Dynamic Pricing Strategy of Provider with Different QoS Levels in Web Service

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***Abstract*—In order to improve the service provider profit, the pricing strategies in service network have been studied, but primarily in static pricing setting without considering different quality of service (QoS) levels. However, in real situation, providers usually dynamically adjust their prices and offer multiple class services to meet different customers. Moreover, because service provider will satisfy demands of customers on a specific future date, customers may cancel order. In this paper, we establish a new dynamic pricing model to consider order cancellation ration and different QoS levels for maximizing provider revenue. The analytical results from this new model reveal that the optimal capacity and prices are derived via closed-form solutions. Finally, a numerical example is presented to illustrate that the proposed method is effective for determining the optimal capacity and prices. In addition, sensitivity analysis of the optimal capacity and profit with respect to some important parameters are also conducted to illustrate the optimal decision characteristics.**

***Index Terms*—pricing strategy, quality of service (QoS), cancellation ratio, web service**

I. INTRODUCTION

During recent years, web service has gained tremendous development in modern business. In the e-business domain, one of the most challenging issues is pricing strategy of web service. The service is a special produce that is simultaneously produced and consumed. For example, when a people who makes a reservation for traveling by air can enjoy this service only when the customer arrives and a schedule is prepared for a particular day and time. If the service has not been sold before the scheduled departures, its economic value is lost. As such, services are considered non-storable products [1].

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In the existing related models concentrating on pricing, many researchers have observed the phenomenon that demands for an item may be affected by price. Polatoglu [2] examined an inventory model for developing pricing and procurement decisions simultaneously. Khouja [3] investigated a newsboy problem in which discount prices are decision variables and discount strategies are used to sell excess inventory. Pan et al. [4] constructed a mathematical model in which the demand is price-dependent to analyze pricing and order size for a service product when customers are segmented into two types.

Meanwhile, some researchers have also studied the pricing when the demand simultaneously depends on price and time. Gupta et al. [5] considered an inventory model when the demand intensity and reservation prices are time dependent. Rakesh and Steinberg [6] simultaneously determined the pricing and ordering decisions for an inventory system in which the demand is assumed to be time and price dependent.

Urban and Baker [7] addressed a deterministic inventory model in which the demand is a multivariate function of price, time and inventory level, and extended the model to a case with a single price markdown. Chun [8] developed inventory models for determining the optimal list price and order quantity for a seasonal/perishable product which is sold for a limited period of time.

When consumers make purchased decision, they consider not only costs but also quality of service (QoS). Under this demand structure, a provider has been proposed to offer different service versions to meet multiple customer demand in web service domain. This is becoming a common practice that is based on the demand of different QoS levels.

QoS is the collective summation of service measures, which determines the degree of user satisfaction of the service [9]. Common measures of QoS are delay, reliability and missing data probability in data communication networks. Delay specifies how long it takes for data to travel across the network from source to destination [10].

Reliability represents the variance in data transmission. Audio and video applications are quite sensitive to delay and reliability, whereas common data services are insensitive to either [11]. Missing data represents information dropped or irrecoverably damaged by the network. It typically stems from data collision and buffer overflows. Sudden changes in transmission may also cause data loss [12].

Thus, without an appropriate pricing strategy, any prioritization is useless; if there were no price difference between the priority classes, all users would select the high priority class. In other words, the prices of the priority classes should give users an incentive to join the "right" priority class. This is a common practice done by imposing a higher charge on the high-priority class.

Some relative literatures can be reviewed. For example, Guan et al. [13] presented a decentralized auction-based scheme for bandwidth allocation and pricing in a differentiated service-based network. Mandjes [14] constructed the new model that analyzed pricing strategies on different services. Zhang et al. [15] proposed a general framework in which service providers offering multi-class services to meet different demands.

To boost revenue, provider may dynamically adjust their prices to sell more services than before. For example, airlines can use computer reservation systems to dynamically change ticket prices according to actual sales status. Some literatures have also studied dynamic pricing problems. Gallego and Ryzin [16] proposed a dynamic pricing model for selling a fixed number of items by a deadline. They found the optimal pricing policy in closed form under exponential demand. You [17] dealt with a dynamic pricing and lot sizing problem for seasonal products.

However, this advantage is accompanied by numerous costs and problems. Costs associated with the dynamic pricing approach include costs on computer equipment, data update, and information technology. With the advancement of information technology, costs and problems are decreasing. The pricing or promotion strategy can be easily applied to many practical problems. Due to this advantage of dynamic pricing, this paper considers dynamic pricing according to the actual ratio between capacity and demand.

