Presentation of dynamic model to control Rooms’ inventory to Revenue Management in hospitality industry

Nikoofekr Mohammad Hadi1, Soleimani Rohollah2

1Department of industrial engineering, Faculty of engineering, University of Hormozgan, Bandar Abbas, Iran
2Department of physics, Faculty of Sciences, University of Hormozgan, Bandar Abbas, Iran

Abstract: Controlling Rooms’ inventory and pricing are two main debates Revenue management of hospitality industry. In this essay it tries to be calculated Best allocation, control Rooms’ inventory so that all rooms are sold in time of service and hotel gets the most benefit. This presented model tries to calculate Capacity of each class with creating logical and proper relationship between price and demand assuming the price is clear. This model use Dynamic Programming time to solve problem of controlling Rooms’ inventory and finally it converts to two systems with equation and unknown. This approach for solving problem makes practical solution of the model easier in real problems. Keywords: Revenue management, Inventory Control, Dynamic Programming, pricing, Nonlinear programming

1. INTRODUCTION

Have you ever thought a person who sits next to you in airplane has paid money for buying ticket can be half of money you have paid? Or this point that why do you pay money for reservation room in several months ago much cheaper than you don’t reserve rooms before? Answer this question is concealed in concept which called yield management or revenue management. This term is used in many Service industries to descript techniques for allocation of limited resources. Like airplane chairs or hotels rooms when customer diversity is high and business customers, passengers or Recreational passengers[1-2-3]. Revenue management is not new problem and its antiquity goes to time that first service to the customers face with limited capacity however it may be able to say research compiled on revenue management problem has started since airlines American company has been set in with name of SABRE In the mid-1980s. This system allows company change thicket prices in each path according to anticipated customer demand rates. Company with this system can complete vacant capacities with adopting an appropriate strategy by offering these cheap tickets and with this way you can obtain highly benefit equals to 500 million dollars. These days revenue management has been done important innovation in service industry[9-10]. These applications are obvious in other serving applications. For instance Hotels Marriott use efficiency management system to increase incomes (100 million dollars for each year) by sort of low increasing in capacity and prices[6-7-8]. Even factory owners use management techniques to increase profits. Yield management can be strong tools in manager’s hand. Because it is predictable by use of demands customers with proper method and it is important in product programming.

2. REVENUE MANAGEMENT IN HOSPITALITY INDUSTRY

Revenue Management has the most efficiency by Operations Management Perspective if below conditions are prepared:

1 – Inventory is perishable this means that at the end period destroy inventory and it can’t be stored.
2 – Categorize customer demands according to certain classes. Company can differ between groups of customers and each group curve has different curve 3 - constant price is high and variable cost is low.
4 – Product is saleable in advance
5 – Demand is variable from one time to the other time or one customer class to the other.

Hotels have five characteristics in management discussion which they have been mentioned before. Hotels have two rate of price. One is during a week for businessman and another is for people who go to holidays. Variable cost is very low with each room (like cleaning) comparison with price of adding one room to the all hotel. Available rooms are not transferable from one night to the other and rooms can divert to the travel tours or conferences en masses. Finally Potential
customers may shorten their stay or they never go to hotel for reservation for no reason.

3. Model Hypothesizes

1. Present model try to calculate presented model tries to calculate capacity of each class with creating logical and proper relationship between price and demand assuming the price is clear
2. In this model certain period before service time divided to equal finite number period and model find the number of capacity with customers’ behavior demands in each period (considering with price classes)
3. Model uses dynamic programming approach to discrete time to control rooms’ inventory and finally convert two systems with n equations and unknown.
4. This approach in solving problem makes practical solution of the model easier rather than other models in real problems.
5. It does not consider any particular distribution in supposition for solving model. In practical it can be used proper distribution instead of them and the cases which input distribution complicate. It can achieve complex distribution by using a curve fitting and proper regression with simple and reasonable estimate and use in model.
6. Demand distribution assume continuous in this model
7. In presented model 4 consider researchers use model for simplicity
   a. demand for each class equal \( x_i \)
   b. demand for each class is independent from other class.
   c. no canceling reservation
   d. no canceling group reservation
8. Model prices with simple and reasonable method and effective communication between control rooms’ inventory problem unlike similar models doesn’t lead to complex math.
9. Presented model doesn’t use improbable distributions for simplicity
10. In this model depending on hotel policy time of staying can be influence or ineffective.

