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A new model for optimal design in e-ticket pricing in airline industry

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Abstract

E-commerce companies are grappling with complex work in determining the appropriate price for product or service. The product pricing, in accordance with existing limitations and different methods to determine the cost of product, has been the center of attention. Revenue management has been defined as selling the right product to the right customer in suitable time. On the one hand, sellers tend to sell their products to purchasers of high value and on the other hand if they wait long for their valued customers, sales period may be end up with unsold units that can be sold to customers with low value. In airline industries are considered as this type of product, because if the aircraft flies, with seat vacant, the cost cannot be undone. In this study, a series of data are performed as airline industry always performs data for ticket sales. A mathematical model is then designed to perform the same data. The results revealed that the company's overall revenue and profit, has increased.

Keywords:

Pricing strategies, Dynamic pricing, revenue management techniques, airline ticket pricing.

1. Introduction

Pricing in simple language, is to determine the price for a particular goods or services. In order to determine the price, there is no fixed solution or magic. The most important role of price, is to act in

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line with more efficient allocation of resources and service and to maximize the profit. Buyers will go markets , the pricing is done based on cost, this method in no way is responsible for pricing on electronic markets. Pricing is an art and pricing decisions reflects a combination of insight, past experiences and complex analysis.

On the other hand, nowdays, the internet and the electronic world has changed all aspects of human life. The markets have been consequently changed in nature and form. As the nature of market has been changed, it can be predicted that others will also be changed. The assessment of pricing is therefore important in different circumstances with respect to the world of internet and put significant effects on the organization's economy, particularly in electronic markets where there is no direct relationship with customer, and the sales work and consumer acquisition are done only through a website. Entrepreneur should note to the fact that the target price is in line with the image of the product which can be seen by the customer. The company takes disadvantage if the customer feels that the price of items is higher than their values. This issue is very important for products and services which have an expiration date. Therefore, patterns and models which offer, through using past experiences, the best price in certain situation should be used. On the other hand they should have little error percentage, because the error is unrecoverable and in case of repetition, leads the firm into bankruptcy. In this paper, the optimal price in cases where the demand is low and fixed and high, is determined using simulation airlines with multi-criteria decision-making models, that results in increased significant revenue, compared to base case. In fact, the target is how the seller should deal with demands – despite limited number of goods – limited amount of time and changes in values of goods and also how the airline can offer a dynamic to maximize the profit..

2. LITERATURE REVIEW

The rapid evolution of information technologies and the growth of internet and e-commerce is a key sources for assessment of dynamic pricing models. In the electronic world, collecting various information (on demands, inventory levels, competitive strategies, etc.) and processing it in real time are possible. This fact allows administrators to dynamically control changes in the market using each variable. Revenue management is defined as selling the right product to the right customer. On the one hand, sellers tend to sell their products to purchasers of high value, so that they can obtain high profit, and on the other hand if they wait long for their valued customers, sales period may be end up with unsold units that can be sold to customers with low value. Dynamic pricing strategies are available to exploit and balancing profitability of capacity. Dynamic pricing techniques are particularly useful for industries having high running costs, perishable items, short sale ranges and price-sensitive demands. The internet, also, enables dynamic pricing for a wide range of products through supply chain. Dynamic pricing models are used for revenue management networks. Advances in revenue management techniques has historically started by pioneering researches conducted by Littlewood. (1972), Rothstein. (1971), Rothstein. (1974) on reservation of the number of seats in hotel and airport. Then, Belobaba (1989) and the success of American airports in that regard was really impressive. Another sign of this improvement was the publication of an assessment article by Weatherford & Bodily. (1992). offering a classification of existing areas and an agenda for future studies. Nowdays, revenue management has been naturally implemented for other industries including retail, car-rental agency, hotels, internet and broadband providers, passenger railway lines, sea lanes and electric power supply. Revenue management has provided some models to optimize revenue as in the following areas: In the areas of retail (Subrahmanyan & Shoemaker. 1996). in the area of car-rental agencies (Carroll & Grimes. 1995; Geraghty & Johnson. 1997), for hoteliers (Bitran, & Gilbert, 1996; Bitran & Mondschein. 1995) in the section of broadband and internet providers (Nair & Bapna. 2001), in passenger railway lines (Ciancimino, et al. 1999) in sea lanes (Ladany & Arbel. 1991) and in electric power supply (Schweppe et al., 2013; Oren & Smith, 2012).

