A Modified Callable Mechanism for Seat Inventory Control of Airlines Based on Buy-Up Behavior

CHENG LI AND FANGYI YIN
Shanghai University of Engineering Science, Shanghai 201620, China
Corresponding author: Cheng Li (Lcheng8066@126.com)

This work was supported by the National Social Science Foundation of China under Grant 15BJL104 and Grant 18BJL039.

ABSTRACT This paper introduces the buy-up behavior to the callable mechanism of seat inventory control, creating a modified callable mechanism, and studies the airline revenue under the modified mechanism. Specifically, the willingness to pay of consumers was taken as the reference of utility, according to the utility metrics of the prospect theory. Then, the willingness to pay for three types of tickets was expressed in the form of exponential smoothing. Next, the buy-up (demand transfer) probabilities were derived under four different relationships between the willingness to pay and ticket prices. On this basis, the traditional callable mechanism was modified, and the conditions for revenue growth were identified for different buy-up behaviors. Finally, the modified callable mechanism and the traditional one were compared through two cases study. The results show that, the modified mechanism, which considers the buy-up behavior, achieved a 3.17% (in CASE A) or 0.74% (in CASE B) higher airline revenue than the traditional mechanism. The research results shed new light on the callable mechanism from the perspective of consumer choice.

INDEX TERMS Air transport, callable mechanism, buy-up behavior, revenue management, willingness to pay.

I. INTRODUCTION
The development of aviation industry has greatly stimulated the demand for air transport, resulting in problems like reservation, change and cancellation. In the aviation market, the travel demand is highly fluctuating and thus difficult to predict. For airlines, the demand fluctuations must be fully considered to make more revenues. The common ways to boost revenues include overselling and opportunistic cancellations [1].

The callable mechanism, which was adopted by Caterpillar to reduce inventory risks offers a viable option to accurately forecast the demand for air transport [2]. Many scholars have explored the roles of this mechanism in the aviation industry. For instance, Gallego et al. [3] demonstrated that the callable mechanism facilitates the seat inventory control of high demand routes in the peak season, bolstering the revenues of airlines. Focusing on revenue management in off-season, Yu and Zhang [4] probed into the seat inventory control of a single flight, constructed a stochastic integer optimization model based on three-stage callable mechanism for seat cancellation, and proved that the model enables airlines to optimize the number of cancelled seats and realize risk arbitrage. Li et al. [5] held that the main strategy for airlines to make Pareto gains is to offer callable products, because there is no spill of low-fare consumers. Lin et al. [6] applied buy-back policy to order issuance and execution, and built a revenue model that increases the revenues of the asset provider and the intermediary.

In the meantime, the buy-up behavior of consumers has been widely introduced to revenue management. Coase [7] was the first to explore revenue management from the perspective of consumer behavior, pointing out that consumers identify the best purchase opportunity based on the forecast of future price. Tikani et al. [8] considered the integrated hub location and revenue management problem in the airline industry to maximize the revenue of transportation network and minimize hub installation costs, a two-stage stochastic model had been derived to determine the locations of hubs and protection levels in the ticket sale process, and an efficient modification of genetic algorithm had been proposed for the large-scale problems. Chen et al. [9] considered a
canonical revenue management (RM) problem wherein a monopolist seller posts prices for multiple products that were for sale over a fixed horizon so as to maximize expected revenues, and demonstrated that static prices surprisingly remain asymptotically optimal in the face of strategic customers for a multi-product setting and for a broad class of customer utility models. Kunnumkal and Talluri [10] proposed a new Lagrangian relaxation method for DC-NRM based on an extended set of multipliers. Kalyan and Garrett [11] constructed a model to control the seat allocation of airlines, based on the probability that a specific consumer purchase product at a certain price. Yoon et al. [12] fully considered reservation cancellation and refund policies, and solved these problems by approximate linear programming. Anderson and Wilson [13] explored the strategic behavior of consumers on the same flight, when offered time-varying prices. Li et al. studied the seat inventory control and pricing, according to the strategic behavior of consumers [14], [15]. Xu et al. [16] created several models for the case that overbooking and group booking are allowed in a single segment with multiple price levels, including a robust model for travel behavior, a nominal model without considering the error in predicted demand, as well as an improved expected marginal seat revenue (EMSR) model. Drawing on previous research on one-way transfer of demand, Huo and Qin [17] provided a probability distribution function of demand transfer, which describes the presales of airlines under the two-way transfer of demand. Yin and Li [18] constructed a three-stage callable model based on the probability of the customer purchasing a certain ticket. Li and Zhao [19] depicted consumer behavior with the discrete multinomial logit (MNL) model, modified the seat allocation model based on the demand transfer probability, and validated the modified model through example analysis.

Over the years, much attention has been paid to the flexible control of the callable mechanism, owing to the negative impact and inevitable prediction bias of overselling. Previous studies [1]–[6], [9]–[19] have demonstrated callable products as a riskless source of additional revenue, and the significance of consumer choice to seat inventory control. Domestic and foreign research on the callable mechanism is based on the case of independent customer demand, which is obviously not in line with the actual sales situation. In real life, passengers have buy-up behavior between different fares. However, there is a little report that investigates the callable mechanism from the angle of consumer choice. To make up for the gap, this paper modifies the traditional callable mechanism based on the buy-up behavior, and applies the modified callable mechanism to examine the conditions for revenue growth of airlines under different probabilities of buy-up behavior. Based on this, this paper introduces the buy-up behavior to the callable mechanism of seat inventory control, creating a modified callable mechanism, and studies the airline revenue under the modified mechanism. Firstly, we apply the theory of MNL with the prospect theory to calculate the passengers’ buy-up behavior probability. Secondly, the willingness to pay for three types of tickets is expressed in the form of exponential smoothing. The buy-up (demand transfer) probabilities are derived under four different relationships between the willingness to pay and ticket prices. Finally, the traditional callable mechanism is modified, and the conditions for revenue growth are identified for different buy-up behaviors. And the modified callable mechanism and the traditional one are compared through two cases study.

In a word, the theory and method proposed in this paper can be used to solve the problem of callable mechanism under buy-up behavior of real airline customers, and its research work and research results provide references and guidance at the theoretical and practical level for the seat control decision of airlines, and lay a foundation for related research and application.

II. PROBLEM DESCRIPTION

Suppose an airline implements the callable mechanism in a flight [3], [4], [18], and the flight offers three types of tickets: callable tickets, cheap tickets, and expensive tickets. The three types of tickets are ranked as callable tickets, cheap tickets and expensive tickets in ascending order of price.