3.1 Model Parameters

K: the number of room hotels
L: the number of luxury rooms
M: the number of ordinary rooms
N: total number of luxury rooms
\( F_i(x_i) \): Customers input function distributions in t period at the hotel

\( p_{lt} \): The allocated price to the luxury room in t period which is left to the presented time service
\( p_{ut} \): The allocated price to the luxury room in t period which is left to the presented time service
\( L_t \): selling capacity luxury rooms in t period which are left to the presented time service
\( M_t \): selling capacity ordinary rooms in t period which are left to the presented time service
\( K_t \): Total selling capacity rooms in t period which are left to the presented time service

\( Y_{Lt} \): All remaining capacity luxury rooms for period 1 to t
\( Y_{Mt} \): All remaining capacity ordinary rooms for period 1 to t
\( Y_L \): All remaining capacity rooms for period 1 to t
\( R_t(Y_L, L_t) \): Income of selling luxury rooms for period 1 to t
\( R_t(Y_{Mt}, M_t) \): Income of selling ordinary rooms for period 1 to t
\( R_t(Y_L, K_t) \): All income of selling rooms for period 1 to t
\( T_i \): Time (i) of staying traveler

In this model each period assume like a class. The price of rooms and the allocated capacity for selling rooms are variable. The total number of period (number of classes) assume N and input customer distribution follow \( F_i(x_i) \) in t period.

For example supposed one hotel is decided to allocate its room to the customers in N period. Numbers of hotels rooms are K. Hotel has two kinds of rooms which include luxury and ordinary rooms. They are used by business travelers (Time-sensitive) and Recreational travelers (price-sensitive).

It is obvious that the prices of luxury rooms are more expensive than ordinary rooms. In n period (n period is left to time of presented serving) hotels sell its room with low price (luxury room with \( p_{lt} \) and ordinary room with \( p_{M_t} \)). In n-1 period hotel increase prices and so whatever we close to the time service the price of room are increasing. The philosophy of this strategy is hidden behind simple division at the view of customers. This division separate customers into two groups: 1 – sensitive-time 2- sensitive-price

Sensitive-time customers don’t demonstrate to the changing room prices very much due to this group are between wealthy people or manager and workers who is
paid their cost by their pleasant company this customers
are sensitive-time changing. Instead of sensitive-price
customers are ready to buy sooner than time of presented
time service. These customers are sensitive-price so they
certain strategy in best way to answer customers’ need
of two both groups.

In this model number of selling constant period are
apparent and constant and also price of rooms in each
period assume apparent. So that \( p_1 > p_2 > \ldots > p_s \)

In addition it is assumed t show the number of remaining
period until presented time service to the customers.
This model tries to achieve the best allocated inventory
control Rooms’ inventory so all room are sold in
presented time service and maximum profit goes to hotel.

### 3.2 Modeling and solving problems

P For molding and solving problem use dynamic
continuous-time programming.

\[
R_t(Y_t, K_t) = R_t(Y_{t1}, L_t) + R_t(Y_{M1}, M_t)
\]

\[
R_t(Y_{t1}, L_t) = \int_{0}^{L_t} f(x_t)(x_t p_t dx_t) + \int_{L_t}^{\infty} f(x_t)(x_t p_t dx_t) + R_s(Y_{t1} - L_t)
\]

\[
0 \leq L_t \leq Y_t
\]

\[
R_t(Y_{M1}, M_t) \text{ Show income of selling luxury rooms in}
\]

period time from \( 1 \) to \( t \).

\[
R_t(Y_{M1}, M_t) = \int_{0}^{\infty} f(x_t)(x_t p_t dx_t) + \int_{M_t}^{\infty} f(x_t)(x_t p_t dx_t) + R_s(Y_{M1} - M_t)
\]

\[
0 \leq M_t \leq Y_{M1}
\]

Show income of selling ordinary rooms in period time
from \( 1 \) to \( t \).

\[
R_t(Y_{M1}, M_t) = \int_{0}^{\infty} f(x_t)(x_t p_t dx_t) + \int_{M_t}^{\infty} f(x_t)(x_t p_t dx_t) + R_s(Y_{M1} - M_t)
\]

\[
\left\{ \begin{array}{l}
0 \leq L_t \leq Y_t
\\
0 \leq M_t \leq Y_{M1}
\end{array} \right.
\]

\[
R_t(Y_{M1}, M_t) \text{ Show income of selling ordinary rooms in}
\]

period time from \( 1 \) to \( t \).