The directing impacts of security and abstract standards on the connection between consumer loyalty and AET repurchase goal was explored (Liang & Shiau. 2018). Three significant measurements in particular client's assumptions, administration quality and past experience as a free factor and client discernment as the needy variable were contemplated (Santosh & Kumar. 2019). It was indicated that client trust has incompletely influenced on client devotion, brand picture has not mostly influenced on client dependability and administration quality has somewhat influenced on client reliability. Traveloka ought to have a decent quality dependent on client discernment not just spotlight on building their image picture as a site booking number one since it has no critical impact to client unwaveringness (Tumewu et al., 2017). Exploration discoveries affirm that air terminal strength can make a huge impact on ticket valuing. Contrast between full assistance transporter and ease transporter ticket cost is one of the other significant components lastly presence of banner aircraft as a value controller in a course can influence ticket cost (Kiarashrad, et al. 2020).

Discount profundity expands client buy expectation by improving view of the authenticity and estimation of the LPG. Severe discount conditions upgrade client buy goal by expanding the credibility of the LPGs (Jeng & Lo. 2019). The job of online trust on interceding the connection between e-WOM and aircraft e-ticket buying goal was explored (Ahmad, et al. 2020). The outcomes of a research showed that the proposed advancement structure can give a helpful schedule to travelers, satisfactory income for train organizations and improve social value to meet government targets. These industries are all the same for the main problems in revenue management (Zhan et al., 2020). In systems based on webpages, an interface helps the consumer to identify and choose items for offering. After the consumer has registered a price, the representative of a consumer sends the offer to appropriate seller who responds by rejection or acceptance of the offer. Here, the seller is important. In fact, the target is how the seller should deal with demands – despite limited number of goods – limited amount of time and changes in values of goods and also how the airline can offer a dynamic decision to maximize the profit.

3. MATHEMATICAL MODEL FOR IMPROVEMENT IN AIRLINE INDUSTRY

In this model, we apply a series of strategy to sell the seats during time period T to maximize the expected revenue. Additionally, we increase airline's total expected revenue by determining optimal price using the remaining time periods and available seats. This pricing policy includes the right price for each reservation class and the right time for booking. In this model, reservation classes and the possibilities of reservation request for different seats are investigated using multi-criteria decision making function such as origin and destination flights. Value and related cost, and total revenue are calculated and diagrams based on airline data are ultimately drawn that important results are achieved which contributes a lot to the pricing in this industry.

3.1 hypothesis

We have a total time *T* that is divided into smaller time periods where t_1 is the period for final decisions, and t_2 is the period before the final period and up to the end of the period *(t1>t2>…>tn).*
We also assume that we have N+1 airport that are numbered *0,1,2,3,….,N.* For example in time period t_j, one flight from airport *j-1* travels to airport *j*.
And travelling from airport *j* to airport *k* is started that are shown as $t_{j,k}$.

- In this model, cancelled tickets will not be examined.
- Request for multiple seat reservation are generally rejected or accepted.
- If the customer's request is rejected, the request for further travels will not be checked.

3.2 Definition of variables

T= Total time of decision-making periods
(j,k)= A travel from airport *j* to airport *k*
T_j= Decision making period departure from airport *j* to airport *j-1*
L^{jk}= Total number of reserved classes for departure from airport *j* to airport *k*
Ij= Maximum capacity of flights from airport *j* to airport *j-1*
i= A vector whose elements are the number of seats available for all flights at onset of a time period
$i=\{i_1,i_2,\ldots,i_n\}$

$S^{jk}(i)$= Total number of seats available for departure from airport j to airport k.
λ_{tl}^{jk}= the probability of a request for reservation of class l for departure from airport j to airport k during time period t
L=1,2,…, L^{jk} reserved classed
θ_{tlm}^{jk}= the probability of a request for reservation of class l for departure from airport j to airport k during time period t for seat m
M_{tl}^{jk}= The maximum number of seat issued for every reservation in each request.
c_{tl}^{jk}= The cost of maintaining a customer in reservation class l for departure from airport j to airport k incurred by the airline.
From the above definition, we conclude that if $t<t_j$, it means that it is removed from the period allowed to buy the ticket and therefore $\lambda_{tl}^{jk}=0$ and if $t>t_j$, it means that the time period has not yet finished, $\lambda_{tl}^{jk}>0$ depending to the period we are. For all time periods, we have:

$$\sum_{j=0}^{N-1}\sum_{k=j+1}^{N}\sum_{l=1}^{L_{jk}}\lambda_{tl}^{jk}\leq 1\ \ t.$$

This means that the probability of request for ticket reservation from airports 0 to N in reservation class is different from one to Ljk has value smaller or equal to 1.