In terms of sales logic, callable, cheap and expensive tickets are sold in different periods \((0, T_1), (T_1, T_2)\) and \((T_2, T_3)\). During the third period, if the number of expensive tickets being demanded surpasses that of expensive tickets available, then the callable tickets will be recalled with compensation.

Traditionally, the callable mechanism for seat inventory control assumes that the demand for each type of ticket is fulfilled in the corresponding period, that is, the demand for cheaper tickets is satisfied earlier than the more expensive tickets, and that the demands for different types of tickets are independent of each other [13].

In real-world scenarios, the buy-up behavior of consumers may occur due to time, ticket price and reference utility. On each flight, the number of seats available in each class is limited at a specific time. Once a type of ticket is sold out, the consumers that intend to purchase that type of tickets will purchase more expensive tickets at a certain probability. In this case, the airline should fully consider the impact of buy-up behavior on revenue management.

Before selling tickets, the airline predicts the original demand for the flight based on historical data. The original demands for the three types of tickets are independent of each other. The different types of tickets will be sold in turn in ascending order of price.

In the first period, the consumers are interested in callable tickets. It is assumed that these consumers can forecast the future price, assess the time utility, and evaluate the price difference between different types of tickets. If price has higher utility than time, the consumers will purchase callable tickets; if time has higher utility than price, the consumers will purchase the other two types of tickets. At the end of all periods, the actual demand \((D_i')\) of consumers for each type of
Therefore, the total revenue of the airline after implementing the traditional callable mechanism can be expressed as:

$$R_K = p_K V_K + p_L S_K + p_H W_K - p_L Q_K$$  \hspace{1cm} (1)$$

B. CRITERIA AND PROBABILITIES OF BUY-UP BEHAVIOR

The above analysis shows that, the consumer choice between ticket types can be discussed by the discrete MNL model (Multinominal Logit Model). According to the random utility theory, the MNL mainly depicts the consumer choice with the aim to maximize the utility.

Here, the utilities $U_i$ of ticket purchases are measured by the prospect theory proposed by Kahneman and Tversky [20], Tversky et al. [21], and Yang et al. [22]. Unlike traditional utility measurement strategy, Kahneman and Tversky constructed a new value function and decision weight to measure the utilities:

$$v(Δω_i) = \begin{cases} 
Δω_i^γ & Δω_i ≥ 0 \\
-λ(-Δω_i)^β & Δω_i ≤ 0 
\end{cases}$$  \hspace{1cm} (2)$$

$$ω(p_i) = \frac{p_i^γ}{(p_i^γ + (1-p_i)^γ)^{1/γ}}$$  \hspace{1cm} (3)$$

where, $v(Δω_i)$ is the value function and $ω(p_i)$ is weight function, $ω_i$ and $ω_j$ are the absolute utility and reference utility, respectively; $Δω_i = ω_i - ω_j$ is the difference between the two utilities; $α \in (0, 1)$, $β \in (0, 1)$ and $γ ≥ 1$ are the levels of risk aversion, risk seeking, and loss avoidance of consumers, respectively. Here, the willingness to pay of consumers is taken as the reference for utility.

Based on Yang et al. [22], this paper sets the willingness to pay to the reference level, denotes the price of type $i$ tickets as $p_i$, and characterizes the willingness to pay for type $i$ ticket as $r_i \sim N(μ_i, σ_i^2)$. Based on Popescu’s research [23], the willingness to pay for different types of tickets can be expressed in the form of exponential smoothing:

$$r_i = b_i[a_r \bar{r}_i + (1-a) p_i] + ϕ_i$$  \hspace{1cm} (4)$$

where, $a \in (0, 1)$ is the memory parameter about the impact of historical prices on consumers; $b_i > 1$ is how many times the willingness to pay for type $i$ tickets goes to that for type $i$ tickets; $ϕ_i \sim N(0, σ_i^2)$ is the noise term of the willingness of consumers to pay for type $i$ tickets.

For consumers, if price utility of type $i$ tickets is greater than that of type $i$-1 tickets ($μ_i > μ_{i-1}$), the demand for type $i$-1 tickets will be transferred to type $i$ tickets. If there exists a noise term $ϕ_i \sim N(0, σ_i^2)$ in the willingness of consumers to pay for type $i$ tickets, then the willingness to pay is greater than or smaller than the ticket price, and $r_i \sim N(μ_i, σ_i^2)$. Then according to appendix A, the probability $q_j^i$ of buy-up behavior can be expressed as:

$$q_j^i = F_{(i-1), 1}^1 q_{(i-1), 1}^j + F_{(i-1), 2}^2 q_{(i-1), 2}^j + F_{(i-1), 3}^3 q_{(i-1), 3}^j + F_{(i-1), 4}^4 q_{(i-1), 4}^j$$

$$= F_{(i-1), 1}^1 q_{(i-1), 1}^j + F_{(i-1), 2}^2 q_{(i-1), 2}^j + F_{(i-1), 3}^3 q_{(i-1), 3}^j + F_{(i-1), 4}^4 q_{(i-1), 4}^j$$  \hspace{1cm} (5)$$
TABLE 2. Revenue and sales volume of the airline in each period.

|                              | First period \((0, T_1)\) | Second period \((T_1, T_2)\) | Third period \((T_2, T_3)\) |
|------------------------------|-----------------------------|-------------------------------|-----------------------------|
| Ticket type and price        | Callable ticket, \(p_K\)    | Cheap ticket, \(p_L\)         | Expensive ticket, \(p_H\)   |
| Number of seats available    | \(K\)                       | \(L_K\)                       | \(C - S_K\)                 |
| Actual sales volume          | \(V_K = \min\{D_K, K\}\)   | \(S_K = \min\{D_L, L_K\}\)  | \(W_K = \min\{D_H, C - S_K\}\) |
| Actual number of tickets     | 0                           | 0                             | \(Q_K = \min\{V_K(D_H + V_K + S_K - C)^+\}\) |
| being recalled               |                             |                               |                             |
| Revenue                      | \(p_KV_K\)                  | \(p_LS_K\)                    | \(p_HW_K - p_LQ_K\)         |

TABLE 3. Revenue and sales volume of the airline in each period as per the modified callable mechanism.