For first period (one period remains to serving presented
(time) we have:

\[
R_t(Y_{M1}, M_t) = \int_{0}^{L_t} f(x_t)(x_t p_t dx_t) + \int_{L_t}^{\infty} f(x_t)(x_t p_t dx_t) + R_s(Y_{M1} - M_t)
\]

\[
\left\{ \begin{array}{l}
0 \leq L_t \leq Y_t
\\
0 \leq M_t \leq Y_{M1}
\end{array} \right.
\]

In order that we find optimal number for \( L_t \) and \( M_t \) in
target function. We derived once into \( L_t \) and once into
\( M_t \) and then equal to zero.

\[
\frac{dR_t(Y_t, K_t)}{dL_t} = p_t f_t(L_t) + p_t(1 - \int_{0}^{L_t} f_t(L_t) dx_t) + L_t p_t(-f_t(L_t)) = 0
\]

\[
= p_t(1 - f_t(L_t)) \geq 0
\]

So function \( R_t(Y_{t1}, L_t) \) is not descent and we have:

\[
L^*_t = Y_t
\]

\[
\frac{dR_t(Y_t, K_t)}{dM_t} = p_t f_t(M_t) + p_t(1 - \int_{0}^{M_t} f_t(M_t) dx_t) + M_t p_t(-f_t(M_t)) = 0
\]

Function \( R_t(Y_{M1}, M_t) \) is not descent also and we have:

\[
M^*_t = Y_{M1}
\]

So we have:

\[
R_t(Y, K) = \int_{0}^{L_t} f_t(x_t)(x_t p_t dx_t) + \int_{L_t}^{\infty} f_t(x_t)(x_t p_t dx_t) + \int_{0}^{M_t} f_t(x_t)(x_t p_t dx_t) + R_s(Y_t - L_t)
\]

\[
\left\{ \begin{array}{l}
0 \leq L_t \leq Y_t
\\
0 \leq M_t \leq Y_{M1}
\end{array} \right.
\]

We have also:

\[
L_t = Y_{L2} - L_2
\]

\[
M_t = Y_{M2} - M_2
\]

We will have this after substitution.

\[
R_t(Y, K) = \int_{0}^{L_t} f_t(x_t)(x_t p_t dx_t) + \int_{L_t}^{\infty} f_t(x_t)(x_t p_t dx_t) + \int_{0}^{M_t} f_t(x_t)(x_t p_t dx_t) + R_s(Y_t - L_t)
\]

\[
\left\{ \begin{array}{l}
0 \leq L_t \leq Y_t
\\
0 \leq M_t \leq Y_{M1}
\end{array} \right.
\]

Because we want to find optimal number \( L_2 \) and \( M_2 \)
we derived above target function once into \( L_2 \) and once
into \( M_2 \) and then equal to zero.

\[
\frac{dR_t(Y, K)}{dL_2} = p_t(1 - \int_{0}^{L_2} f_t(L_2) dx_t_2) - p_t(1 - f_t(Y_{L2} - L_2)) = 0
\]
According to above equation $L_2$ calculate after simplification from below equation

$$p_{L_2}(1 - F_2(L_2^*)) = p_{L_1}(1 - F_1(Y_{L_2} - L_2^*))$$

Since $L_2$ is part of $Y_{L_2}$, we have

$$L_2^* = \alpha_2 Y_{L_2} \quad 0 \leq \alpha_2 \leq 1$$

We have also:

$$\frac{dR(Y_2, K_2)}{dM_2} = p_{M_2}(1 - \int_{x_{M_2}} f_2(M_2)dx_{M_2}) - p_{M_1}(1 - F_2(Y_{M_2} - M_2)) = 0$$

According to above equation $M_2$ calculate after simplification from below equation

$$p_{M_2}(1 - F_2(M_2^*)) = p_{M_1}(1 - F_1(Y_{M_2} - M_2^*))$$

Since $M_2^*$ is part of $Y_{M_2}$, we have

$$M_2^* = \beta_2 Y_{M_2} \quad 0 \leq \beta_2 \leq 1$$

As result we have:

$$R_3(Y_3, K_3) = \int_{x_{M_3}-L}^{x_{M_3}} f_3(x_3)(x_{M_3}P_{M_3})dx_{M_3}$$

For third period (three periods remain presented time service) we have:

$$R_3(Y_3, K_3) = \int_{x_{M_3}-L}^{x_{M_3}} f_3(x_3)(L_3P_{L_3})dx_{L_3} + \frac{dM_3}{dL_3} f_3(x_3)(x_{M_3}P_{M_3})dx_{M_3} + \int_{x_{M_3}-L}^{x_{M_3}} f_3(x_3)(M_3P_{M_3})dx_{M_3} + R_3^*(Y_3 - K_3, K_3)$$