At the same time, customers usually purchase service through a reservation system and will consume the product on a certain future date. Lee and Ng [18] provided service organizations generally used an advance sale system to monitor demand besides pricing strategy. You [19] investigated a service inventory model in which the firm sells the product through an advance booking system.

It is noted that customers with reservation may withdraw their orders before receiving them. A decision maker, without considering this phenomenon, thus may over-estimate the actual demand. From an economic point of view, the phenomenon of order cancellation can not be disregarded when making capacity size and pricing decisions.

But, in web service domain, there is limited research in revenue management that concerns dynamic pricing strategy of web service with different QoS levels. However, in real situation, providers usually can dynamically adjust their prices and offer multiple class services to meet different customer requirements.

In order to offer more practical and meaningful model to dynamic pricing strategy of provider, we present a new model in this paper, which differs from past studies in that it includes four features, as follows:

(1) Demand depends on price and time.

(2) Provider offers multiple class services to meet different requirements of customers.

(3) Customers with reservation can cancel order, penalty depends on sale price and time.

(4) The time point of price adjustment is random, when provider only has a price-change.

The purpose of this paper is to maximize the profit by making the following decisions:

(1) Capacity decision specifying how capacity is constructed.

(2) Pricing decision specifying how much price of every class service is during every selling stage.

II. A DYNAMIC PRICING MODEL WITH DIFFERENT QOS LEVELS

In this section, we construct a new dynamic pricing model to maximize provider profit. The following content discusses our model in detail.

A. Notation and assumptions

In this subsection, we assume that a provider plans to offer a certain service to customers who will consume or use it on a certain future date, purchasing through a reservation system. We also assume that the provider must determine the capacity and the selling prices at the start of the selling period. The selling price scheme is assumed to include both an initial and a secondary unit selling price. The provider is postulated to have previously specified a price-change time at the start of the selling period. This arrangement is intended to maximize the total expected profit by simultaneously determining the capacity of the provider, initial unit selling price, and secondary unit selling price. We first make the following assumptions:

(1) Provider only has a price-change in selling period, namely dividing the selling period into 2 selling stages at random time point T_1.

(2) Multiple class services can meet different requirements of customers.

(3) Demand rate of different QoS levels is used as a function of selling price and time.

(4) Capacity of provider is not surplus.

(5) Customers with reservation can cancel order, penalty depends on sale price and time.

(6) Customers can always be satisfied.

Before describing our model, the following notations are defined. We will use the following notations and decision variables throughout this paper.

- m: Number of QoS levels
- T: Advance selling period
- T_1 Random time point of price-change, $0 \le T_1 \le T$
- p_{1j}: Initial unit selling price of the jth QoS level during time $[0, T_1]$, $j = 1, 2, ..., m$
- p_{2j}: Secondary unit selling price of the jth QoS level during time $[T_1, T]$, $j = 1, 2, ..., m$
- p_{ij}: Unit selling price of the jth QoS level which is set during the ith selling stage, $i = 1, 2$, $j = 1, 2, ..., m$
- D_{ij}: Demand of the jth class service over the ith selling stage
- α_j: Scale parameter of demand of the jth class service, $j = 1, 2, ..., m$
- b_j: Shape parameter of demand of the jth class service, $j = 1, 2, ..., m$
- β_j: A coefficient for reflecting relationship of price and demand of the jth class service, $j = 1, 2, ..., m$
- c_j: Unit service cost of the jth QoS level, $j = 1, 2, ..., m$
- r_j: The proportion of cancellations of the jth QoS level, where is a positive variable with the value of [0, 1), $j = 1, 2, ..., m$
- $I_{ij}(t)$: Reservation level of the jth QoS level during the ith stage at time point t, $i = 1, 2$, $j = 1, 2, ..., m$
- Q_{ij}: Reservation level of the jth QoS level during the ith selling stage, $i = 1, 2$, $j = 1, 2, ..., m$
- Q_j: Total reservation level of the jth QoS level during advance sale period, $j = 1, 2, ..., m$
- Q: Total capacity level
- R_{ij}: Profit function of the jth QoS level during the ith stage, $i = 1, 2$, $j = 1, 2, ..., m$
- R_j: Profit function of the jth QoS level, $j = 1, 2, ..., m$
- R: Total profit function when the number of price adjustments is the same in different QoS levels

According to the real situation, we will develop a new model presented in this section for dynamic pricing strategy problem of the provider in web service with considering one price-change in random time poin, cancellation and different Qos levels. The following subsection discusses this model in detail.