|                              | First period \((0, T_1)\) | Second period \((T_1, T_2)\) | Third period \((T_2, T_3)\) |
|------------------------------|-----------------------------|-------------------------------|-----------------------------|
| Ticket type                  | Callable ticket, \(p_K\)    | Cheap ticket, \(p_L\)         | Expensive ticket, \(p_H\)   |
| Number of seats available    | \(K\)                       | \(L_K\)                       | \(C - S_K\)                 |
| Willingness to pay           | \(r_K - N(u_K, \sigma_K^2)\) | \(r_L - N(u_L, \sigma_L^2)\) | \(r_H - N(u_H, \sigma_H^2)\) |
| Transfer probability         | \(q_K^i\)                   | \(q_L^i\)                     | 0                           |
| Actual demand                | \(D_K = (1 - q_K^i)D_K\)    | \(D_L = (1 - q_L^i)(D_L + D_Kq_K^i)\) | \(D_H = D_T + q_H^i(D_T + D_Kq_K^i)\) |
| Actual sales volume          | \(V_K = \min\{D_K, K\}\)   | \(S_K = \min\{D_L, L_K\}\)  | \(W_K = \min\{D_H, C - S_K\}\) |
| Actual number of tickets     | 0                           | 0                             | \(Q_K = \min\{V_K(D_H + V_K + S_K - C)^+\}\) |
| being recalled               |                             |                               |                             |
| Income value                 | \(p_KV_K\)                  | \(p_LS_K\)                    | \(p_HW_K - p_LQ_K\)         |

where,

\[
F_{(i-1)i}^1 = \left[1 - \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)\right] \times \left[1 - \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)\right]
\]

\[
F_{(i-1)i}^2 = \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right) \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)
\]

\[
F_{(i-1)i}^3 = 1 - \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right) \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)
\]

\[
q_{(i-1)i}^2 = q_{(i-1)i}^2
\]

\[
q_{(i-1)i}^2 = \Phi \left(\frac{(1 + b_i - b(a)p_{i-1} - p_i - (1 - b(a))u_{i-1})}{\sqrt{(1 - b(a))^2 \sigma_{i-1}^2 + \eta_i^2}}\right)
\]

C. MODIFICATION OF TRADITIONAL CALLABLE MECHANISM

Considering buy-up behavior, the actual demands for the three types of tickets \(D_K, D_L\) and \(D_H\) can be expressed as:

\[
D_K' = (1 - q_K^i)D_K
\]

\[
D_L' = (1 - q_L^i)(D_L + (D_K - D_K'))
\]

\[
D_H' = D_H + q_L^i(D_L + D_Kq_K^i)
\]

In each formula, the transfer demand is subtracted from the original demand for the lower type tickets and added to the original demand for higher type tickets.

Based on Table 1, the traditional callable mechanism was thus modified to include the demand transfer induced by buy-up behavior. Table 3 shows the revenue and sales volume of the airline in each period in the modified callable mechanism.

Therefore, the total revenue of the airline after implementing the modified callable mechanism can be expressed as:

\[
R_K = p_KV_K' + p_LS_K' + p_HW_K' - p_LQ_K'
\]

IV. COMPARATIVE ANALYSIS

During the peak season, the original demand for each type of ticket is equal to or greater than the number of those tickets available: \(D_K \geq K, D_L \geq L_K\) and \(D_H \geq C - S_K\). According to appendix B, the variation in airline revenue induced by buy-up behavior \(\Delta R(K)\) was discussed as follows:

Case 1: If the demand transfer probabilities satisfy \(q_K^i \leq 1 - \frac{D_K}{D_L + D_Kq_K^i}\) and \(C - S_K - D_H \leq q_L^i \leq \frac{D_Kq_K^i + D_L - L_K'}{D_L + D_Kq_K^i}\), then \(\Delta R(K) = R_K' - R_K = 0\).

Case 2: In the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy \(q_L^i > 1 - \frac{D_K}{p_K}\) and \(C - S_K - D_H \leq q_L^i \leq \frac{D_Kq_K^i + D_L - L_K'}{D_L + D_Kq_K^i}\), meanwhile the ticket prices satisfy \(\frac{p_L - p_K}{p_H - p_L} > \frac{K - D_K'}{L_K'}\).
Table 4. The seat inventory control (case A).

| Ticket type     | Price | Number of seats available | Consumer demand |
|-----------------|-------|---------------------------|-----------------|
| Callable tickets| 700   | 70                        | 90              |
| Cheap tickets   | 820   | 180                       | 210             |
| Expensive tickets| 1,000 | 90                        | 110             |

**Case 3:** In the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^L_K > 1 - \frac{K}{D_k}$ and $q^H_K > \frac{C - S_k - D_H}{D_l + D_k q_K}$.

**Case 4:** For $D'_H = D_H + q^L_K (D_L + D_k q'_K) > D_H$ and $D_H \geq C - S_K$, in the peak season, there must be $D'_H \geq C - S'_K$, indicating the lack of solution in Case 4.

**Case 5:** In the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^L_K > 1 - \frac{K}{D_k}$, $q^H_K > \frac{C - S_k - D_H}{D_L + D_k q'_K}$, moreover the ticket prices satisfy $\frac{p_H - p_k}{p_H - p_L} > \frac{D'_L - L'_k}{K - D'_k}$.

**Case 6:** There must be $D'_H < D_H$, which contradicts with the actual relationship: $D'_H = D_H + q^L_K (D_L + D_k q'_K) > D_H$. The contradiction indicates the lack of solution in Case 6.

**Case 7:** In the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^L_K \leq 1 - \frac{K}{D_k}$ and $\frac{D_k q'_K + D_L - L'_k}{D_k + D_k q'_K} > q^L_K$.

**Case 8:** In the peak season, the airline revenue will decrease due to the buy-up behavior, if the demand transfer probabilities satisfy $q^L_K > 1 - \frac{K}{D_k}$ and $\frac{D_k q'_K + D_L - L'_k}{D_k + D_k q'_K} < q^L_K < \frac{C - S_k - D_H}{D_L + D_k q'_K}$.

V. CASE STUDY

To verify its performance, according to Yang et al. [22], the modified callable mechanism was compared with the traditional one through a case analysis on a flight with 300 seats available.

A. CASE A

The seat inventory control is explained in Table 4.

The traditional callable mechanism does not consider the consumer choice. Table 5 lists the airline revenue obtained by the traditional mechanism.

Next, the buy-up probabilities and ticket demands were computed by the modified callable mechanism, under the willingness to pay of $R_k \sim N (710, 8)$, $r_1 \sim N (826, 9.2)$ and $r_2 \sim N (995, 5.2)$. Table 6 lists the airline revenue obtained by the traditional mechanism.

As shown in Tables 5 and 6, the airline achieved a revenue of RMB 265560 under the modified callable mechanism, 3.17% higher than that (RMB 257400) under the traditional callable mechanism. The revenue growth verifies the validity of the modified callable mechanism.