As result:

$$M_3^* = \beta_3 Y_{M_3} \quad 0 \leq \beta_3 \leq 1$$

For forth period (four periods remain to presented time service) we have:

$$R_4(Y_4, K_4) = \int_{x_{M_4}-L}^{x_{M_4}} f_4(x_4)(x_{M_4}P_{M_4})dx_{X_4} + \frac{dM_4}{dL_4} f_3(x_3)(x_{M_4}P_{M_4})dx_{M_4} + R_4^*(Y_4 - K_4, K_4)$$

After substitution we will have:

$$\frac{dR_4(Y_4, K_4)}{dL_4} = p_{L_4}(1 - \int_{x_{L_4}} f_4(L_4)dx_{L_4})$$

Because we want to find optimal number $L_3$ and $M_3$ in target function. We derived target function once into $L_3$ and once into $M_4$ and then equal to zero.

Derived function into $L_3$ is:

$$\frac{dR_4(Y_3, K_3)}{dL_3} = p_{L_3}(1 - \int_{x_{L_3}} f_3(L_3)dx_{L_3}) - p_{L_4}\alpha_2(1 - F_2(\alpha_2 Y_{L_3}))$$

According to above equations $L_3$ calculate after simplification from below function

$$P_{L_3}(1 - F_3(L_3)) = P_{L_2}\alpha_2(1 - F_2(\alpha_2 Y_{L_3})) + P_{L_4}(1 - \alpha_2)(1 - F_4(1 - \alpha_2)Y_{L_3})$$

As result:

$$L_3^* = \alpha_3 Y_{L_3} \quad 0 \leq \alpha_3 \leq 1$$

According to above equations $M_3$ calculate after simplification from below function

$$P_{M_3}(1 - F_3(M_3)) = P_{M_2}\beta_2(1 - F_2(\beta_2 Y_{M_3})) + P_{M_4}(1 - \beta_2)(1 - F_4(1 - \beta_2)Y_{M_3})$$

As result:

$$M_3^* = \beta_3 Y_{M_3} \quad 0 \leq \beta_3 \leq 1$$
\[
P_{L_4}(1 - F_4(L_4)) = \alpha_3 P_{L_3}[1 - F_3(\alpha_3 Y_{L_3})] \\
+ \alpha_4 (1 - \alpha_3) P_{L_2}[1 - F_2(\alpha_2 (1 - \alpha_3) Y_{L_3})] \\
+ (1 - \alpha_4)(1 - \alpha_3) P_{L_1}[1 - F_1((1 - \alpha_2)(1 - \alpha_3) Y_{L_3})]
\]
As result:
\[
L_4 = \alpha_4 Y_{L_4} \
0 \leq \alpha_4 \leq 1
\]
Derived function into \( M_4 \) is:
\[
dR_4(Y_4, K_4) = \frac{dM_4}{dM_4} \]
According to above equation \( M_4 \) calculates after the simplification from below equation
\[
P_{M_4}(1 - F_4(M_4)) = \beta_4 P_{M_3}[1 - F_3(\beta_4 Y_{M_3})] \\
+ \beta_2 (1 - \beta_4) P_{M_2}[1 - F_2(\beta_2 (1 - \beta_4) Y_{M_3})] \\
+ (1 - \beta_2)(1 - \beta_4) P_{M_1}[1 - F_1((1 - \beta_2)(1 - \beta_4) Y_{M_3})]
\]
As result:
\[
M_4 = \beta_4 Y_{M_4} \
0 \leq \beta_4 \leq 1
\]
For fifth period (fifth periods remain to presented time service) we have:
\[
R_5(Y_5, K_5) = \int_{x_{L_5}=0}^{L_5} f_5(x_{L_5}) (x_{L_5} P_{L_5}) dx_{L_5} \\
+ \int_{x_{M_5}=0}^{M_5} f_5(x_{M_5}) (x_{M_5} P_{M_5}) dx_{M_5} \\
+ \int_{x_{M_5}=M_5}^{\infty} f_5(x_{M_5}) (M_5 P_{M_5}) dx_{M_5} \\
+ R_4(Y_5 - K_5, K_4)
\]
We derived target function once into \( L_4 \) and once into \( M_4 \) and then equal to zero.

