ISSN: 2349-6495(P) | 2456-1908(O)

Pricing Models for Perishable Goods with Customer Perception

Manoj Kumar[1], Nausherwan Raunaque[2]

[1]Director, Samalkha Group of Institutions, Samalkha, Panipat, Haryana, India
[2]Ph.D. Student, Department of Management, Sri Satya Sai University of Technology &Medical Sciences, Sehore, MP, India

Abstract— *In this paper, the pricing problem for perishable goods with customer perception is studied. Firstly, the customer value theory is introduced. Secondly, the problem is described. Then, the pricing model of perishable goods is established, in consideration of customer perception. At last, some data analysis and discussion are made via a concrete case study, the optimal pricing policy and maximum expected profit of the retailers are gained and some useful management conclusions are drawn.*
Keywords—Perishable goods, Revenue management, Customer Perception, Reservation price.

I. INTRODUCTION

Perishable goods, also known as seasonal products, have some distinct features such as short sale cycles, low value of unsold goods and uncertain demands. There are many examples of perishable goods, for instance, plane seats, hotel rooms, cinema tickets, newspapers and magazines, videos and discs, food, medicines and fashionable clothes, etc. Due to the technological improvement, fiercer market competition, the product life cycle have been greatly shortened and the innovation accelerated, more and more products (e.g. Electronic product, personal computer and information product) now have the same features as the perishable goods[1].

In recent market, there are many perishable goods and industries with perishable features, so it is one of the crucial decisions for the enterprises to price the products and services.The sale time is limited for perishable goods. Products or services will be worthless out of the shelving time or a certain time limit, in term the opportunity to gain profits through selling the products will disappear forever. The demand for perishable goods fluctuates, facing the choice of various customers. Some customers are willing and also have the ability to buy the product at a high price immediately after its appearance in the market, but some customers prefer lower price at the cost of flexibility. So the decision makers face the situation to balance the two sides—the customer drain because of high price and the loss of consumer surplus (the difference between the actual price of the product and the reservation price of the customers) due to lower price. The traditional pricing policies, such as the cost-added policy, competition-oriented policy cannot suit the case of perishable goods quite well. Therefore, we need a new pricing strategy.

Revenue management, which is the most updated scientific management method in the world, is to achieve the best optimization of existing resources of the enterprise through scientific projection of market demand and pricing without adding cost, in term to gain the maximum profit. The core of the method is to sell the appropriate products to the appropriate customers at an appropriate price in an appropriate time so as to gain the maximum economic profits [2].

Actually, pricing for perishable goods is a problem of revenue management. In consideration of the customer perception, this paper has made analysis and research on the pricing problem of the perishable goods with the help of the profit management theory. First it introduces the customer value theory. Then it gives a description of the problem being researched. Then it establishes a pricing model of perishable goods in consideration of customer perception. At last it makes some data analysis and discussion through a concrete case study, from which we draw the optimal pricing and largest expected profit of the retailers and some other meaningful conclusions.

Take a comprehensive view of study on pricing for perishable goods at home and abroad, we find that almost researchers think that customers are homogenous. Some papers have mentioned the concerning concept but these papers cannot be seen so much. At abroad, the research on revenue management about customer choice behavior largely focused on optimizing the model and improving the algorithm, on the assumption that demand from the initial order to meet arbitrary arrival. We can find some similar researches of Belobaba and Weatherford [3], Weatherford [4].The most representative is Talluri and van Ryzins [5]. They have put forward a model of discrete-time option. Through a literature search, we cannot find a research on pricing models for perishable goods with customer perception.

II. DESCRIPTION AND ASSUMPTION OF THE PROBLEM

We consider a retailer who sells some perishable goods at sale point S, of which the amount is Q. The customers' arrival rate at time t is $\lambda(t)$.

According to Bitran's [6] assumption of customer demand model, the market potential customer purchase rate (demand) follows Poisson distribution. Each potential customer has subjective value of a product (often based on their own experiences, the alternatives information and other information received).The population of potential customers is characterized by a distribution of reservation price for a product. Reservation price is the maximum price that they are willing to pay for the product. Customers will buy the product only if their reservation price is no less than the product's price.

According to Lasear's[7] research, the probability density function and the cumulative distribution function of customers' subjective value can be expressed as $f(p)$ and $F(p)$ .When the product price is p, $F(p)$ is the probability when the reservation price is less than p, which denotes the proportion of customers unwilling to buy ,while $1-F(p)$ denotes the proportion of customers willing to buy .Customers' subjective value varies from each other. As the various customers' subjective value could be completely reflected by setting different parameters, we use Weibull distribution which has a shape parameter m and a scale parameter v to express the distribution of customers' subjective value.

We define the random demand at S is i, the expected profit in one single-period is $V(Q,p)$ .Then we will establish a model and analyze how to price for gaining the maximum expected profit.

III. MODEL FORMULATION AND SOLUTION

3.1 Model formulation

The retailer's optimal pricing for perishable goods is to gain the maximum expected profit. So we first draw the maximum expected profit in one single-period. Then we obtain the price, which is the optimal one, when the profit is the maximum.