It can also be seen from Table 5 that, the actual demand for callable tickets $D'_k = 35 < K$, that for cheap tickets $D'_k = 168 < L'_k$ and that for expensive tickets $D'_H = 207 > C - S'_K$. The results are in line with Case 5 in Section 4. According to the analysis in Case 5, Section 4, in the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^L_K > 0.223$ and $q^H_K > 0.322$, at the same time the ticket prices satisfy $\frac{p_H - p_k}{p_H - p_L} = 0.667 > \frac{D'_L - L'_k}{K - D'_k} = -0.343$.

In the above example, the demand transfer probabilities were $q^L_K = 0.6147$ and $q^H_K = 0.3667$, which fulfill the above constraints. In addition, the ticket prices also meet the above inequality. The 3.17% increase in revenue under our mechanism demonstrates the correctness of the comparative analysis in Section 4.

B. CASE B

When customer demand is twice of the seat allocation, the following is the seat situation of the airline implementing the callable mechanism (Table 7):

When the factors of passenger choice behavior are not considered, the benefits can be obtained as shown in Table 8:

Table 5. Airline revenue as per the traditional callable mechanism.

| Ticket type and price | First period | Second period | Third period |
|-----------------------|--------------|---------------|--------------|
| Callable ticket, $p_X$| 70           | 180           | 110          |
| Cheap ticket, $p_L$  | 0            | 0             | 60           |
| Expensive ticket, $p_H$| 890         | 147600        | 60800        |

Table 6. Airline revenue as per the modified callable mechanism.

| Ticket type and price | First period | Second period | Third period |
|-----------------------|--------------|---------------|--------------|
| Callable ticket, $p_X$| 70           | 180           | 110          |
| Cheap ticket, $p_L$  | 0            | 0             | 35           |
| Expensive ticket, $p_H$| 890         | 137760        | 103300       |

Table 7. The seat inventory control (case B).

| Ticket type     | Price | Number of seats available | Consumer demand |
|-----------------|-------|---------------------------|-----------------|
| Callable tickets| 700   | 70                        | 140             |
| Cheap tickets   | 820   | 180                       | 360             |
| Expensive tickets| 1,000 | 90                        | 180             |
The revenue after considering the buy-up behavior is as follows:

It can be concluded from Table 8 and Table 9 that the sales revenue of the traditional callable mechanism is RMB 259,200, while the sales revenue of the revised callable mechanism is RMB 261,120. Therefore, compared with the traditional sales model of recall mechanism, the calculation of the revised model can increase the revenue of airlines by 0.74%, and 0.74% (CASE B) < 3.17% (CASE A), indicating that the revenue growth rate of buy-to-up behavior is affected by the amount of customer demand.

### VI. CONCLUSION

This paper introduces the buy-up behavior to the callable mechanism of seat inventory control, creating a modified callable mechanism. Specifically, the discrete MNL model was adopted to describe the consumer behavior. The utilities of ticket purchases were measured by the prospect theory proposed by Kahneman and Tversky. Based on empirical evidence, the willingness to pay was taken as the reference for utility, and that for different types of tickets was expressed in the form of exponential smoothing. Next, the buy-up (demand transfer) probabilities were derived under four different relationships between the willingness to pay and ticket prices. On this basis, the traditional callable mechanism was modified. Furthermore, the impacts of demand transfer probabilities on airline revenue were discussed in the peak season. Finally, the modified mechanism was proved valid through case analysis. The results show that, the airline can make more revenue, if the buy-up behavior is included in the callable mechanism.

Of course, there are still some limitations with this research: only one airline is considered and the buy-down behavior is not covered. Thus, the future research will take account of more airlines to discuss the callable mechanism with buy-up behavior, and will take the buy-down behavior into deliberation. Through formula analysis and two case studies, the following conclusions can be drawn:

1. In this paper, the modified model is divided into eight cases to discuss the airlines’ revenue in the peak demand season.
2. In CASE A or CASE B, we can see that the revenue value considering passengers’ buy-to-up behavior is high when the demand is independent, indicating that considering passengers’ choice behavior can increase the revenue of airlines.
3. In CASE A, the returns of the callable mechanism model before and after considering passengers’ buy-to-up behavior increased by 3.17%. In CASE B, when passenger demand is twice the number of seats allocated, considering buy-to-up behavior increases the revenue of airlines by 0.74%, which indicates that the revenue growth of airlines considering buy-to-up behavior is affected by the number of passengers.

Of course, there are still some limitations with this research: only one airline is considered and the buy-down behavior is not covered. Thus, the future research will take account of more airlines to discuss the callable mechanism with buy-up behavior, and will take the buy-down behavior into deliberation.

### APPENDIX A

The willingness to pay and ticket price are analyzed in different cases below.

**Case 1:** The willingness to pay for type \( i \) and type \( i-1 \) tickets are greater than prices of the two types of tickets \( (r_i > p_i \text{ and } r_{i-1} > p_{i-1}) \).

The probability \( F_{(i-1)\|i}^{1} \) of a \( r_i > p_i \) nd \( r_{i-1} > p_{i-1} \) can be expressed as:

\[
F_{(i-1)\|i}^{1} = P(r_i > p_i) \times P(r_{i-1} > p_{i-1}) = [1 - P(r_i \leq p_i)] \times [1 - P(r_{i-1} \leq p_{i-1})] = \left[1 - \Phi\left(\frac{p_i - u_i}{\sigma_i}\right)\right] \times \left[1 - \Phi\left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)\right]
\]  

(10)

Since type \( i \) ticket has greater utility than type \( i-1 \) tickets \( (u_i > u_{i-1}) \). Derived from (2), we get the willingness to pay has a positive correlation with the ticket price:

\[
(r_i - p_i)^{\alpha} > (r_{i-1} - p_{i-1})^{\alpha}
\]  

(11)

Since \( \alpha \in (0, 1) \), (11) can be simplified as:

\[
r_i - p_i > r_{i-1} - p_{i-1}
\]  

(12)

Substituting (4) into (12), we have:

\[
b_i [ar_{i-1} + (1 - a) p_{i-1}] + \varsigma_i - p_i > r_{i-1} - p_{i-1}
\]  

(13)
That is,
\[
(1 - b_i a) r_{i-1} - \varphi_i < (1 + b_i - b_i a) p_{i-1} - p_i \tag{14}
\]

In this case, the consumers always prefer to purchase type \(i\) tickets, as long as \((14)\) is satisfied. In other words, the demand for type \(i-1\) tickets will be transferred to type \(i\) tickets. Let \(q_{(i-1)i}^1\) be the probability of the demand transfer from type \(i-1\) tickets to type \(i\) under \(r_i > p_i\) and \(r_{i-1} > p_{i-1}\).