B.Mathematical model

To have a new dynamic pricing model on web service, the demand for the service depends on the selling price and time, demand function is nonlinear and given by

$$D_{ij} = \alpha_j e^{-b_j t} - \beta_j p_{ij} \tag{1}$$

where t indicates the passed time in selling period; α_j, β_j and b_j are non-negative parameter; D_{ij} is the demand rate at the jth QoS level over the ith selling stage.

Since customers usually purchase service in advance, this work makes the realistic assumption that customers with reservations may cancel their order before receiving their orders. Customers who withdraw their orders are postulated to be charged the penalty. Meanwhile, the penalty is assumed to be linearly dependent with the passed time during a selling period. Then, we have

$$\theta_t = \frac{t}{T} \tag{2}$$

where θ_t denote the ratio of penalty to sales price when a customer cancels his/her reservation at time t of selling period. Meanwhile, the assumption that the ratio increases with time is restrictive, such a phenomenon is not uncommon because the fee of cancellation often increases as the consumption day draws nearer. For instance, data transmission which will be held three days later is likely to charge higher penalty than another task which will be held a couple of weeks later. Aside from this, it is likely that hosts will spend more money for canceling a shortterm notice dinner party because there is not enough time to another schedule. However, Thus, it is not uncommon that a long-term schedule has a lower penalty of being canceled instead of one in the near future. Taking this situation into account, this paper investigates the case where the portion of penalty increases with time.

Moreover, we assume that services remaining at the end of the sales season are disposed of zero. Then, the reservation level changes at a rate of $D_{1j} - r_j I_{1j}(t)$ during period [0, T_1]. Accordingly, the reservation level of the system during time period [0, T_1] can be given by the following differential equation:

$$\frac{\partial I_{1j}(t)}{\partial t} = D_{1j} - r_j I_{1j}(t), \quad 0 \le t \le T_1. \tag{3}$$

At time, $t = T_1$, the price is changed to p_{2j}. During the period from time T_1 to T, the reservation level changes at a rate of $D_{2j} - r_j I_{2j}(t)$ owing to demand and cancellations. Consequently, the system reservation level during period [T_1, T] can be described by the following differential equation:

$$\frac{\partial I_{2j}(t)}{\partial t} = D_{2j} - r_j I_{2j}(t), \quad T_1 \le t \le T. \tag{4}$$

Clearly, the initial reservation level is 0 in selling period. Additionally, based on the assumption that the firm can predict how price and time influence demand, the reservation level of j class service is expected to reach the level Q_j at the end of the selling period. Thus, the boundary conditions for the reservation level are

$$I_{1j}(0) = 0, \quad I_{2j}(T) = Q_j. \tag{5}$$

The differential equations in Eqs. (3) and (4) can be solved using Eq. (1) and the above boundary conditions Eq. (5). The solutions to the differential equations are given by Eqs. (6) and (7), respectively:

$$I_{1j}(t) = \frac{\alpha_j(e^{-b_j t} - e^{-r_j t})}{r_j - b_j} + \frac{\beta_j p_{1j}(e^{-r_j t} - 1)}{r_j}, \tag{6}$$

$$I_{2j}(t) = \frac{\alpha_j(e^{-b_j t} - e^{r_j(T-t) - b_j T})}{r_j - b_j} + Q_j e^{r_j(T-t)} + \frac{\beta_j p_{2j}(e^{r_j(T-t)} - 1)}{r_j}. \tag{7}$$

Thus, the system reservation level is developed. Now, we will develop the profit function of this problem. Profit of the *j*th QoS level is composed of sales revenues R_j^{sale}, cancellation revenues R_j^{cancel} and cost $R_j^{\cos t}$. The profit function can be derived according to Eqs. (6) and (7).