Derived function into \( L_5 \) is:
\[
dR_5(Y_5, K_5) = 0
\]
\[
P_{L_5}(1 - F_5(L_5))= \alpha_5 P_{L_4}[1 - F_4(\alpha_5 Y_{L_4})] \\
+ \alpha_6 (1 - \alpha_5) P_{L_3}[1 - F_3(\alpha_6 (1 - \alpha_5) Y_{L_3})] \\
+ \alpha_7 (1 - \alpha_6)(1 - \alpha_5) P_{L_2}[1 - F_2(\alpha_7 (1 - \alpha_5)(1 - \alpha_6) Y_{L_3})] \\
+ (1 - \alpha_7)(1 - \alpha_6)(1 - \alpha_5) P_{L_1}[1 - F_1((1 - \alpha_7)(1 - \alpha_6)(1 - \alpha_5) Y_{L_3})]
\]
As result:
\[
L_5 = \alpha_5 Y_{L_5} \
0 \leq \alpha_5 \leq 1
\]
Derived function into \( M_5 \) is:
\[
dR_5(Y_5, K_5) = 0
\]
\[
P_{M_5}(1 - F_5(M_5)) = \beta_5 P_{M_4}[1 - F_4(\beta_5 Y_{M_4})] \\
+ \beta_6 (1 - \beta_5) P_{M_3}[1 - F_3(\beta_6 Y_{M_3})] \\
+ \beta_7 (1 - \beta_6)(1 - \beta_5) P_{M_2}[1 - F_2((1 - \beta_6)(1 - \beta_5) Y_{M_3})] \\
+ (1 - \beta_7)(1 - \beta_6)(1 - \beta_5) P_{M_1}[1 - F_1((1 - \beta_7)(1 - \beta_6)(1 - \beta_5) Y_{M_3})]
\]
As result:
\[
M_5 = \beta_5 Y_{M_5} \
0 \leq \beta_5 \leq 1
\]
According to above stages we achieve below total chart:

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As result for calculation equation \( n \geq 2 \) in each stage is obtained below total formula.
\[
P_n (1 - F_n(L_n)) = \sum_{j=1}^{n} \prod_{i=1}^{j-1} A_i \left( 1 - F_{L_{(i-1)}} \left( \sum_{j=1}^{i} A_j \right) \right)
\]
As the same way for ordinary rooms calculation equation \( n \geq 2 \) in each stage is obtained below total formula.
\[
P_n (1 - F_n(L_n)) = \sum_{j=1}^{n} \prod_{i=1}^{j-1} A_i \left( 1 - F_{Y_{(M_{(i-1)}}) \left( \sum_{j=1}^{i} A_j \right) \right)
\]
Since staying travelers (time servicing) in rented hotel rooms are not obvious hospitality industries against airlines. There is always this probability that present short-staying travelers will cause loss of attraction opportunity probability passengers who want to have long-staying. This state can be assumed approximately equal to virtual successive discussion.

(In successive controlling more expensive classes in completion of capacity have possible use less expensive classes, too. But this state is not true for the classes with cheaper prices.)
Another problem we face in hotels is that time-staying travelers are variable and they are not identical. We can achieve the allocated optimal capacity for one special day. According to time-staying travelers are variable for other days (day after special days) what we do to find allocated optimal capacity for the next days. Hotels strategy usually is like this that they start pre-sale some months ago. Travelers who make reservation for certain days have this facility that he can make reservation room for future days if hotels don’t start pre-sale.

So that there are two possibilities a demanded person is next day of service or not.

\[ \delta_{ij} = \begin{cases} 
1: & \text{if demanded person for luxury } \text{room for } j \text{ day after due date} \\
0: & \text{otherwise} 
\end{cases} \]

Number of remaining luxury rooms for \( j \) next days after servicing

\[ Y_{Ln} = Y_{L_0} - \sum_{i=1}^{j} \delta_{ij} \]

After we find the number of vacant room for everyday it calculate like allocated optimal capacity room. For ordinary rooms do according above method.

4. CONCLUSION

Presented model with simple and reasonable method has effective relationship between control rooms’ inventory and pricing strategy. Model uses discrete-time dynamic programming for solving which convert to \( n \) systems with \( n \) unknown. This kind of modeling and way of answering use discrete-time dynamic programming. Answer the problem does with certain clear principles in realistic world. They are simpler than Available models which ends to complex math. With this solution method time-staying travelers are variable. For each period vacant rooms information should solve with mentioned method again.

REFERENCES


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