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Operational strategy of customized bus considering customers’ variety seeking behavior and service level

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ABSTRACT

In recent years, customized bus (CB) is becoming an innovative model of the public transport system (PTS) in China. This service provides an advanced, timely, personalized, and flexible responses to the demand of the PTS, especially of commuters. Obviously, it could have an impact on public transport (PT) service. For instance, CB services influence the customers’ variety-seeking behavior, which results in changes of customer options in different periods. Therefore, customers could be divided into different groups of preference. In this paper, we construct a two-period Hotelling game model by variety-seeking behavior and service level. The results show that, in the first stage, the departure frequency of CB and PT is influenced by variety-seeking behavior and service level. In the second stage, departure frequency is influenced by service level only. Next, although the departure frequency of bus impacts the changes of passenger ratios in different stages, service level appreciably impacts passenger number. From customer surplus and social welfare, we find that adjustment of service level can increase social welfare, which means that CB and PT will reach an optimum effect. The present work can provide a valuable reference to policymakers, practitioners, and others.

1. Introduction

The public transport (PT) as a representative of the public transport system (PTS), has reduced the cost of social travel and improved operational efficiency. However, it has some weaknesses in practice. For example, congestion, unpunctuality, and frequent transfer are the disadvantages of PT when passengers enjoy pleasant travel experience. At the operation level, PT could not get the demand of passengers timely and accurately, which causes the problem of deadhead status sometimes. The reasonable mode of transportation has great significance, since it improves operational efficiency, customer experience, and social benefit.

The customized bus (CB) is an innovative model of the public transport system, which plays a positive role in terms of relieving operation pressure. The citizens can upload the demand for travel to the operational platform through websites or APPs, and the bus company plans the route of operation according to travel demands and the distribution of passenger flow. It means the passengers have one-stop and customized trip service from community to workplace. This mode will reduce waste of time, optimize travel condition, and improve efficiency. In consideration of CB’s advantages, most provinces in China have launched CB. For instance, there is a “Customized Bus and Minibus Connected City” service in Wuhan. This service enables the passengers to inquire about the route and book the ticket through Alipay or WeChat on the Internet and makes trips easier and life more convenient. In due course, this mode can improve the efficiency of travel. Others as examples include “Deer EV” in Shanghai and “Heart of Bus” in Hangzhou. In the future, Xiongan New Area will also develop the customized and responsive buses to provide more convenient, comfortable, and personalized services. The public transportation service jointly launched by Nanjing Public Transport Group and Didi Bus is concentrated on providing commuters with fast and direct commuting buses in morning and evening rush hours, which can shorten the commuting time by 33.5%. Citizens can customize their “exclusive” commute routes according to their travel needs (IT Home, 2018). These existing practices reflect the characteristics of high efficiency, convenience, and comfort of customized public transport. Therefore, the emergence of CB can satisfy the travel needs of most commuters and achieve a balance of travel supply and demand.

The variety-seeking behavior, by existing studies, is an exploratory...
action, which means that the customer will make the next purchase even if the consequences of this action are unknown in order to change the internal and external environment to bring a satisfying consumption experience driven by intrinsic motivation (Baumgartner and Steenkamp, 1996). This phenomenon will be more obvious in the bus service. According to Mintel’s report on Chinese customers’ diverse experiences and quality of life in 2019, more than four in five (81%) customers said that they prefer adventures such as buying new products or traveling to new places to staying the same. It means that Chinese customers desire and pursue diverse experiences and quality of life, and that businesses will miss the boat if they do not innovate (Sohu, 2019; Zhongguancun Online, 2014). For instance, the popularity of the Double Eleven has gone beyond shopping itself and become a carnival of entertainment and consumption driven by consumerism. The younger generation prefer unique things and new brands which are an important part of their lifestyle. The new digital payment technology, for instance, the Face Recognition Technology (FRT) which is a great consumption experience, has brought great convenience to young consumers (Leju, 2019).