Also if $t<t_j$، $\theta_{tlm}^{jk}=0$ and if $t>t_j$, we have $\sum_{m=1}^{M_l^{jk}}\theta_{tlm}^{jk}\leq 1$.
In this model we have a price that if the airline put the price on its ticket, there will be no request on behalf of the customer who leaves the reservation system. Here, we call it null price or b_l^{jk}.
A_l^{jk} = the set of acceptable price for reservation class l from airport j to airport K.
The highest price in the set A, is b_l^{jk}. Here, there is optimal price that the customer has accepted and buys the ticket. This is the price x ($x\in A_l^{jk}$) and its probability is $p_l^{jk}(x)$.

$p_{\mathrm{l}}^{\mathrm{jk}}$(x) = The probability of customer's request for ticket in reservation class l for departure from airport j to airport k.

In $b_{\mathrm{l}}^{\mathrm{jk}} = \max\{x|p_{\mathrm{l}}^{\mathrm{jk}}(x) > 0, \mathrm{x} \in A_{\mathrm{l}}^{\mathrm{jk}}\}$

And the cost for each reservation class in certain flight is $c_{\mathrm{l}}^{\mathrm{jk}}$ which is less than $b_{\mathrm{l}}^{\mathrm{jk}}$.

Note: In order to increase the expected revenue from tickets that has been sold, it is based on finding optimal reservation price for each seat and remaining time before flight.

3.3 Optimized equation

We examine two functions:

$\upsilon_t(i)$= maximum expected revenue when decision making period is t and the vector of remaining seat is i.

$g_{\mathrm{lmt}}^{\mathrm{jk}}(i,x)$ = maximum expected revenue for remaining seat of vector I with price x

For m seats in reservation class l for departure from airport j to airport k in time periods t, a request is inserted.

υ_0(i)= expected revenue in time t=0 is equal to 0

υ_{t-1}(i)= expected revenue when there is no customer in period t

If a customer requests m seat in reservation class l for departure (j,k), the probability is $\lambda_{\mathrm{tl}}^{\mathrm{jk}} * \theta_{\mathrm{tlm}}^{\mathrm{jk}}$. Two cases shall be examined:

1. The number of remaining seats for particular departure shall be less than m, in other words $S^{jk}(i) < m$
2. The number of remaining seats for particular departure shall not be less than m, in other words $m < S^{jk}(i)$.

In first case:

The request is rejected, because the remaining seats cannot attract the customer's satisfaction. In this case, the expected revenue is υ_{t-1}(i)

In second case:

We assume the price for m seats in reservation class l for departure (j,k), so the expected revenue $g_{\mathrm{lmt}}^{\mathrm{jk}}$(i,X) are obtained as the following:

$$g_{\mathrm{lmt}}^{\mathrm{jk}}(\mathrm{i},\mathrm{x}) = \mathrm{p}_{\mathrm{l}}^{\mathrm{jk}}(x)\left(mx - mc_l^{jk} + \upsilon_{t-1}(i - me_{jk})\right) + \left(1 - p_l^{jk}(x)\right)\upsilon_{t-1}(i) = \upsilon_{\mathrm{t-1}}(\mathrm{i}) + \mathrm{mp}_{\mathrm{l}}^{\mathrm{jk}}(x)(x - c_l^{jk} - (\upsilon_{\mathrm{t-1}}(i)\upsilon_{t-1}(i - me_{jk}))/m) \quad, t \geq 1 \qquad (1)$$

