Assortment Optimization with Product Level Demand and Substitution Information

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ABSTRACT

This article presents a mathematical model for jointly optimizing base stock levels for the multiple items subject to service level goals. The proposed model uses the expected demand and substitution probabilities between products as inputs and has been used to analyze the effects of demand variability on profitability under service level constraint. The results of the analysis demonstrate that neglecting customer-driven substitution or excluding the impacts of variability and correlations in demand leads to significantly inefficient assortments.

KEYWORDS

Assortment Planning, Demand Variability, Mixed Integer Programming, Retail

INTRODUCTION

The issue of understanding customer preferences and offering them a profit-maximizing assortment of products/choices is fundamental in domains such as retail and revenue management (Rusmevichientong, Shen et al., 2010). Retailers need to think about profits, but customer satisfaction through maintenance of a desired service level is key to survival in a competitive environment (Wen & Chen, 2010; Yücel, Karaesmen et al., 2009). Modern day assortment planning therefore focuses on solving the twin problem of what products to stock and in what quantity while accounting for the desired service level that needs to be fulfilled (Mahajan & van Ryzin, 2001).

Customer satisfaction, a key element of competitive strategy, can be measured in different ways—delivery speed, cost, quality, customization, personal attention, product variety, etc. (Cobb, 2017; Kurdhi, Santoso et al., 2016). In the context of assortment planning, customer satisfaction is related to (a) the ability of the retailer to stock the specific product that the customer is looking when she is looking for it (i.e., satisfy the customers primary demand), and (b) the retailers ability to offer an acceptable substitute in case the primary demand cannot be satisfied. Given the shelf size constraints and the cost of maintaining a large variety, there is a tradeoff in profitability and customer satisfaction. In this paper, we focus on service level and profitability in the retailing environment, and analyze the impact of maintaining a low inventory cost for product assortment on achieving desired service level under different constraints.

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In this environment, a number of issues complicate the optimization of product assortment. First, customer demand for products is not known precisely because of high demand variability. When a particular product assortment is facing demand uncertainties, stock outs can occur during a certain time period. A stock out may cause lost sales and product substitution. Therefore, safety stocks should be kept to increase the service levels. Safety stocks are necessary to make the product assortment, which is driven by forecasts of product demand, responsive to demand variability and to achieve predefined target service levels. Second, when certain products are not stocked or stocked out, substitution causes the demand for the remaining products to increase, affecting their optimal inventory levels. If there is no acceptable substitute, a lost sale happens (Smith & Agrawal, 2000). The substitution results in correlated demand, which is one of our focuses in this study.

In our current work we develop an inventory control system that achieves the desired aggregate and separate service levels at a minimized cost. Given true demand, its variability and substitution structure, this paper provides a tool for solving the problem of product assortment and inventory planning for a given product category under customer-driven demand substitution in a single-period setting. A mixed-integer programming model is introduced for this problem in order to determine which product types should be included in the assortment, as well as the optimal ordering quantities for the offered product types. Safety stock is also introduced into the model to handle demand variability. On the demand type, we take into account independent and dependent demand, and then examine their impacts on the profitability. By solving this model with different settings of demands and parameters designed in our computational experiments, we analyze the importance of various aspects of the problem such as variability in estimation, service levels and different types of demand, and compare their performances in terms of profitability and quality of service under these different combinations of conditions. Our model also takes into account other realistic issues in retail context such as customer substitution behavior and inventory management decisions in the presence of shelf space limitations and other constraints. The model finds an optimal policy that maximizes expected total profit over a planning horizon for which demand and customers’ substitution preferences can be forecasted.

Our optimization model can easily incorporate realistic issues such as shelf space limitations and customer service level together with product assortment and inventory management. It may be important to plan these issues simultaneously and our approach provides a tool for carrying out such an analysis. To summarize, in the retailing sector, decisions on product assortment, customer services and inventory levels are closely-related with each other. In this paper, we formulate the multi-product inventory, product assortment problem with different types of demand under resource constraints with the objective of maximizing expected profit. We evaluate various scenarios by solving the proposed mixed-integer programming problem to optimality.

LITERATURE REVIEW

Assortment optimization is an active area of research, as assortment optimization problems find important applications in retailing and revenue management. It has been considered under a number of different constraints such as inventory control, profit margin, customer preference and customer satisfaction (Caro & Gallien, 2007; Yuan, Yang et al., 2015). There are also assortment studies without constraints on the offered assortment, which can be solved efficiently under some certain circumstances. Numerous optimization algorithms have been correspondingly proposed to obtain optimal product assortments under a variety of contexts and assumptions.

Our focus in this paper is on product assortment under demand substitution and correlation, together with other relevant retail store management issues such as shelf space allocation and service level. A mixed-integer programming model is formulated for a single-period product assortment problem with deterministic demand under both dependent and independent demand. The purpose of
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