China is densely populated nowadays and it is necessary to develop a variety of three-dimensional outbound traffic, which means that the passengers will have a better travel experience. For instance, Beijing Public Transportation Group takes public transport miniaturization and community-orientation as the main development direction in the future. It uses flexible small buses to operate as community buses in more demand in areas with great demand. In this way, bus companies can respond to the calls of passengers for better accessibility and more flexible lines (Chinabuses, 2018). Therefore, commuters, senior citizens, and young people, especially commuters, are all likely to benefit from such application scenarios. Sometimes, passengers will consider their preferences in order to seek a good service experience and shorten the travel time. In this case, it is necessary to consider the crowd with multiple experiences, who like to try new ways of travel, and more opportunities for consumption. It is an unavoidable problem in CB development as well. In the public transit system of CB and PT, how does the variety-seeking behavior impact operation and management of different types of buses? In previous studies, the improvement in service has an important influence on bus operation (Chen et al., 2016; Cervero, 2016; Demircan and Tunc, 2019). Therefore, a research question arises naturally: in the application scenarios of CB and PT, if there are passengers with variety-seeking behavior, how to improve the service in order to rationalize operation without rushing headlong into a mass.

Therefore, in this study, we construct a Hotelling model with a two-period style to study variety-seeking behavior and bus services in the transport system of CB and PT. From the aspects of public welfare, we consider fare of the bus as an exogenous variable, and waiting time and passenger numbers as endogenous variables. In other words, we can obtain the change of departure frequency from waiting time. Also, we consider the proportion of passengers in different stages, conditioning the first stage, the second stage, and the double stage. Next, by introducing the upper and lower limits of the government’s expected proportion, we can obtain the amount of input in service level and the proportion of diversified choices in different proportion conditions. After that, we analyze customer surplus and social welfare.

In the first stage, the departure frequency of CB and PT is influenced by the input of service and variety-seeking behavior. In the second stage, the departure frequency is influenced by the input of service only. Our concern is passenger numbers in different stages, considering the proportion of passengers in two stages on CB and PT. We find that given a pair of passenger ratio to government or bus company, it will have a positive impact on the improvement in service level under the comprehensive impact of variety-seeking behavior and services level. The improved service level of PT will inhibit the proportion of passengers with variety-seeking behavior in the second stage and the double stage. Why would changing services have this effect? The results indicate that although the impact of bus departure frequency changes the proportion of passengers in different stages, the input of services appreciably impacts passenger numbers. The underlying reason is that PT can control the input level of services. Under the basic condition of bus operation, the government or bus company can improve bus services in order to increase the number of passengers. The higher the expected passenger numbers ratio, the higher the level of services required. When the reasonable proportion is reached, with a portion of passengers transferred from CB, the value perceived by from PT is similar to what CB acquire, and the proportion of the market population reaches equilibrium.

Furthermore, we analyze the customer surplus and social welfare under the proportional constraints on different quantities. Interestingly, we find that, in the first stage, the customer surplus will change more significantly than in the second stage. In the second stage, the increase of input in different service levels will influence the change of customer surplus with the constraint on high proportion. At this point, we consider adjusting the services level to increase social welfare, which means that CB and PT reach the optimum effect.

Currently, the literature focuses on two aspects of research on CB, namely, route planning (Tong et al., 2017; Guo et al., 2019) and case (or factor) study (Cao and Wang, 2016; Wang et al., 2019). There is little discussion of operational strategy or customer (or passenger) behavior. It is an important question (or gap) that should be focused on concerning CB because the changes in passenger or consumer behavior will have an impact on the operation of buses. Therefore, the contribution of this paper is introducing the idea of game into a CB operation scenario. We consider two-stage with different proportions of passenger numbers and input level of services under the condition of passenger ratios. Besides, we also find the interactive relationship between variety-seeking behavior and service level in the bus scenario. The research results show the reasonable input level of services in different stages in order to rationalize the bus operations of CB and PT. In addition, the results can also make social welfare and customer surplus reach a higher level and provide reference for bus operation.

The remainder of this paper is organized as follows. Section 2 reviews the literature. In Section 3, we introduce the model setting and the assumption. In Section 4, we analyze the model with the quantity proportion of passengers. In Section 5, we analyze the model through numerical illustration. Section 6 provides managerial implications and Section 7 concludes this paper.

2. Literature

Currently, studies have already covered some aspects of this paper, including CB, diversified seeking behavior, and multi-period issues.