In the following, from N departure in airport, particular direction is intended. Thus, in the following vectors, the particular direction is initialized and other directions are 0 as the following:

$$e_{0\mathrm{k}} = (\underset{1}{1}, \underset{2}{1}, \ldots, \underset{k}{1}, \underset{k+1}{0}, \ldots, \underset{N}{0}),$$

$$e_{\mathrm{jk}} = (\underset{1}{o}, \underset{2}{0}, \ldots, \underset{j}{0}, \underset{j+1}{1}, \ldots, \underset{k}{1}, \underset{k+1}{0}, \ldots, \underset{N}{0}), \quad j \geq 1$$

$$\mathrm{i} - e_{\mathrm{jk}} = (i_1, \ldots, i_j - 1, i_{j+1} - 1, \ldots, i_k - 1, i_{k+1}, \ldots, i_N).$$

$$\upsilon_{\mathrm{t}}(\mathrm{i}) = \left(1 - \sum_{\mathrm{l}=1}^{\mathrm{L_{jk}}} \lambda_{\mathrm{tl}}^{\mathrm{jk}}\right)\upsilon_{\mathrm{t-1}}(\mathrm{i}) + \sum_{\mathrm{l}=1}^{L_{jk}} \lambda_{tl}^{jk} \sum_{m=1}^{M_l^{jk}} \theta_{tlm}^{jk} (\upsilon_{\mathrm{t-1}}(\mathrm{i})\mathrm{I}(\mathrm{S}^{\mathrm{jk}}(\mathrm{i}) < m) + max\ g_{tlm}^{jk}(i,x)I(S^{jk}(i) \geq m)), t \geq 1 \qquad (2)$$

A function defined for the case where is TRUE,S, the value is equal to 1 , and if it is FALSE, the value is equal to 0.
In this case, a function Z is added.: The average values for each seat that has been sold in departure (j,k) in period t = Z_{tm}^{jk} are as follows:

$$z_{tm}^{jk}(i) = \frac{\upsilon_t(i) - \upsilon_t(i - me_{jk})}{m} \text{ و } S^{jk}(i) \geq m\,, t \geq 0$$
$$max\ g_{tlm}^{jk}(i,x) = \upsilon_{t-1}(i) + \ m\ max\ p_l^{jk}(x)\left(x - z_{t-1,m}^{jk}(i) - c_l^{jk}\right), t \geq 1 \qquad (3)$$

From the above formula, we concluded that in order to maximize $p_l^{jk}(x)$ the value of z , c shall be decreased so that the values of x and p are increased. And the expected revenue is therefore increased.
If we assume a variable like v that has total costs and values, as a result we have:
$K_l^{jk}(\nu) = \max p_l^{jk}(x)(x - \nu) \text{ و } x \in A_l^{jk}$
As the following we have:

$$\upsilon_t(i) = \upsilon_{t-1}(i) + \sum_{j=0}^{N-1} \sum_{k=j+1}^{N} \sum_{l=1}^{L_{jk}} \lambda_{tl}^{jk} \sum_{m=1}^{M_l^{jk}} \theta_{tlm}^{jk}\ mK_l^{jk}(z_{t-1,m}^{jk}(i) + c_l^{jk}) I\left(S^{jk}(i) \geq m\right) \qquad (4)$$

In airline industry, two policies are generally are considered for seat reservation:
1. Reservation capacity in critical condition.
2. Critical periods for decision-making.

In the first case, we examine the condition where the number of requests for seat reservation is equal to 1 when t=1. In this case, the following equation is obtained:

$$\upsilon_1(i) = \sum_{l=1}^{L} \lambda_{1l} K_l(c_l) I(i \geq 1)$$
$$Z_1(i) = \sum_{l=1}^{L} \lambda_{11}\left(K_l(c_l) - K_l(c_l) I(i \geq 2)\right)$$

In the second case, we examine the condition where the tickets shall be sold as soon as possible due to lack of time, the right price shall be considered according to the number of remaining seats and days.
For the first case, a series of data has been taken. Using this data and the above model, the diagrams are drawn and are analyzed in the following:

3.4 Input Data

Table (1): The probability of buying tickets

	λ_{t1}^{01}	λ_{t2}^{01}	λ_{t3}^{01}
T_1	0.08	0.09	**0.06**
T_2	0.07	0.05	**0.07**
T_3	0.04	0.03	**0.07**
T_4	0.06	0.02	**0.05**
T_5	0.04	0.03	**0.025**