Since \(r_i - 1 \sim N(u_{i-1}, \sigma^2_{i-1})\) and \(\varphi_i \sim N(0, \eta_i^2)\), we have \((1 - b_i a) r_i - \varphi_i \sim N((1 - b_i a) u_{i-1}, (1 - b_i a)^2 \sigma^2_{i-1} + \eta_i^2)\), in the light of the nature of the normal distribution.

Then, the value of \(q_{(i-1)i}^1\) can be computed as:
\[
q_{(i-1)i}^1 = P \{(1 - b_i a) r_{i-1} - \varphi_i < (1 + b_i - b_i a) p_{i-1} - p_i\} = \Phi \left(\frac{(1 + b_i - b_i a) p_{i-1} - p_i - (1 - b_i a) u_{i-1}}{\sqrt{(1 - b_i a)^2 \sigma^2_{i-1} + \eta_i^2}}\right) \tag{15}
\]

**Case 2:** The willingness to pay for type \(i\) and type \(i-1\) tickets are equal to or smaller than the prices of the two types of tickets \((r_i \leq p_i\) and \(r_{i-1} \leq p_{i-1}\)).

The probability \(F_{(i-1)i}^2\) of \(r_i \leq p_i\) and \(r_{i-1} \leq p_{i-1}\) can be expressed as:
\[
F_{(i-1)i}^2 = P \{(1 - b_i a) r_{i-1} - \varphi_i < (1 + b_i - b_i a) p_{i-1} - p_i\} = \Phi \left(\frac{p_i - u_i}{\sigma_i}\right) \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right) \tag{16}
\]

Since type \(i\) ticket has greater utility than type \(i-1\) tickets \((u_i > u_{i-1})\), Derived from formula (2), we get the willingness to pay has a negative correlation with the ticket price:
\[
-\gamma (p_i - r_i)^{\beta} > -\gamma (p_{i-1} - r_{i-1})^{\beta} \tag{17}
\]

Since \(\beta \in (0, 1)\) and \(\gamma \geq 1\), (17) can be simplified as:
\[
p_i - r_i < p_{i-1} - r_{i-1} \tag{18}
\]

Substituting (4) into (18), we have:
\[
p_i - b_i [ar_{i-1} + (1 - a) p_{i-1}] - \varphi_i < p_{i-1} - r_{i-1} \tag{19}
\]

That is,
\[
(1 - b_i a) r_{i-1} - \varphi_i < (1 + b_i - b_i a) p_{i-1} - p_i \tag{20}
\]

Hence, \((20)\) is the same as \((14)\). Thus, the probability \(q_{(i-1)i}^2\) of the demand transfer from type \(i-1\) tickets to type \(i\) tickets under \(r_i \leq p_i\) and \(r_{i-1} \leq p_{i-1}\) can be expressed as:
\[
q_{(i-1)i}^2 = \Phi \left(\frac{(1 + b_i - b_i a) p_{i-1} - p_i - (1 - b_i a) u_{i-1}}{\sqrt{(1 - b_i a)^2 \sigma^2_{i-1} + \eta_i^2}}\right) \tag{21}
\]

**Case 3:** The willingness to pay for type \(i\) tickets is greater than the price of these tickets \((r_i > p_i)\) and the willingness to pay for type \(i-1\) tickets is equal to or smaller than the price of these tickets \((r_{i-1} \leq p_{i-1})\).

The probability \(F_{(i-1)i}^3\) of \(r_i > p_i\) and \(r_{i-1} \leq p_{i-1}\) can be expressed as:
\[
F_{(i-1)i}^3 = P \{r_i > p_i\} \times P \{r_{i-1} \leq p_{i-1}\} = \left[1 - P \{r_i \leq p_i\}\right] \times P \{r_{i-1} \leq p_{i-1}\} = \left[1 - \Phi \left(\frac{p_i - u_i}{\sigma_i}\right)\right] \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right) \tag{22}
\]

Under \(r_i > p_i\) and \(r_{i-1} \leq p_{i-1}\), the willingness to pay has a positive correlation with the price of type \(i\) tickets, while the willingness to pay has a negative correlation with the price of type \(i-1\) tickets. In this case, the consumers always choose type \(i\) tickets. Therefore, the probability \(q_{(i-1)i}^3\) of the demand transfer from type \(i-1\) tickets to type \(i\) tickets under \(r_i > p_i\) and \(r_{i-1} \leq p_{i-1}\) equals 1.

**Case 4:** The willingness to pay for type \(i\) tickets is equal to or smaller than the price of these tickets \((r_i \leq p_i)\) and the willingness to pay for type \(i-1\) tickets is greater than the price of these tickets \((r_{i-1} > p_{i-1})\).

The probability \(F_{(i-1)i}^4\) of \(r_i \leq p_i\) and \(r_{i-1} > p_{i-1}\) can be expressed as:
\[
F_{(i-1)i}^4 = P \{r_i \leq p_i\} \times P \{r_{i-1} > p_{i-1}\} = P \{r_i \leq p_i\} \times [1 - P \{r_{i-1} \leq p_{i-1}\}] = \Phi \left(\frac{p_i - u_i}{\sigma_i}\right) \times \left[1 - \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)\right] \tag{23}
\]

Under \(r_i \leq p_i\) and \(r_{i-1} > p_{i-1}\), the willingness to pay has a negative correlation with the price of type \(i\) tickets, while the willingness to pay has a positive correlation with the price of type \(i-1\) tickets. In this case, the consumers always choose type \(i\) tickets. Therefore, the probability \(q_{(i-1)i}^4\) of the demand transfer from type \(i-1\) tickets to type \(i\) tickets under \(r_i \leq p_i\) and \(r_{i-1} > p_{i-1}\) equals 0.

To sum up, the probability \(q_i^j\) of buy-up behavior can be expressed as:
\[
q_i^j = F_{(i-1)i}^1 q_{(i-1)i}^1 + F_{(i-1)i}^2 q_{(i-1)i}^2 + F_{(i-1)i}^3 q_{(i-1)i}^3 + F_{(i-1)i}^4 q_{(i-1)i}^4 \tag{24}
\]

where,
\[
F_{(i-1)i}^1 = \left[1 - \Phi \left(\frac{p_i - u_i}{\sigma_i}\right)\right] \times \left[1 - \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)\right]
\]
\[
F_{(i-1)i}^2 = \Phi \left(\frac{p_i - u_i}{\sigma_i}\right) \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)
\]
\[
F_{(i-1)i}^3 = \left[1 - \Phi \left(\frac{p_i - u_i}{\sigma_i}\right)\right] \times \Phi \left(\frac{p_{i-1} - u_{i-1}}{\sigma_{i-1}}\right)
\]
\[
q_{(i-1)i}^1 = q_{(i-1)i}^2 = q_{(i-1)i}^3 = q_{(i-1)i}^4 = 0
\]

**APPENDIX B**

This section compares the airline revenues of traditional and modified mechanisms in the three periods of ticket sales.
The only difference between the two mechanism lies in that the traditional mechanism does not consider the buy-up behavior, with a buy-up probability of \( q_i^I = 0 \). The variation in airline revenue induced by buy-up behavior can be expressed as (25), shown at the bottom of this page.