In terms of CB, most scholars focused on operational strategies. For example, Milla et al. (2012) proposed an operation control scheme of a linear CB system based on expert rules and fuzzy logic, making the control strategy of CB more flexible and feasible. From the perspective of reliability, Wu et al. (2015) put forward a general model of bus route dispatch to minimize the total dispatching deviation taking the uncertainty of bus travels time into account. By analyzing the previous operation of CB comprehensively, Liu and Ceder (2015) identified the best operational plan and pointed out that the service philosophy of CB could effectively meet the growing demand for population mobility nationwide. Liu et al. (2016) established a methodology analysis framework to quantify the operational performance indicators in order to evaluate and compare the performance of CB and the traditional PT system. They also stressed that the CB system was more profitable in Auckland than in Paris through case study. Cao and Wang (2016) took the development of CB in Harbin as an example and applied the logistic regression model to analyze the key factors influencing CB, including private cars, the distance between home and workplace, travel satisfaction level, and overtime. Finally, some suggestions for the development of CB in medium-sized cities were proposed. Cao and Wang (2017) considered an optimization method of passenger allocation in CB. He believed that CB could significantly reduce travel time, waiting time,
and delays. With the increase in passenger capacity of CB, the benefit would show a downward trend in the future. Qiu et al. (2018) proposed a spatial clustering algorithm based on pair density which could be used to address the location and route issues such as the location of potential passengers as well as the waiting points of vehicles. Considering travel constraints, satisfaction, service quality, and family impacts, Li et al. (2019) analyzed the operational conditions of CB in Shanghai from the aspects of service level, in-vehicle time, travel time, and ticket price. Focusing on the people-bus-route matching problem, Han et al. (2019) discovered the combination of 49-seat CB and 18-seat CB was the most economical of all options. Besides, CB with lower capacity tended to be more cost-effective than that with higher capacity. Guo et al. (2019) constructed a mixed-integer programming model under the complete space-time constraints to deal with the bus route optimization problem. Based on the characteristics of CB, the utilization of vehicle capacity, and local services, bus routes as well as passenger allocations were analyzed and optimized. Lyu et al. (2019) used a mathematical programming method that could optimize the location, route, schedule on CB and the probability of passengers choosing CB simultaneously to earn a higher profit. Hao et al. (2020) investigated the travel mode of customized school buses in Zhao tong to provide theoretical reference for management policies of CB. He et al. (2020) introduced a type of crowd-sourcing bus service with privacy enhancement Privibus which employed a route planning method to select the best route, reduce the cost of passengers’ time, generate substantial profits, and ensure the wide coverage of the crowd-sourcing service as well. In the research of CB, the literature focuses on the problems of vehicle routing, passenger assignment, and time window. Different from the studies mentioned above, this paper concentrates more on the change of frequencies and passenger numbers between CB and PT based on the two-stage Hotelling model. In addition, our research also considers the rational operational strategy of CB from the perspective of passenger numbers. The psychological concept of variety-seeking behavior was first introduced into marketing early in 1955 by Leuba, and it was also an important feature of consumers in purchasing activities (McAlister, 1982). Trijp et al. (1996) insisted that compared to repurchases and some other derivative behaviors, seeking behavior was more likely to happen to brand switching. He also assessed the intensity as well as the potential motive of brand switching. Ratner and Kahn (2002) pointed out that people would consider more diversity in consumption decision-making when the public supervised their behavior. Shen and Weyer (2010) studied the conditions under which a spontaneous and deliberate process exerted influence on the variety-seeking behavior. Fishbach et al. (2011) implied that consumers’ consumption behavior could be activated unconsciously to affect their satisfaction, thus contributing to the diversity of their choices while Meixner and Knoll (2015) also focused on the study of multiple choices of brand switching. Chuang et al. (2013) held the view that in order to get more fun of sharing products, people would make choices consistently with others’ opinions in the network information. Moreover, Lin and Kuo (2019) attached more emphasis to the impacts on the interaction between product temperature and its ambient temperature on product seeking behavior. Niu et al. (2019) perceived the variety-seeking behavior of consumers led to the mild competition in the first stage and fierce competition in the second, while the existence of this behavior would weaken the motivation of enterprises to improve their quality levels. In this paper, Niu’s study is a reference but what distinguishes our study from theirs lies in the fact that the operation scenario of CB and PT is taken as the research target. The paper detects the difference between degrees of influence by diversified choices on CB operation frequency in different stages if certain threshold conditions are met. Through further analysis, customer surplus and social welfare are found to be reduced by the variety-seeking behavior of consumers. However, when the factor of service input in different stages is taken into consideration, the variety-seeking behavior will have a positive effect on social welfare instead, which is also remarkably distinct from Niu’s analysis.