Table (2): Optimal price and the probability of buying with the same price

A_1^{01}	p_1^{01}	A_2^{01}	p_2^{01}(x)	A_3^{01}	p_3^{01}
300	0.90	400	0.80	600	0.85
330	0.85	430	0.75	630	080
360	0.80	460	0.70	660	0.70
400	0.00	500	0.00	700	0.00
400	0.00	500	0.00	700	0.00

Table (3): Costs

c_1^{01}	c_2^{01}	c_3^{01}
20	40	50

Table 4: The probability of request for m seats

θ_{t11}^{01}	θ_{t12}^{01}	θ_{t13}^{01}
0.20	0.25	0.25

3.5 Results of model

The intended model has been coded in MATLAB software and is implemented using the above data. The results obtained are given in figures 1, 2, 3, 4, 5, 6. In this case, time period T is divided into 5 time periods, in order to show each period from the opening for ticket sales until losing total revenue. The relevant codes are given in Appendix 1. In these diagrams, total revenue is in the vertical axis and 3 reservation class in horizontal axis. Total time for opening the site for reservation until closing and airplane flight, is divided into 5 periods.

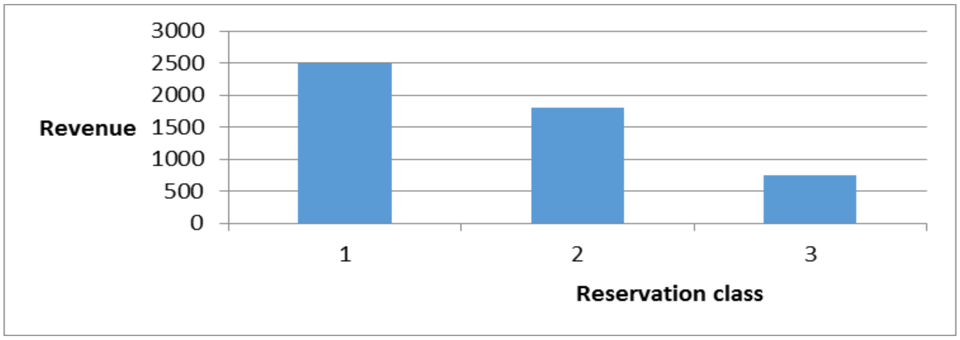

Figure 1: Period t_1

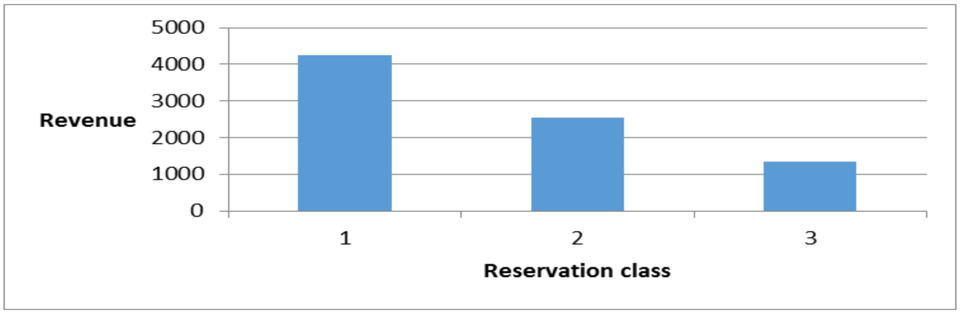