(1) Sales revenues

$$\begin{aligned} R_{1j}^{sale} &= I_{1j}(T_1)p_{1j} \\ &= p_{1j} \times \left[\frac{\alpha_j(e^{-b_jT_1} - e^{-r_jT_1})}{r_j - b_j} \right. \\ &\quad \left. + \frac{\beta_j p_{1j}(e^{-r_jT_1} - 1)}{r_j}\right], \end{aligned} \tag{8}$$

$$\begin{aligned} R_{2j}^{sale} &= [I_{2j}(T) - I_{2j}(T_1)] \times p_{2j} \\ &= p_{2j} \times \left[Q_j - \frac{\alpha_j(e^{-b_jT_1} - e^{-r_jT_1})}{r_j - b_j} \right. \\ &\quad \left. - \frac{\beta_j p_{1j}(e^{-r_jT_1} - 1)}{r_j}\right], \end{aligned} \tag{9}$$

$$\begin{aligned} R_j^{sale} &= \sum_{i=1}^{2} R_{ij}^{sale} \\ &= R_{1j}^{sale} + R_{2j}^{sale} \\ &= p_{1j} \times \left[\frac{\alpha_j(e^{-b_jT_1} - e^{-r_jT_1})}{r_j - b_j} \right. \\ &\quad \left. + \frac{\beta_j p_{1j}(e^{-r_jT_1} - 1)}{r_j}\right] + p_{2j} \times \\ &\quad \left[Q_j - \frac{\alpha_j(e^{-b_jT_1} - e^{-r_jT_1})}{r_j - b_j} - \right. \\ &\quad \left. \frac{\beta_j p_{1j}(e^{-r_jT_1} - 1)}{r_j}\right] \end{aligned} \tag{10}$$

where R_{ij}^{sale} is sale revenue of the *j*th QoS level during the *i*th stage, $i = 1, 2, j = 1, 2, \ldots, m$.

(2) Cancellation revenues

$$\begin{aligned} R_{1j}^{cancel} &= \int_0^{T_1} \theta_t p_{1j} r_j I_{1j}(t)dt \\ &= \int_0^{T_1} \frac{tp_{1j}r_j}{T} \times \left[\frac{\alpha_j(e^{-b_jt} - e^{-r_jt})}{r_j - b_j} \right. \\ &\quad \left. + \frac{\beta_j p_{1j}(e^{-r_jt} - 1)}{r_j}\right] dt \\ &= \left[\frac{-e^{-b_jT_1} - T_1 b_j e^{-b_jT_1} + 1}{b_j^2} \right. \\ &\quad \left. - \frac{-e^{-r_jT_1} - T_1 r_j e^{-r_jT_1} + 1}{r_j^2}\right] \times \\ &\quad \frac{\alpha_j p_{1j} r_j}{T(r_j - b_j)} + \frac{\beta_j r_j p_{1j}^2}{r_j T} \times \left[-\frac{T_1^2}{2} + \right. \\ &\quad \left. \frac{-e^{-r_jT_1} - T_1 r_j e^{-r_jT_1} + 1}{r_j^2}\right], \end{aligned} \tag{11}$$

$$\begin{aligned} R_{2j}^{cancel} &= \int_{T_1}^{T} \theta_t p_{2j} r_j I_{2j}(t)dt \\ &= \int_{T_1}^{T} \frac{tp_{2j}r_j}{T} \times \left[\frac{\alpha_j(e^{-b_jt} - e^{r_j(T-t)-b_jT})}{r_j - b_j} + \right. \\ &\quad \left. \frac{\beta_j p_{2j}(e^{r_j(T-t)} - 1)}{r_j} + Q_j e^{r_j(T-t)}\right] dt \\ &= \left[\frac{(-1 - Tb_j)e^{-b_jT} + (T_1 b_j + 1)e^{-b_jT_1}}{b_j^2} \right. \\ &\quad - \frac{e^{(r_j - b_j)T}[(-1 - Tr_j)e^{-r_jT} +}{r_j^2} \\ &\quad \left. \frac{(T_1 r_j + 1)e^{-r_jT_1}]}{r_j^2}\right] \times \frac{p_{2j} r_j \alpha_j}{T(r_j - b_j)} + \\ &\quad \frac{p_{2j}^2 r_j \beta_j}{T r_j} \times \left[\frac{T_1^2}{2} - \frac{T^2}{2} + \right. \\ &\quad \left. \frac{(-1 - Tr_j) + (T_1 r_j + 1)e^{r_j(T-T_1)}}{r_j^2}\right] + \\ &\quad \left[\frac{(-1 - Tr_j)e^{-r_jT} + (T_1 r_j + 1)e^{-r_jT_1}}{r_j^2}\right] \\ &\quad \times \frac{p_{2j} r_j \alpha_j}{T(r_j - b_j)}, \end{aligned} \tag{12}$$

$$\begin{aligned} R_j^{cancel} &= \sum_{i=1}^{2} R_{ij}^{cancel} \\ &= R_{1j}^{cancel} + R_{2j}^{cancel} \end{aligned} \tag{13}$$

where R_{ij}^{cancel} is cancellation revenue of the *j*th QoS level during the *i*th stage, $i = 1, 2, j = 1, 2, \ldots, m$.