To maximize the profit in single-period, we should first gain the demand function affected by subjective value.

Arrival rate of customers to buy at time t at the sale point S ($\lambda(t,p)$) is jointly decided by customers' arrival rate $\lambda(t)$, the probability of arriving customers to buy $(1-F(p))$ and the distribution of the subjective value changing over time.

Based on the research of Bitran, we assume that the subjective value follows the Weibull distribution.

The probability density function of the Weibull distribution is:

$$f_W(x)=\begin{cases}\frac{k}{b}\left(\frac{x-a}{b}\right)^{k-1}\ell^{-\left(\frac{x-a}{b}\right)^k}, & x\geq a\\ 0, & x<a\end{cases}$$

Where the shape parameter $k>0$, the scale parameter $b>0$, and the location parameter is a.

The distribution of the subjective value is:

$$F(p)=1-e^{-(vp)^m}$$

$$f(p)=F'(p)=vm(vp)^{m-1}e^{-(vp)^m}$$

Where $k=m$, $b=\frac{1}{v}$, $p=x-a$ .Thus

$$\lambda(t,p)=\lambda(t)(1-F(p))=\lambda(t)(1-(1-\ell^{-(vp)^m}))=\lambda(t)\ell^{-(vp)^m}$$

(1)

Assume i is the random demand at the sale point S, and $V(Q,p)$ is the expected profit in single-period. Because we have assumed that the market potential customer purchase rate (demand) follows Poisson distribution, the probability distribution of the random demand i at the sale point S is:

$$\Pr\{D(p)=i\}=\frac{[\lambda(t,p)]^i\,\ell^{-\lambda(t,p)}}{i!}$$

(2)

Thus the maximum expected profit in single-period at the sale point S is:

$$\mathrm{Max}\,V(Q,p)=\mathop{\mathrm{Max}}_{p\geq 0}\left\{\sum_{i=0}^{Q}p\cdot i\cdot\Pr\{D(p)=i\}+p\cdot Q\cdot\left(1-\sum_{i=0}^{Q}\Pr\{D(p)=i\}\right)\right\}$$

(3)

Where $\sum_{i=0}^{Q}p\cdot i\cdot\Pr\{D(p)=i\}$ is the profit when random demand is not more than the total volume of products.And $p\cdot Q\cdot\left(1-\sum_{i=0}^{Q}\Pr\{D(p)=i\}\right)$ is the profit when random demand is more than the total volume of products.

The boundary condition is:

$$V(0,p)=0$$

(4)

The formula (4) means that when inventory at the sale point S is zero, we can no longer make a profit.

3.2 Model solution

$p*$ is the optimal price when we obtain the maximum expected profit. We use Mathematica5.0 to solve the model, but we cannot gain analytical solutions. For given all parameters, approximate solution of $p*$ can be obtained.

We take fashion industry for example, and further analyze the pricing model for perishable goods.

Assume $Q=4$, $\lambda(t)=5$, $m=1$, $v=0.0037$ (see, References[6]), and we can obtain that the approximate solution of $p*=291.136$, the maximum expected profit $V(Q,p)=484.018$.

IV. DATA ANALYSIS

4.1 The effect of the diversity of customers' subjective value on pricing and profit

Given $Q=4$ and $\lambda(t)=5$.

Assume A: $m=5$, $v=0.0045$; B: $m=4$, $v=0.0043$; C: $m=3$, $v=0.0041$; D: $m=2$, $v=0.0039$; E: $m=1$, $v=0.0037$.

And $f(p)=vm(vp)^{m-1}e^{-(vp)^m}$

Where $p\in(0,450)$, figure 1 shows the curve of the probability density function at A, B, C, D, E, respectively.

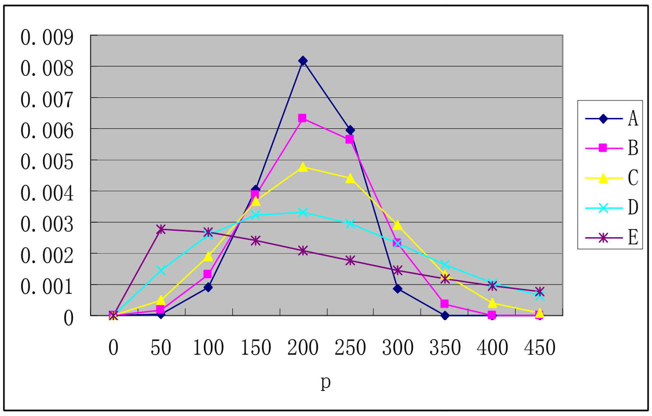

Fig.4-1:The Probability Density Function at Different Customers' Subjective Value.

