel, Shen, Simchi-Levi, and Teo (2002) extend the previous research to include a fixed ordering cost and limited production capacity. Biller et al. (2005) focused on models where the seller faces a deterministic demand.