(3) Cost

$$R_j^{cost} = Q_j c_j \tag{14}$$

where $R_j^{\cos t}$ is cost of the *j*th QoS level, $j = 1, 2, \ldots, m$.

Thus, our problem can be formulated as follows:

$$R_j = R_j^{sale} + R_j^{cancel} - R_j^{cost}, \tag{15}$$

$$p_{ij} \le \frac{\alpha_j e^{-b_jt}}{\beta_j}. \tag{16}$$

The provider aims to maximize expected profit by simultaneously determining 1) the capacity of service provider, and 2)unit selling price of service in every stage with different QoS levels. The following section, we show the optimal capacity and prices of different class services are derived from closed-form solutions.

III. SYSTEM ANALYSIS

In this section, we will develop a solution procedure in deal with the mathematic programming model proposed in the previous section. It is observed that $I_{1j}(T_1) = I_{2j}(T_1)$, namely

$$\frac{\alpha_j(e^{-b_jT_1} - e^{-r_jT_1})}{r_j - b_j} + \frac{\beta_j p_{1j}(e^{-r_jT_1} - 1)}{r_j} = \frac{\beta_j p_{2j}(e^{r_j(T-T_1)} - 1)}{r_j} + \frac{\alpha_j(e^{-b_jT_1} - e^{r_j(T-T_1)-b_jT})}{r_j - b_j} + Q_j e^{r_j(T-T_1)}. \quad (17)$$

Thus, we can used Eq. (17) to obtain Q_j.

$$Q_j = \frac{\alpha_j(e^{-b_jT} - e^{-r_jT})}{r_j - b_j} + \frac{e^{-r_jT} - e^{-r_j(T-T_1)}}{r_j} \times \beta_j p_{1j} - \frac{\beta_j p_{2j}(1 - e^{-r_j(T-T_1)})}{r_j}. \quad (18)$$

According to Eq. (18), Q_j can be expressed in terms of p_{1j} and p_{2j}, thus allowing us to reduce the unknown variables in objective function R_j. Substituting Eq. (18) into Eq. (15), this work aims to maximize the expected profit, subject to the constraint Eq. (16), namely $D_{ij} \geq 0$ for $i = 1, 2$.

Theorem 2.3.1. For any given parameters, $R_j(p_{ij})$ is a concave function of p_{ij}.

Proof. First, we have

$$H = \begin{pmatrix} \frac{\partial^2 R_j}{\partial p_{1j}^2} & \frac{\partial^2 R_j}{\partial p_{1j}\partial p_{2j}} \\ \frac{\partial^2 R_j}{\partial p_{1j}\partial p_{2j}} & \frac{\partial^2 R_j}{\partial p_{ij}^2} \end{pmatrix} > 0.$$

as well as the following inequalities, namely Eqs.(19) and (20):

$$\frac{\partial^2 R_j}{\partial p_{1j}^2} < 0, \quad (19)$$

$$\frac{\partial^2 R_j}{\partial p_{2j}^2} < 0. \quad (20)$$

Thus, we see that inequalities H, Eqs.(19) and (20) satisfy the sufficient condition. Hence, we have completed the proof. △

Setting

$$\frac{\partial R_j}{\partial p_{1j}} = 0, \quad (21)$$

$$\frac{\partial R_j}{\partial p_{2j}} = 0. \quad (22)$$

Let p_{ij}' be the solutions to Eqs. (21) and (22), and p_{ij}^* be the optimal selling price of the jth QoS level during the ith selling stage for $i = 1, 2$, $j = 1, 2, ..., m$. Combining Eqs.(19) and (20), $p_{1j}^* \leq \frac{\alpha_j e^{-b_jT_1}}{\beta_j}$ and $p_{2j}^* \leq \frac{\alpha_j e^{-b_jT}}{\beta_j}$, we can obtain the following theorem.

Theorem 2.3.2. $p_{1j}^* = p_{1j}'$ for $p_{1j}' \leq \frac{\alpha_j e^{-b_jT_1}}{\beta_j}$, $p_{1j}^* = \frac{\alpha_j e^{-b_jT_1}}{\beta_j}$ for $\frac{\alpha_j e^{-b_jT_1}}{\beta_j} \leq p_{1j}'$, $p_{2j}^* = p_{2j}'$ for $p_{2j}' \leq \frac{\alpha_j e^{-b_jT}}{\beta_j}$, and $p_{2j}^* = \frac{\alpha_j e^{-b_jT}}{\beta_j}$ for $\frac{\alpha_j e^{-b_jT}}{\beta_j} \leq p_{2j}'$.