Figure 2: The first period t2z

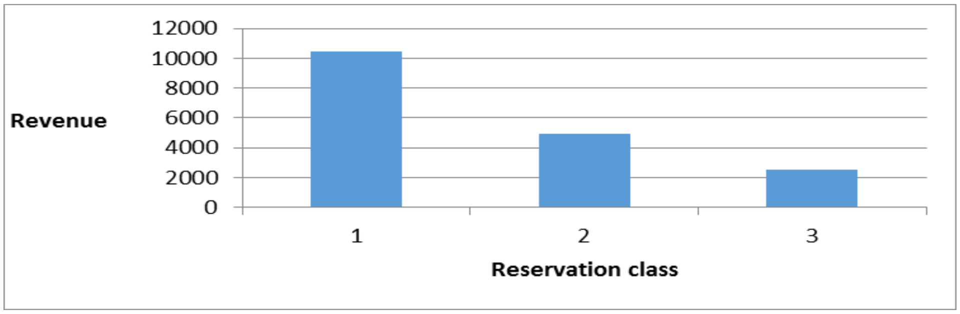

Figure 3: The third period t3

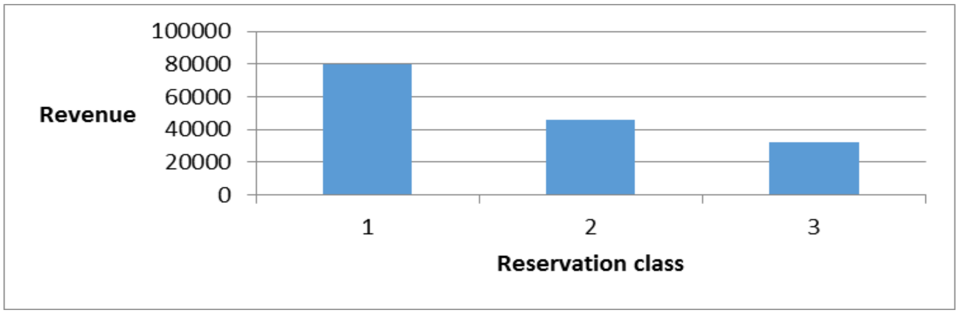

Figure 4: The fourth period t4

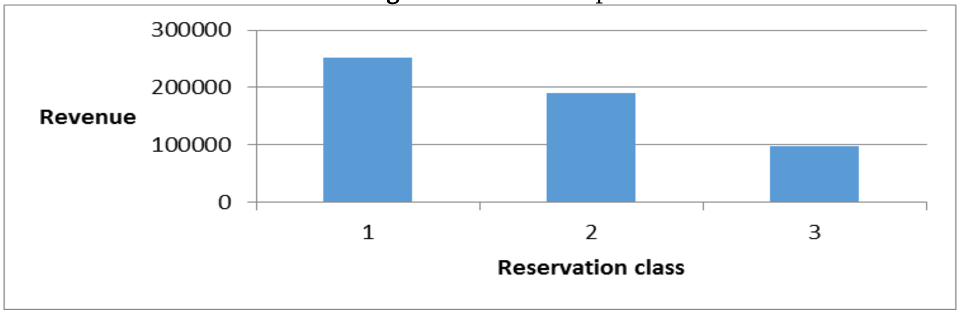

Figure 5: The fifth period t5

This diagram shows the total revenue of particular travel based on 5 time periods t1, t2, t3, t4, t5 in three classes l1, l2, l3.

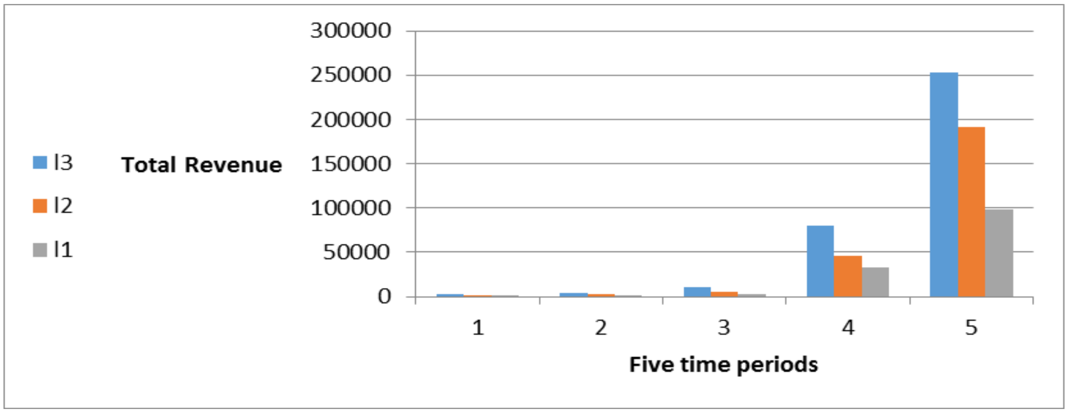

Figure 6: Comparison of total revenue in five time periods.

By analyzing and comparing these five diagrams, we find out that in the primary periods, the request for travelling is not significantly high in the initial periods, but it is increased at final time periods. In class L3, due to the cheap prices compared to that of class L2, and L2 compared with L1, revenue is increased in this model. The total revenue is increased, when approaching to final time periods, due to various reasons such as cheap tickets or hurry in buying, if the request is high. If the request is low at that particular time, the adopt the best price based on past experiences and suggested models to attract customers' satisfaction.