Previous studies have made great contributions to the research of multi-period decision strategies as well. S. Li et al. (2016) proposed a multi-period and multi-path recharging location model, which could expand the recharging network of public electric vehicles to satisfy the origin-destination (O-D) traveling demand dynamically. By applying an infinite-layer Markov decision-making model and analyzing its characteristics, X. Li et al. (2016) illustrated the multi-period ordering policies of new products together with the clearance pricing strategies of out-of-season products. Aydin (2017) constructed a service quality evaluation framework of rail transit based on a survey of passengers’ satisfaction to perform a multi-stage assessment of the service quality. Mogale et al. (2017) studied the food supply chain in the Indian public distribution system (PDS) to eliminate the deficit in India. Mohammed et al. (2017) built an optimization programming model of supply chain considering carbon footprint under two different types of uncertainties. Then, the impacts of different carbon policies on supply chain strategies and operational decisions were discussed in detail. Horcher and Graham (2018) focused on the study of multi-period PT supply and deemed it was difficult to distinguish the capacity network between road sections and periods when demands were interdependent but not entirely identical. Results of the multi-period supply analysis indicated the relationship between urban structure, daily activity mode, and PT performance. Ahn and Han (2018) developed a two-stage stochastic model to design an integrated network that could optimize the supply of public utilities and carbon dioxide reduction strategy simultaneously, given the uncertain demand. Finally, it proved that the uncertainty of the demand for public utilities exerted more considerable impacts on the integrated network than that for carbon dioxide reduction. Unlike the previous research, this paper established a two-stage operation model of CB and PT, and paid more attention to the influence of CB and PT service on customer surplus and social welfare given the diversified choices. All the studies mentioned above can be summarized in the following four aspects, namely diversified seeking behavior, service quality, multi-period decisions, and social welfare, as is demonstrated in Table 1.

### Table 1

| Literature | Variety-seeking behavior | Service quality | Multi-period decisions | Social welfare |
|-----------|--------------------------|----------------|------------------------|---------------|
| Meixner and Knoll (2015); | ✓ | ✓ |
| Tian et al. (2018); | ✓ | ✓ |
| Yuen et al. (2018); | ✓ | ✓ |
| Lyu et al. (2019) | ✓ | ✓ |
| Li et al. (2016); | ✓ | ✓ |
| Aydin (2017); | ✓ | ✓ |
| Mohammed et al. (2017); | ✓ | ✓ |
| Tantiwattanakul and Dumrongthit (2019) | ✓ | ✓ |
| Xin and Sun (2018) | ✓ | ✓ |
| Jeong and Maruyama (2018); | ✓ | ✓ |
| Niu et al. (2019) | ✓ | ✓ |
| Gu et al. (2018); | ✓ | ✓ |
| Wang et al. (2020) | ✓ | ✓ |
| Liu et al. (2016) | ✓ | ✓ |
| Our study | ✓ | ✓ |

3. Model

3.1. Model setting

In this section, we consider CB and PT competition in the market based on the Hotelling model (Hotelling, 1990). We assume that the passengers follow a uniform distribution of 0–1, and then CB and PT are located between point 0 and point 1, respectively. The passengers are
evenly distributed between 0 and 1; they are free to choose one between CB and PT depending on the utility of the ride. The level of CB’s service is 1, and the service level input coefficient λ of PT is between 0 and 1. Whatever kind of bus it is, there is a unit of operating costs c. In the CB, we can obtain the service level of S. The coefficient of service cost is α, which represents a change in service input. Therefore, the unit of revenue that each passenger can obtain from CB is (p_0 - αS); likewise, the unit of revenue from PT is (p_0 - αS). The net passenger utility of CB is U_a = v - f_a - mx - p_a, and that of PT is U_b = v - f_b - m(1 - x) - p_b, where x_0 is specific customers’ location, and m(0 > m) represents the unit match cost. f_i represents the waiting time and cost of customers. We consider that departure frequency is related to waiting time. Specifically, κ_i represents the operation cost of the bus, where κ_i means departure frequency of unit vehicle. To simplify, c = 1. In addition, we determine the proportion of passengers in different modes of transportation and introduce the proportionality coefficients K1 and K2 (0 < K1 < K2 < 1), which represents the upper and lower limits of the quantity ratio. The departure frequency of CB is lower than that of PT according to the actual conditions.