According to Theorem 2.3.1. and Theorem 2.3.2., the optimal initial unit selling price is p_{1j}^*, the optimal secondary selling price is p_{2j}^* and the optimal renting/ordering quantity of j service class is

$$Q_j^* = \frac{\alpha_j(e^{-b_jT} - e^{-r_jT})}{r_j - b_j} + \frac{\beta_j p_{1j}^*(e^{-r_jT} - e^{-r_j(T-T_1}}{r_j} - \frac{\beta_j p_{2j}^*(1 - e^{-r_j(T-T_1)})}{r_j}. \quad (2$$

In the next subsection, we present a numerical example to illustrate the preceding new method presented in this section and make sensitive analysis about some important parameters.

IV. A NUMERICAL EXAMPLE

The previous theory can be illustrated by the following example. Suppose the service provider offers this service at a unit cost $c_j = 5$, cancellation ratio $r_j = 0.05$, sells it through reservation on $T = 200$ and $T_1 = \frac{T}{2}$. Then, demand function is

$$D_{ij} = \alpha_j e^{-b_jt} - \beta_j p_{ij} = 150e^{-0.005t} - 4p_{ij}.$$

Using these theorems developed in the previous subsection, Table 1 reveals that the optimal capacity and expected profit of the jth QoS level.

This work refers to the data set used in the above example as a basic data set. That is, $w = \{\alpha_j = 150, \beta_j = 4, c_j = 5, T = 40, r_j = 0.05, b_j = 0.005\}$. Specifically, the changes in the optimal decision values Q_j and R_j are investigated when only one parameter in set w changes while the others remain the same. Tables I-VI illustrate the sensitivity analysis for the above example. The numerical analysis demonstrates that

(1) Q_j and $p_{2j}(p(2j))$ are decreasing in T while R_j is concave and $p_{1j}(p(1j))$ is increasing in T (Table I, Figure 1 and Fig. 7).
(2) R_j, $p_{1j}(p(1j))$ and $p_{2j}(p(2j))$ is increasing in r_j while Q_j is decreasing in r_j (Table II, Figure 2 and Fig. 8).
(3) Q_j, R_j and $p_{2j}(p(2j))$ are decreasing in b_j while $p_{1j}(p(1j))$ is increasing in b_j (Table III, Figure 3 and Fig. 9).
(4) Q_j, R_j, $p_{1j}(p(1j))$ and $p_{2j}(p(2j))$ are increasing in α_j (Table IV, Figure 4 and Fig. 10).
(5) Q_j, R_j, $p_{1j}(p(21j))$ and $p_{2j}(p(2j))$ are decreasing in β_j (Table V, Figure 5 and Fig. 11).
(6) Q_j and R_j are decreasing in c_j while $p_{1j}(p(1j))$ and $p_{2j}(p(2j))$ are increasing in c_j (Table VI, Figure 6 and Fig. 12).

Notably, the above results show that variations in some important parameters can cause change in capacity and profit of provider. This method enables the purchasing

TABLE I.
SENSITIVITY FOR T.

T	100	150	200	250	300
R_j	31711	41043	43688	42818	40319
Q_j	2948	2416	1900	1479	1146
p_{1j}	7.4	8.49	8.98	9.09	8.97
p_{j2}	8.71	8.37	7.53	6.57	5.66

TABLE II.
SENSITIVITY FOR r_j.

r_j	0.03	0.04	0.05	0.06	0.07
R_j	38751	42220	43688	44285	44485
Q_j	3574	2526	1900	1501	1230
p_{1j}	7.37	8.29	8.98	9.51	9.92
p_{j2}	6.78	7.24	7.53	7.73	7.87

managers to calculate the optimal capacity and price decision to each class service in data communication service.

V. CONCLUSION

Pricing strategy of provider with different QoS levels in web network is one of the most important activities of e-commerce. Providers usually offer multiple price adjustments and different QoS levels to different customers. Numerous researchers in the past had studied the pricing problem. However, few considered a situation in which customers were required to make reservations and were allowed cancellations when demand depended on price and time. Then, a new model was developed for pricing policy with different Qos levels.