4. Conclusion

Todays, determining the appropriate price for a product or service is very important. This requires that the companies should be aware of their operating costs, and the information about their suppliers, and they should know how much the customers value for the product and what demands they will have in the future. The company therefore needs to have a lot of information about their customers. In electronic markets, the price is influenced by the uniqueness of the product, awareness of alternative product or service, total cost, subscriber cost, impact of price-quality, and stock. Sellers can choose different strategies by examining these impacts on products and services that can be provided in electronic markets. These strategies allow the probability of right pricing according to cost, customers and competitors, and also give an appropriate profit margin for sellers. In order to know what strategy responds best to which circumstances, the proposed models shall be implemented practically. Due to high costs of implementation of each strategy, that are not economical in the real world, we used market simulator and designed a mathematical model that are encoded in MATLAB software. The results are given using diagrams, according to which the profit margin, compared to base case has changed considerably and increased by about 30%.

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Appendix:

```
% t=1
s=100;
m=1;
 A=[ 300 400 600];
c=[20 40 50];
teta=[0.2 0.25 0.25];
```

```
landa=[0.08 0.09 0.06];
p=[0.9 0.8 0.85];
for cont=1:3
  l(cont)=cont;
  g(cont)=p(cont)*(m*A(cont)-m*c(cont));
end
for cont=1:3
    l(cont)=cont;
  v01(cont)=landa(cont)*teta(cont)*g(3)*s;
end
v1(1)=v01(1);
 v1(2)=(v01(1)+v01(2));
 v1(3)=(v01(1)+v01(2)+v01(3))
figure(1),plot(l,v1)
%******************
% t=2
  A=[ 330 430 630];



 landa=[0.07 0.05 0.07];
p=[0.85 0.75 0.8];
for cont=1:3
  g(cont)=p(cont)*(m*A(cont)-m*c(cont))+(1-p(cont))*v1(cont);
end
for cont=1:3
  v02(cont)=v1(cont)+landa(cont)*teta(cont)*g(3)*s;
end
v2(1)=v02(1);
 v2(2)=(v02(1)+v02(2));
 v2(3)=(v02(1)+v02(2)+v02(3))
figure(2),plot(l,v2)
%********************
%    t=3
A=[ 360 460 600];
 landa=[0.04 0.03 0.07];
p=[0.88 0.7 0.7];
for cont=1:3
g(cont)=p(cont)*(m*A(cont)-m*c(cont))+(1-p(cont))*v2(cont);
end
for cont=1:3
 v03(cont)=v2(cont)+landa(cont)*teta(cont)*g(3)*s;
end
v3(1)=v03(1);
v3(2)=(v03(1)+v03(2));
v3(3)=(v03(1)+v03(2)+v03(3))
figure(3),plot(l,v03)
%********************
```

```
%    t=4
A=[ 460 500 700];
 landa=[0.06 0.02 0.05];
p=[0 0 0];
for cont=1:3
   g(cont)=p(cont)*(m*A(cont)-m*c(cont))+(1-p(cont))*v3(cont);
end
for cont=1:3
    v04(cont)=v3(cont)+landa(cont)*teta(cont)*g(3)*s;
end
v4(1)=v04(1);
 v4(2)=(v04(1)+v04(2));
 v4(3)=(v04(1)+v04(2)+v04(3))
figure(4),plot(l,v4)
%*********************
%    t=5
A=[ 460 500 700];
 landa=[0.04 0.03 0.02];
p=[0 0 0];
for cont=1:3
    g(cont)=p(cont)*(m*A(cont)-m*c(cont))+(1-p(cont))*v4(cont);
end
for cont=1:3
    v05(cont)=v4(cont)+landa(cont)*teta(cont)*g(3)*s;
end
v5(1)=v05(1);
 v5(2)=(v05(1)+v05(2));
 v5(3)=(v05(1)+v05(2)+v05(3))
figure(5),plot(l,v5);
%*********************
k=[1 2 3 4 5];
vt1=[v1(1) v2(1) v3(1) v4(1) v5(1)];
vt2=[v1(2) v2(2) v3(2) v4(2) v5(2)];
vt3=[v1(3) v2(3) v3(3) v4(3) v5(3)];
figure(6),plot(vt1)
```