During the peak season, the original demand for each type of ticket is equal to or greater than the number of those tickets available: \( D_K \geq K, D_L \geq L_k \) and \( D_H \geq C - S_K \). On this basis, the variation in airline revenue induced by buy-up behavior \( \Delta R(K) \) was discussed as follows:

**Case 1:** The actual demand for each type of ticket is equal to or greater than the number of those tickets available: \( D_K' \geq K, D_L' \geq L_k \) and \( D_H' \geq C - S_K' \). In other words, the probability of demand transfer from callable to cheap tickets and that of demand transfer from cheap to expensive tickets satisfy \( q_{ikk}^L \leq 1 - \frac{K}{D_K} \) and \( C - S_K - D_H \leq \frac{q_{ikk}^L}{D_L + D_k q_k^L} \), respectively.

Then, the variation in airline revenue induced by buy-up behavior can be computed by (26), as shown at the bottom of this page.

Since \( D_H' \geq C - S_K' \) and \( D_H \geq C - S_K \), we have \( \Delta R(K) = (p_H - P_L) (L_K - L_K') \).

According to problem description, we have \( P_L < P_H \), which leads to \( p_H - p_L > 0 \). The above analysis shows that \( L_K = \theta (C - V_K) = \theta (C - K) \) and \( L_K' = \theta (C - V_K') = \theta (C - K) \). Hence, \( L_K = L_K' \) and \( \Delta R(K) = R_K' - R_K = 0 \). That is to say, in the peak season, the airline revenue does not change with the buy-up behavior, if the demand transfer probabilities satisfy \( q_{ikk}^L \leq 1 - \frac{K}{D_K} \) and \( C - S_K - D_H \leq \frac{q_{ikk}^L}{D_L + D_k q_k^L} \).

**Case 2:** The actual demand for callable tickets is smaller than the number of those tickets available \( D_K < K \); the actual demand for cheap tickets is equal to or greater than the number of those tickets available \( D_H' \geq C - S_K' \); the actual demand for expensive tickets is equal to or greater than the number of those tickets available \( C - S_K - D_H \leq \frac{q_{ikk}^L}{D_L + D_k q_k^L} \). In other words,
the demand transfer probabilities satisfy $q^H_K > 1 - \frac{K}{D_K}$ and $\frac{C - S_K - D_H}{D_L + D_K q^H_K} \leq q^H_L \leq \frac{D_K q^H_K + D_L - L'_K}{D_L + D_K q^H_K}$.

Then, the variation in airline revenue induced by buy-up behavior can be computed by (27), as shown at the bottom of the previous page.

Under our mechanism, there is $L_K = \theta (C - K)$ and $L'_K = \theta (C - V_K') = \theta (C - D'_K)$. Since $D'_K < K$, we have $L'_K > L_K$. Whereas $D'_H \geq C - S'_K$ and $D_H \geq C - S_K$, we have $D'_H - (C - S'_K) + D'_K \geq D'_K$ and $D_H - (C - S_K) + K \geq K$. Therefore, the following can be obtained:

$$\Delta R (K) = (p_L - p_K) \left[ K - (1 - q^H_K) D_K \right] - (p_H - p_L) (L_K - L_K)$$

(28)

In this case, the airline revenue only increases if $\Delta R (K) > 0$. Hence, we have $\frac{pl - pk}{ph - pl} > \frac{K - D_H}{L_K - L_K}$. That is to say, in the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^H_K > 1 - \frac{K}{D_K}$ and $\frac{C - S_K - D_H}{D_L + D_K q^H_K} \leq q^H_L \leq \frac{D_K q^H_K + D_L - L'_K}{D_L + D_K q^H_K}$. Meanwhile, the ticket prices satisfy $q^L_L \leq \frac{D_K q^H_K + D_L - L'_K}{D_L + D_K q^H_K}$, and the demand transfer probabilities satisfy $q^L_L \leq \frac{C - S_K - D_H}{D_L + D_K q^H_K}$. Then, the variation in airline revenue induced by buy-up behavior can be computed by (29), as shown at the bottom of this page.

Similar to Case 1, we have $L_K = L'_K$. Thus, $D'_L < L'_K = L_K$, and $D_H - (C - S'_K) + K \geq K$ and $D_H - (C - S_K) + K \geq K$. Then, the following can be obtained:

$$\Delta R (K) = R'_K - R_K = p_K \left[ \min \{ D'_K, K \} - \min \{ D_K, K \} \right] + p_L \left[ \min \{ D'_L, L'_K \} - \min \{ D_L, L_K \} \right] - p_H \left[ \min \{ V_K, (D'_H + V'_K + S'_K - C)^+ \} - \min \{ V_K, (D_H + V_K + S_K - C)^+ \} \right]$$

(29)

$$= p_K (K - K) + p_L (D'_L - L_K) + p_H (L_K - D'_L)$$

$$\Delta R (K) = R'_K - R_K = p_K \left[ \min \{ D'_K, K \} - \min \{ D_K, K \} \right] + p_L \left[ \min \{ D'_L, L'_K \} - \min \{ D_L, L_K \} \right] - p_H \left[ \min \{ V_K, (D'_H + V'_K + S'_K - C)^+ \} - \min \{ V_K, (D_H + V_K + S_K - C)^+ \} \right]$$

$$= p_K (K - K) + p_L (D'_L - L_K) + p_H (C - D'_L - (C - L_K))$$

(30)

$$= p_K (D'_K - K) + p_L (D'_L - L_K) + p_H (C - D'_L - (C - L_K))$$

Through comparison, it is found that, in the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy $q^H_K \leq 1 - \frac{K}{D_K}$, $q^H_L \geq \frac{D_K q^H_K + D_L - L'_K}{D_L + D_K q^H_K}$ and $q^H_L \geq \frac{C - S_K - D_H}{D_L + D_K q^H_K}$.

**Case 4:** The actual demand for callable tickets is equal to or greater than the number of those tickets available $D'_K \geq K$; the actual demand for cheap tickets is equal to or greater than the number of those tickets available $D'_L \geq L'_K$; the actual demand for expensive tickets is smaller than the number of those tickets available $D'_H < C - S'_K$.