The proposed model simultaneously determines the renting/ordering quantity, initial unit selling price and secondary unit selling price at the beginning of the planning period. The analytical results reveal that the profit function is concave. The analytical outcomes also have led to the development of closed form solutions. These characteristics can be applied to directly calculate the order quantity, the optimal initial unit, and secondary unit selling price when the time point T_1 is random.

Meanwhile, from a numerical example, we prove the proposed model in this paper can effectively help the decision makers to calculate the optimal number of price settings, the optimal capacity and prices.

TABLE III.
SENSITIVITY FOR b_j.

b_j	0.003	0.004	0.005	0.006	0.007
R_j	68194	54304	43688	35518	29184
Q_j	2519	2187	1900	1653	1439
p_{1j}	9.8	9.37	8.98	8.6	8.25
p_{j2}	9.83	8.6	7.53	6.61	5.82

TABLE IV.
SENSITIVITY FOR α_j.

α_j	130	140	150	160	170
R_j	32074	37657	43688	50169	57098
Q_j	1628	1764	1900	2036	2172
p_{1j}	7.93	8.46	8.98	9.5	10.02
p_{j2}	6.61	7.07	7.53	7.99	8.45

TABLE V.
SENSITIVITY FOR β_j.

β_j	2	3	4	5	6
R_j	94015	60435	43688	33675	27029
Q_j	1970	1935	1900	1866	1831
p_{1j}	16.8	11.58	8.98	7.41	6.37
p_{j2}	14.46	9.84	7.53	6.14	5.22

TABLE VI.
SENSITIVITY FOR c_j.

c_j	3	4	5	6	7
R_j	46330	44995	43688	42410	41159
Q_j	1956	1928	1900	1872	1845
p_{1j}	8.52	8.75	8.98	9.51	9.44
p_{j2}	7.29	7.41	7.53	7.73	7.77

The following directions can be considered as futur works.

In real situation, markets usually have many providers When providers make the pricing decision, they must con sider competitor policy. If the model can be re-constructe on free market, it would be more realistic.

In this case, customer can always be satisfied. But, i practice, customers with reservations are not guarantee to receive or enjoy services because provider usuall has limited capacity. In this situation, it does not mea that all unfulfilled customers are lost sales. In som cases, some customers may be willing to accept dela or postponement. Further research could developed th situation where limited capacity is considered.

Finally, it is also worth further investigating whe demand is stochastic. For solving this problem, we mus re-establish our model as a dynamic pricing model an develop another effective method to deal with this nev problem. These are not easy directions to pursue and w will look into those issue in the future.

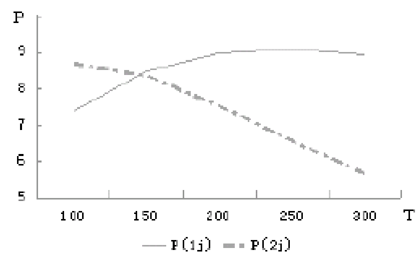

Figure 1. Price with respect to T.

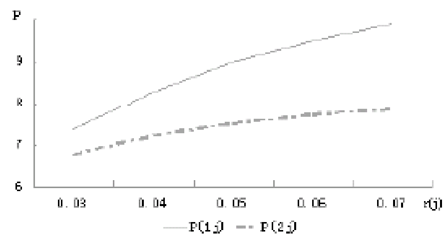

Figure 2. Price with respect to $r(j)(r_j)$.

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We thank Hua Guowei for numerous discussions concerning this work, Yong Fang and Gan Xie for their assistance, and the reviewers for their detailed comments.

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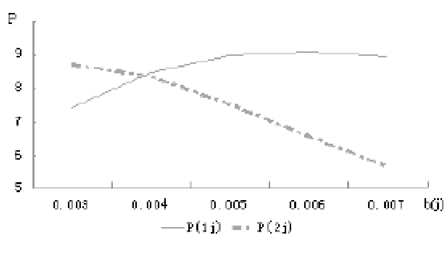

Figure 3. Price with respect to $b(j)(b_j)$.

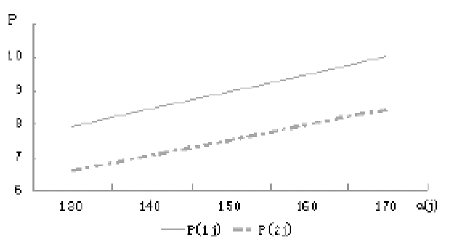

Figure 4. Price with respect to $\alpha(j)(\alpha_j)$.