We introduce a two-stage model to represent the potential variety-seeking behavior among passengers. In the first stage, CB and PT do not increase the service. In this case, passengers consider their original service. In the second stage, the four states are divided by seeking behavior according to service level in different cases. We can define the AS, BS, AT and BT according to bus service level. The coefficient 0 < θ < 1 is the proportion of passengers with variety-seeking behavior. The decision sequence is as follows: In stage 0, CB and PT determine the proportion of passengers in different modes of transportation and introduce the proportionality coefficients K1 and K2 (0 < K1 < K2 < 1), which represents the upper and lower limits of the quantity ratio. The departure frequency of CB is lower than that of PT according to the actual conditions. In stage 2, CB and PT decide their second-period departure frequency simultaneously. The passengers are satisfied with the maximization of the net utility in each stage. A summary of symbol definitions is shown in Table 2.

### Table 2

| Parameter | Description |
|-----------|-------------|
| m         | The cost of passengers for choosing a bus. |
| i         | Input coefficient of traditional public transportation service. |
| θ         | The fraction of variety-seeking passengers in the market. |
| K_i       | The minimum (i = 1) and maximum (i = 2) percentages of the number of passengers on the customized bus that the government or the bus company expect to identify. |
| α         | Input coefficient of bus service. |
| p_0/p_0   | Price of the customized bus or traditional public transportation. |
| v         | Passengers’ perceived value. |
| c         | The unit operation cost of vehicles. |
| δ         | The highest level of bus service. |
| x_0       | Market equilibrium point, k = {0, 1, 2, 3, 4}. |
| q         | Passengers’ quantity. |
| f_i       | The waiting time of the bus in the period j, i = {a, b}, {a = CB; b = PT}; j = {1, 2}. |
| U_a       | Net passenger utility in period j (in bus modes); i = {a, b}, {a = CB; b = PT}; j = {1, 2}. |
| x_1       | The firm’s profit in period j (in bus modes); i = {a, b}, {a = CB; b = PT}; j = {1, 2}. |
| CS_j      | Customer surplus in period j (in bus modes); j = {1, 2}. |
| SW_j      | Social welfare in period j (in bus modes); j = {1, 2}. |

The decision sequence is as follows: In stage 0, CB and PT determine the proportion of passengers in different modes of transportation and introduce the proportionality coefficients K1 and K2 (0 < K1 < K2 < 1). In stage 1, we can divide two kinds of passengers based on bus service experience in different modes. On the one hand, passenger A takes CB. On the other hand, passenger B takes PT. Their net utilities are

\[
U_{a_1} = v - f_{a_1} - mx - p_a \\
U_{b_1} = v - f_{b_1} - m(1 - x) - p_b
\]

In the second stage, passengers can be divided into two groups. One is the usual commuter without any diversified choices, and the other is the passenger with variety-seeking behavior. The four states are divided by seeking behaviors, which are no move, part of PT move to CB, part of CB to PT and the new balance of passengers. The examples are listed below: (1) CB has A + BS passengers and PT has B + AS passengers without an increase in the bus service of either CB or PT; (2) Bus services increase in CB, CB has AS with variety-seeking passengers, and CB has B passengers; (3) Bus services increase in PT. PT has BS with variety-seeking passengers, and CB has A passengers; (4) Bus services increase in both CB and PT, and there will be a new equilibrium with AT and BT. Therefore, their net utilities are (in Fig. 1):

\[
U_{a_2} = v - f_{a_2} - mx - p_a \\
U_{a_3} = v - f_{a_3} - m(1 - x) - p_a \\
U_{b_2} = v - f_{b_2} - mx - p_b + S \\
U_{b_3} = v - f_{b_3} - m(1 - x) - p_b + S
\]