In this case, $V'_K = \min \{ D'_K, K \} = K = V_K$, $S'_K = \min \{ D'_L, L'_K \} = L'_K$, $S'_K = \min \{ D'_L, L'_K \} = L'_K$, $L'_K = \theta (C - V_K') = \theta (C - K)$ and $L'_K = \theta (C - V'_K) = \theta (C - K)$. Thus, we have $L_K = L'_K$, which leads to $S'_K = S_K$.

For $D'_H = D_H + q^H_H (D_L + D_K q^H_K) > D_H$ and $D_H > C - S_K$ in the peak season, there must be $D'_H \geq C - S'_K$, indicating the lack of solution in Case 4.

**Case 5:** The actual demand for callable tickets is smaller than the number of those tickets available $D'_K < K$; the actual demand for cheap tickets is smaller than the number of those tickets available $D'_L < L'_K$; the actual demand for expensive tickets is equal to or greater than the number of those tickets available $D'_H \geq C - S'_K$. In other words, the demand transfer probabilities satisfy $q^H_K > 1 - \frac{K}{D_K}$, $q^H_L \geq \frac{C - S'_K - D_H}{D_L + D_K q^H_K}$ and $q^L_L > \frac{D_K q^H_K + D_L - L'_K}{D_L + D_K q^H_K}$.

Then, the variation in airline revenue induced by buy-up behavior can be computed by (30), as shown at the bottom of this page.

From the above discussion, since $D'_H \geq C - S'_K$ and $D_H \geq C - S_K$, we have $D'_H - (C - S'_K) + D'_K \geq D'_K$ and
In this case, the airline revenue only increases if \( \Delta R(K) > 0 \). Hence, we have \( \frac{p_{L} - p_{K}}{p_{H} - p_{L}} > \frac{D_{L} + D_{K}q_{K}^{H}}{D_{L} + D_{K}q_{L}^{K}} \). That is to say, in the peak season, the airline revenue will increase without any risk due to the buy-up behavior, if the demand transfer probabilities satisfy \( q_{K}^{H} > 1 - \frac{K}{D_{K}} \) and \( q_{L}^{H} \geq \frac{C - S_{K} - D_{H}}{D_{L} + D_{K}q_{K}^{H}} \), moreover the ticket prices satisfy and\( \frac{p_{L} - p_{K}}{p_{H} - p_{L}} > \frac{D_{L} + D_{K}q_{K}^{H}}{D_{L} + D_{K}q_{L}^{K}} \).

**Case 6:** The actual demand for cancellable tickets is smaller than the number of those tickets available \( D_{K} < K \); the actual demand for cheap tickets is equal to or greater than the number of those tickets available \( D_{K}^{H} > L_{K}^{H} \); the actual demand for expensive tickets is smaller than the number of those tickets available \( D_{H}^{H} < C - S_{K}^{H} \). In this case, \( V_{K} = \min \{ D_{K}^{H}, K \} = D_{K}^{H} \), \( S_{K} = \min \{ D_{L}, L_{K} \} = L_{K} \). Since \( D_{L}^{H} < C - S_{K}^{H} \) and \( D_{H}^{H} < C - S_{K}^{H} \), we have \( D_{L}^{H} < C - S_{K}^{H} \) and \( D_{H}^{H} < C - S_{K}^{H} \).

Since \( D_{K}^{H} < K \), we have \( C - \theta(C - D_{K}^{H}) < C - \theta(C - D_{K}) \). Thus, there must be \( D_{H}^{H} < D_{H}^{H} \), which contradicts with the actual relationship: \( D_{H}^{H} = D_{H} + D_{H}^{H} \geq D_{H}^{H} \). The contradiction indicates the lack of solution in Case 6.

**Case 7:** The actual demand for cancellable tickets is equal to or greater than the number of those tickets available \( D_{K}^{H} \geq K \); the actual demand for cheap tickets is smaller than the number of those tickets available \( D_{L}^{H} > L_{L}^{H} \); the actual demand for expensive tickets is smaller than the number of those tickets available \( D_{H}^{H} < C - S_{K}^{H} \). In other words, the demand transfer probabilities satisfy \( q_{K}^{H} \leq 1 - \frac{K}{D_{K}} \) and \( \frac{D_{L} + D_{K}q_{L}^{H}}{D_{L} + D_{K}q_{K}^{H}} < q_{L}^{H} < \frac{C - S_{K} - D_{H}}{D_{L} + D_{K}q_{L}^{H}} \).

Then, the variation in airline revenue induced by buy-up behavior can be computed by (31), as shown at the bottom of this page.

Since \( D_{L}^{H} < C - S_{K}^{H} \) and \( D_{H}^{H} \geq C - S_{K}^{H} \), we have \( D_{L}^{H} < C - S_{K}^{H} \) and \( D_{H}^{H} < C - S_{K}^{H} \). Then, the following can be obtained:

\[
\Delta R(K) = R_{K}^{K} - R_{K} = p_{K} \left[ \min \{ D_{K}^{K}, K \} - \min \{ D_{H}, K \} \right] + p_{L} \left[ \min \{ D_{L}^{K}, L_{K}^{K} \} - \min \{ D_{L}, L_{K} \} \right] 
+ p_{H} \left[ \min \{ D_{H}^{K}, C - S_{K}^{H} \} - \min \{ D_{H}, C - S_{K}^{H} \} \right] 
- p_{L} \left[ \min \{ V_{K}^{C}, (D_{H}^{H} + V_{K}^{C} + S_{K}^{C} - C)^{+} \} - \min \{ V_{K}, (D_{H} + V_{K}^{C} + S_{K}^{C} - C)^{+} \} \right] 
= p_{K} (K - K) + p_{L} (D_{L}^{L} - L_{K}^{L}) + p_{H} (D_{H}^{H} - (C - S_{K}^{H})) 
- p_{L} \left[ \min \{ P_{K}^{C}, (D_{H}^{H} + V_{K}^{C} + S_{K}^{C} - c)^{+} \} - \min \{ V_{K}, (D_{H} + V_{K}^{C} + S_{K}^{C} - c)^{+} \} \right] 
= p_{K} (D_{K}^{K} - K) + p_{L} (D_{L}^{L} - L_{K}^{K}) + p_{H} (D_{H}^{H} - (C - S_{K}^{H})) 
- p_{L} \left[ \min \{ D_{K}^{C}, [(D_{H}^{H} - (C - S_{K}^{H}) + D_{K}^{H})]^{+} - \min \{ K, (D_{H} - (C - S_{K}))^{+} \} \right] 
\]

\[(31)\]
Then, the variation in airline revenue induced by buy-up behavior can be computed by (32), as shown at the bottom of the previous page. Since $D'_H < C - S'_K$ and $D_H \geq C - S_K$, we have $D'_H - (C - S'_K) + D'_K < D'_K$ and $D_H - (C - S_K) + K \geq K$. Thus, the following can be obtained:

$$\Delta R(K) = K'_K - R_K = p_K (D'_K - K) + p_L (D'_L - L_K)$$

$$+ p_H [D'_H - (C - S'_K)] - p_L [D'_H - (C - S'_K) + D'_K - K]$$

$$= p_L (D'_L - L_K) + p_H [D'_H - (C - S'_K)] - p_L [D'_H - (C - S'_K)]$$

$$= \Delta R = p_L (D'_L - L_K) + [p_H - p_L] [D'_H - (C - S'_K)] \leq 0$$

(33)

