Dynamic Pricing Model for Substitutable Products

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ABSTRACT

A dynamic pricing model in airline seat allocation, where a seller offers two substitutable perishable products in the monopolist market, is proposed in this article. The objective is to maximize the total profit gained from both products. We analyze the problem using a multinomial logit model to describe the customer choice behavior. The exact solution is obtained according to the calculated optimal time thresholds. Sellers can dynamically adjust the price policy in the continuous-time process. We also analyze the efficient price strategy according to the marginal expected revenue function. Furthermore, a numerical example is given to illustrate the procedure and the result is compared with the fixed price policy.

Keywords: Monopolist Market, Multinomial Logit Model, Perishable Products, Pricing, Revenue Management, Substitution

INTRODUCTION

Dynamic pricing, which is known as the tactic of yield management, is a set of pricing strategies aimed at maximizing profits. It is widely used in many industries for pricing perishable products, such as airline seat allocation, hotel rooms, rental cars, and seasonal fashion goods. The number of products that remain unsold after a finite time horizon will become vanity with fixed salvaged value. The seller can enhance their revenues by adjusting dynamically the sale price of perishable products instead of adopting a fixed pricing policy. According to the definition proposed by Gallego and van Ryzin (1994), dynamic pricing is an attempt to synthesize a range of optimal prices from a small, static set of prices in response to a shifting demand function. Because of the long ordering time, capacity decisions in this process are usually fixed in the initial sales horizon and cannot be replenished in the short run.

As an effective tool in dynamic pricing, Feng and Xiao (2000) addressed that price policies are affected by two factors: the length of time remaining and the number of items unsold. Intuitively, the sellers can provide a higher price if there is still plenty of time or the inventory level is low. For example, an airline often sells the seats by opening and closing fares, and agents do this by tactical markdowns. The finite set of available prices over the sales horizon is often predetermined in advance because of the management costs. In brief, the main question

DOI: 10.4018/joris.2010101303
is how to sell the product at the right price at the right time.

Product variety is another important factor in dynamic pricing. The demand for certain products depends not only on their own price, but also on the price of other products, we call this kind of behavior “substitution” or “complementarity.” Multi-product case can have significant effect on profit implication. Although a large number of studies have already considered a single type of inventory, Bitran and Caldentey (2003) mentioned that combining the impact of both time and inventory on pricing decisions becomes technically arduous because of the substitution effect. In fact, we can easily find that the seller today provides different but similar products at different levels of service quality and sets different prices on each of them. Customers may substitute their initial choice with a cheaper one, which they can afford or upgrade with additional payment to get a higher service quality. Thus, the possibility exists that a customer who prefers a product with a high service quality will choose to purchase a product at a low price level after all. Since the interaction between prices of products and levels of service quality is complicated, the customer choice model is worth investigation. Each customer will weigh the performance for alternatives using the service quality and the corresponding price, and then buy the product which has the highest utility or just leave. Consequently, to compute revenues, the whole path of demand is needed. This makes the Hamilton-Jacobi-Bellman equation, which is widely used in optimizing the revenue of a single product, complicated when applied to multi-product problems (Bitran & Caldentey, 2003). Therefore, whether simpler model can be constructed for solving such problem becomes an important issue.

In this article, we formulate the optimal dynamic pricing policy of multiple fare classes on the basis of previous research and show that the decision is made according to the inventory level and customer behavior. Although several demand processes are studied in previous research, we use the stochastic Poisson process, which is the common assumption when describing the customer arrival rate. Moreover, we assume that the customer does not show their wishes until they enter the booking system. The customer choice model follows the multinomial logit (MNL) model proposed by van Ryzin and Mahajan (1999). The purpose of this article is to provide the simple pricing decision rule of two substitutable products for maximizing the total expected revenue.

This study focuses on the time threshold and inventory control problem through the dynamic price policy of two perishable products in airline seat allocation. The rest of the article is organized as follows. In the next section, we review the previous work on dynamic pricing policy, the behavior of customer choice and the MNL model. In Section 3, we present the problem statement and construct the proposed pricing model. Numerical examples are presented in Section 4. Section 5 contains the conclusions of this article and discusses the directions for further research.

**LITERATURE REVIEW**

This section reviews the dynamic pricing at the revenue management decision level and the customer choice model in the literature. First, we present the dynamic pricing policies and other relevant problems, and then review the concepts of the behavior of customer choice and the MNL model.

**Dynamic Pricing Policy**

Price is the major determinant of demand behavior. If the price is viewed as a variable that can be controlled, then raising the price sufficiently high can shut down booking classes. Therefore, there is a natural duality between price and seat allocation decisions. Gallego and van Ryzin (1994) used the intensity control theory to develop the dynamic pricing policy in closed form with exponential demand functions. For general demand functions, they analyzed a deterministic version of the problem and obtained an upper
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