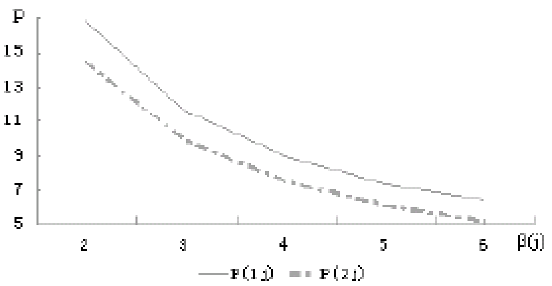

Figure 5. Price with respect to $\beta(j)(\beta_j)$.

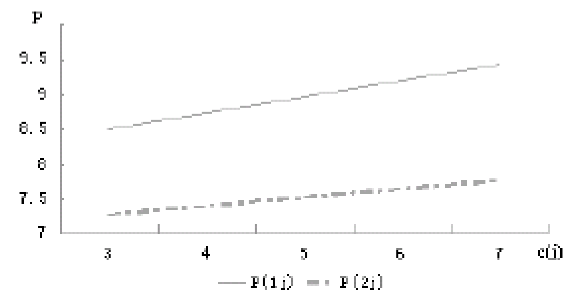

Figure 6. Price with respect to $c(j)(c_j)$.

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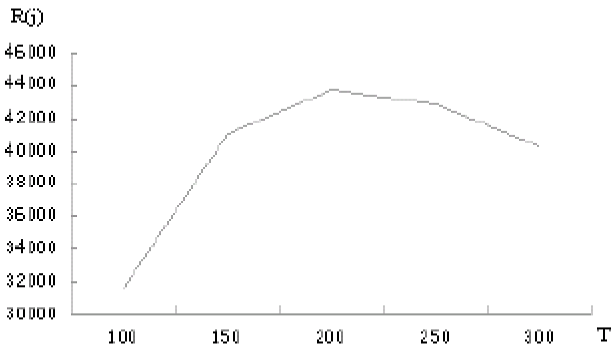

Figure 7. Profit with respect to T.

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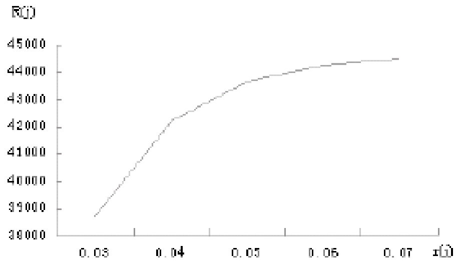

Figure 8. Profit with respect to $r(j)(r_j)$.

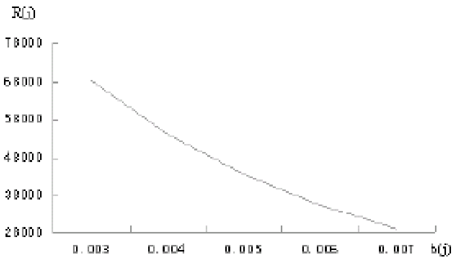

Figure 9. Profit with respect to $b(j)(b_j)$.

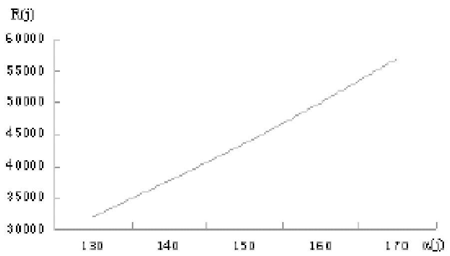

Figure 10. Profit with respect to $\alpha(j)(\alpha_j)$.

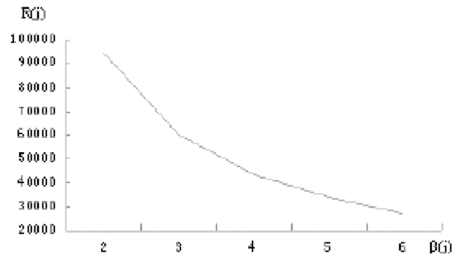

Figure 11. Profit with respect to $\beta(j)(\beta_j)$.

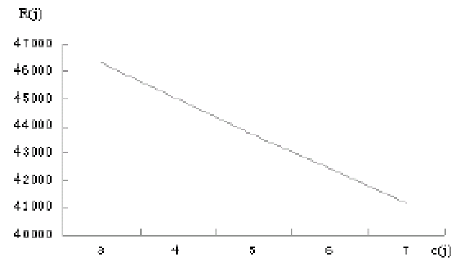

Figure 12. Profit with respect to $c(j)(c_j)$.