Then we can obtain the optimal price and the maximum expected profit at the sale point S, as followings:

A: $p*=177.7$, $V(Q,p)=540.1$; B: $p*=181.2$, $V(Q,p)=536.3$; C: $p*=194.5$, $V(Q,p)=522.4$;

D: $p*=208.9$, $V(Q,p)=503.3$; E: $p*=291.1$, $V(Q,p)=484.0$.

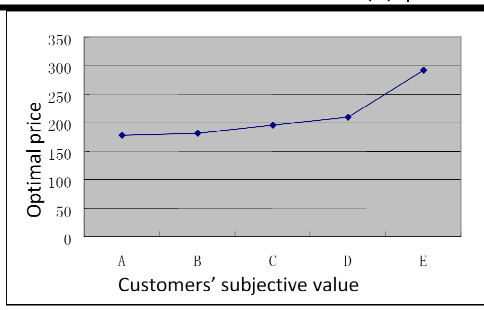

Fig.4-2(a):The Effect of the Diversity of Customers' Subjective Value on Optimal Price.

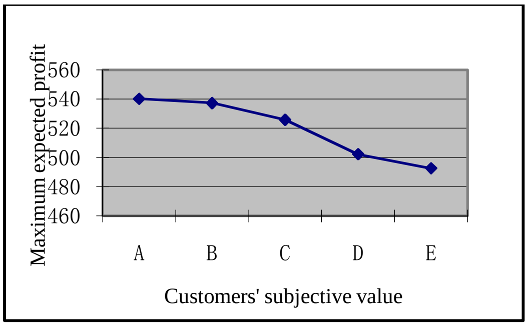

Fig.4-2(b): The Effect of the Diversity of Customers' Subjective Value on MaximumExpected Profit.

From figure 4-1and 4-2(a), we gain the effect of the diversity of customers' subjective value on the optimal price. That is:

(1) The more the diversity of customers' subjective value, the higher the optimal price, and vice versa.

(2) Retailers should initially set a higher price for they are not aware of the customers' subjective value, then adjust the price according to the actual situation.

From figure 4-1and 4-2(b), we gain the effect of the diversity of customers' subjective value on the maximum expected profit. That is:

(1) The more the diversity of customers' subjective value, the lower the maximum expected profit, and vice versa. So the retailers will face more risks when the customers' subjective value is too much different.

(2) If the retailers can forecast the customers' subjective value, they can set a appropriate price to maximize the profit.

4.2 The effect of the customers' arrival rate $\lambda(t)$ on pricing and profit

Given $m=5$ and $v=0.0045$.

Assume A: $\lambda=1$; B: $\lambda=3$; C: $\lambda=3$; D: $\lambda=7$; E: $\lambda=9$, then we can obtain the optimal price and the maximum expected profit respectively. As shown in figure 4-3 and 4-4.

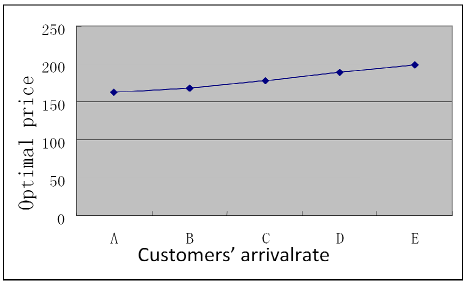

Fig.4-3:The Customers' Arrival Rate and the Optimal Price at the Sale Point S .

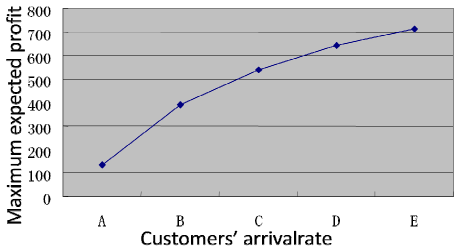

Fig.4-4:The Customers' Arrival Rate and the Maximum Expected Profit at the Sale Point S .

From figure 4-3, we can know the effect of the customers' arrival rate on the optimal price .That is:

（1）The higher the customers' arrival rate at the sale point S , the higher the optimal price, and vice versa.

（2）The retailers can accommodate the number of customers who will to buy products by the price lever. If the customers' arrival rate is high, the retailers will increase the price to make sure that the demand would not be more than the supply.

From figure 4-4, we can know the effect of the customers' arrival rate on the maximum expected profit .That is:

The higher the customers' arrival rate at the sale point S , the higher the maximum expected profit, and vice versa.

V. CONCLUSION

In this paper, the pricing model for perishable goods with customer perception is established. At last, some data analysis and discussion are made via a concrete case study, the optimal pricing policy and maximum expected profit of the retailers are gained and some useful management conclusions are draw.

（1）The more the diversity of customers' subjective value, the higher the optimal price, and vice versa. The more the diversity of customers' subjective value, the lower the maximum expected profit, and vice versa.

（2）Retailers should initially set a higher price for they are not aware of the customers' subjective value, then adjust the price according to the actual situation. If the retailers can forecast the customers' subjective value, they can set an appropriate price to maximize the profit.

（3）The higher the customers' arrival rate at the sale point S , the higher the optimal price and the maximum expected profit, and vice versa.

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