In the first stage, we can solve \( U_{a_0} = U_{b_0} \) to get the indifferent point \( x_0 = \frac{x_1 + x_2 + m - p_a - p_b}{2m} \). Likewise, we can obtain the second stage indifferent points:

\[
x_1 = \frac{-f_{a_2} + f_{a_3} + m - p_a + p_b}{2m} \\
x_2 = \frac{-f_{a_2} + f_{a_3} + m - p_a + p_b + S}{2m} \\
x_3 = \frac{-f_{b_2} + f_{b_3} + m - p_b - Sλ}{2m} \\
x_4 = \frac{-f_{b_2} + f_{b_3} + m - p_b - S - Sλ}{2m}
\]

Noting the proportion of variety-seeking passengers is θ, we can obtain the demand function in different stages:

\[
q_{a_1} = (1 - θ)x_0 + θ(1 - x_0) = \frac{m + (1 - 2θ)(f_{a_1} - f_{a_3}) - (1 - 2θ)(p_a - p_b)}{2m} \\
q_{b_1} = (1 - θ)(1 - x_0) + θx_0 = \frac{m + (1 - 2θ)(f_{b_1} - f_{b_3}) + (1 - 2θ)(p_a - p_b)}{2m} \\
q_{a_2} = (1 - θ)x_1 + θ(x_2 - x_1) + θx_1 + θ(x_4 - x_1) = \frac{(-f_{a_2} + f_{a_3}) + m - p_a + p_b + 2Sθ - 2Sθλ}{2m}
\]
\( q_{i2} = (1 - \theta)(1 - x_1) + \theta(x_1 - x_2) + \theta(1 - x_2) + \theta(x_2 - x_3) = \frac{\left(f_{12} - f_{32}\right) + m + p_b - p_h - S \theta + 2SN\lambda}{2m} \quad (10) \)

According to the reverse reasoning strategy, we derive profit and departure frequency of CB and PT in the second period.

\[
\pi_{a1} = (p_a - aS)q_{a1} - \frac{1}{f_{a1}} \quad (11)
\]

\[
\pi_{a2} = (p_a - aS)q_{a2} - \frac{1}{f_{a2}} \quad (12)
\]

\[
\pi_{b2} = (p_b - aS)q_{b2} - \frac{1}{f_{b2}} \quad (13)
\]

\[
\pi_{b1} = (p_b - aS)q_{b1} - \frac{1}{f_{b1}} \quad (14)
\]

In stages 1 and 2, the profits of CB and PT are

\[
\pi_{a1} + \pi_{a2} = (p_a - aS)q_{a1} - \frac{1}{f_{a1}} + (p_a - aS)q_{a2} - \frac{1}{f_{a2}} \quad (15)
\]

\[
\pi_{b1} + \pi_{b2} = (p_b - aS)q_{b1} - \frac{1}{f_{b1}} + (p_b - aS)q_{b2} - \frac{1}{f_{b2}} \quad (16)
\]

According to profit functions, we can derive the waiting time of CB and PT in stage 1 and stage 2. In addition, we have the equilibrium outcomes as in Lemma 1.

**Lemma 1.**  
(1) In the first stage, waiting time of CB and PT:

\[
\frac{-2A\sqrt{2m(1 + \sqrt{1 - 2\theta})} + B\sqrt{2m(1 + \sqrt{1 - 2\theta})} + 2(m + p_a + p_b(-1 + \theta) - p_h \theta + S \theta - S \lambda))}{2Am} \quad (21)
\]

\[
\frac{2m + 2p_a - 2p_b + A\sqrt{2m(1 + \sqrt{1 - 2\theta})} - 2B\sqrt{2m(1 + \sqrt{1 - 2\theta})} - 2p_a \theta + 2p_b \theta - S \theta + 2S \lambda)}{2B^2 m} \quad (22)
\]

**Fig. 1.** Demand in different periods.
In the previous section, we obtain the profit of CB and PT. In this section, we derive the social welfare (SW), which is used to represent the extra benefit to buyer. Without loss of generality, the CS can be calculated as the net utility of the customer (e.g. Niu et al., 2019). In the
first stage, CS is \( CS_1 = \int_{0}^{x_1} U_a \, dx + \int_{x_1}^{x_2} U_b \, dx \). In the second stage, CS is
\( CS_2 = \int_{0}^{x_1} U_a \, dx + \int_{x_1}^{x_2} U_b \, dx + \int_{x_1}^{x_2} U_a \, dx + \int_{x_1}^{x_2} U_a \, dx + \int_{x_1}^{x_2} U_b \, dx \). The total CS is \( CS_1 + CS_2 \). Lemma 2 provides the illustration.