According to problem description, we have $S_K = L_K = \theta (C - V_K) = \theta (C - K)$. Since $S'_K = D'_L < L'_K = \theta (C - V'_K) = \theta (C - D'_K)$ and $D'_K < K$, there is $C - S'_K > C - S_K$. Therefore, the following can be derived:

$$\Delta R = p_L (D'_L - L_K) + (p_H - p_L) [D'_H - (C - S'_K)] < 0$$

(34)

In other words, in the peak season, in the peak season, the airline revenue will decrease due to the buy-up behavior, if the demand transfer probabilities satisfy $q'_K > 1 - \frac{K}{D_K}$ and $\frac{D'_K q'_K + D'_L - L'_K}{D_L + D'_K q'_K} < q'_L < \frac{C - S'_K - D'_H}{D_L + D'_K q'_K}$.

**REFERENCES**

[1] E. Biyalogorsky, Z. Carmon, G. E. Fruchter, and E. Gerstner, “Research note: Overselling with opportunistic cancellations,” *Marketing Sci.*, vol. 18, no. 4, pp. 605–610, Nov. 1999.

[2] Y. Sheffi, *The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage*, vol. 1. Cambridge, MA, USA: MIT Press, 2005.

[3] G. Gallego, S. G. Kou, and R. Phillips, “Revenue management of callable products,” *Manage. Sci.*, vol. 54, no. 3, pp. 550–564, Mar. 2008.

[4] H. Yu and D.-M. Zhang, “Airline’s optimal seating control strategy under the callable mechanism,” *Syst. Eng. Theory Pract.*, vol. 29, no. 6, pp. 32–38, Jun. 2009.

[5] T. Li, J. Xie, S. Lu, and J. Tang, “Duopoly game of callable products in airline revenue management,” *Eur. J. Oper. Res.*, vol. 254, no. 3, pp. 925–934, Nov. 2016.

[6] D. Lin, C. K. M. Lee, and J. Yang, “Air cargo revenue management under buy-back policy,” *J. Air Transp. Manage.*, vol. 61, pp. 53–63, Jun. 2017.

[7] R. H. Coase, “Durability and monopoly,” *J. Law Econ.*, vol. 15, no. 1, pp. 143–149, Apr. 1972.

[8] H. Tikani, M. Honarvar, and Y. Z. Mehrjerdi, “Developing an integrated hub location and revenue management model considering multi-classes of customers in the airline industry,” *Comput. Appl. Math.*, vol. 37, no. 3, pp. 3334–3364, Jul. 2018.

[9] Y. Chen, V. F. Farias, and N. Trichakis, “On the efficacy of static prices for revenue management in the presence of strategic customers,” *Manage. Sci.*, pp. 5535–5555, Aug. 2019.

[10] C. K. Anderson and J. G. Wilson, “‘Wait or buy? The strategic consumer: Pricing and profit implications,” *J. Oper. Res. Soc.*, vol. 54, no. 3, pp. 299–306, Mar. 2003.

[11] H. Li, Q. Peng, and Q. Yao, “Revenue management model with passenger segment and buy-up behavior,” *J. Math. Pract. Theory*, vol. 42, no. 23, pp. 32–44, 2012.

[12] H. Li, Q. Peng, and M. R. Tang, “Optimal seat inventory control and dynamic pricing for airline with strategic passengers,” *Control Decis.*, vol. 33, no. 7, pp. 1295–1302, 2018.

[13] L. P. Xu, J. L. Li, and L. Yan, “Comparative analysis on single airline capacity control models with overbooking,” *Syst. Eng.-Theory Pract.*, vol. 34, no. 1, pp. 129–137, 2014.

[14] Z. J. Huo and Y. Qin, “Seat inventory control model based on bidirectional diversion of multiple-class demands,” *Syst. Eng.*, vol. 34, no. 1, pp. 116–121, 2016.

[15] F. Y. Yin and C. Li, “Optimization Model of the Callable Mechanism Based on Passenger Choice Behavior,” *Logistics Sci.*, vol. 41, no. 10, pp. 87–89, 2018.

[16] C. Li and J.-N. Zhao, “A container slots allocation model based on demand diversion probability,” *J. Coastal Res.*, vol. 94, no. sp1, pp. 833–837, Sep. 2019.

[17] D. Kahneman and A. Tversky, “Prospect theory: An analysis of decision under risk,” *Econometrica*, vol. 47, no. 2, pp. 263–291, 1979.

[18] V. Tunuguntla, P. Basu, K. Rakshit, and D. Ghosh, “Sponsored search advertising and dynamic pricing for perishable products under inventory-linked customer willingness to pay,” *Eur. J. Oper. Res.*, vol. 276, no. 1, pp. 119–132, Jul. 2019.

[19] H. Li, Q. Peng, and Q. Yao, “Revenue management model with passenger’s purchasing behavior in revenue management situations,” *Chin. J. Manage. Sci.*, vol. 1, pp. 38–42, 2013.

[20] I. Popescu and Y. Wu, “Dynamic pricing strategies with reference effects,” *Oper. Res.*, vol. 55, no. 3, pp. 413–429, Jun. 2007.

CHENG LI received the Ph.D. degree in management science and engineering. He is currently an Associate Professor of management with the College of Air Transportation, Shanghai University of Engineering Science, China. He published articles in various international journals such as *IEEE Access, Journal of Coastal Research, International Journal of System Assurance Engineering and Management,* and others. He has successfully managed various national and local sponsored research projects and grants. His research focuses on management science, including revenue management, demand forecast, and transportation management.

FANGYI YIN was born in China, in December 1992. He is currently pursuing the master’s degree with the Shanghai University of Engineering Science, China. He participated in numerous national and local projects for transportation management in China. He focuses his research efforts on transportation management, including intelligent optimization method, and modeling and analysis of seat allocation.