Lemma 2. (1) Customer surplus in the first stage:

\[
CS_1 = \frac{1}{4m} \left( -m^2 + (p_a - p_b) \right) \right) - 2m(p_a + p_b - 2v) + \frac{2(A - B)^2m}{1 - 2\theta} - \frac{2\sqrt{2m}(A + B)(m - p_a + p_b)}{\sqrt{1 - 2\theta}} \right) \right)
\]

(2) Customer surplus in the second stage:

\[
CS_2 = \frac{1}{4m} \left( 2(A - B)^2m - m^2 + (p_a - p_b)^2 - 2\sqrt{2m}(A + B)(m - p_a + p_b) + S^2 - 2m(p_a + p_b - 2v) + S^2x^2 \right)
\]

(3) Customer surplus in the 1–2 stage:

\[
CS_1 + CS_2 = \frac{1}{4m} \left( 2(A - B)^2m - m^2 + 2(p_a - p_b)^2 - 4m(p_a + p_b - 2v) + \frac{2(A - B)^2m}{1 - 2\theta} \right) \right)
\]

(29)

Where \( A = \frac{1}{\sqrt{p_a - S}} \) and \( B = \frac{1}{\sqrt{p_b - S}} \).

3.3. Customer surplus and social welfare

In the previous section, we obtain the profit of CB and PT. In this section, we derive the customer surplus (CS), which is used to represent the extra benefit to buyer. Without loss of generality, the CS can be
SW_1 = \frac{1}{4m} \left( 2(A-B)^2 m - m^2 + (p_a - p_b)^2 - 2\sqrt{2m}(A+B)(m - p_a + p_b) + S^2 - 2m(p_a + p_b - 2\alpha) \right) \\
+ \frac{1}{B^2} \left( \sqrt{2m(A-B) + m + p_a - p_b + S\theta(-1 + 2\alpha)} + 2\left(\sqrt{2m(-2A + B) + m - p_a + p_b + 2S\theta(1 - \lambda)}\right) \right)

(31)

(3) Social welfare in the 1–2 stage:

SW_1 + SW_2 = \frac{1}{4m} \left( 2(A-B)^2 m - m^2 + 2(p_a - p_b)^2 - 2\sqrt{2m}(A+B)(m - p_a + p_b) + S^2 - 4m(p_a + p_b - 2\alpha) \right) \\
+ \frac{1}{B^2} \left( \sqrt{2\sqrt{A+B}(m - p_a + p_b)} + 2\left(\sqrt{2(A-B)(2-4\theta)m} + m - (p_a - p_b)(-1 + 2\theta)\right) \right) \\
+ \frac{1}{A^2} \left( \sqrt{m(-2A + B) + m + p_a - p_b + S\theta(-1 + 2\lambda)} + 2\left(\sqrt{2m(-2A + B) + m + (p_a - p_b)(-1 + 2\theta)}\right) \right)

(32)

4. Analysis of model

In this section, we introduce the necessary conditions for the discussion of the problem. Firstly, our concern is waiting time in different bus modes. Next, we consider the quantity proportion of CB and PT, and the influence of the suggestibility selection ratio in different control modes in the two stages. At last, we consider the impact of factors of customer surplus and social welfare.

4.1. Analysis of waiting time

From the waiting time of passengers, we can obtain the changes in departure frequency. Therefore, we have Proposition 1 according to service level and waiting time.

Proposition 1. (1) The service level of CB: \frac{p_a + p_b + S\theta}{S\theta} < \lambda < 1; (2) f_{a,1} > f_{a,2}; f_{b,1} > f_{b,2};

Proposition 1 shows the waiting time influence of CB and PT on the service level and the proportion of passengers with variety-seeking choices. Firstly, the departure frequency of CB should be lower than that of PT in reality. It shows that CB has the feature of flexible scheduling in the real conditions of the new public transport mode. Secondly, the departure frequency in the first stage is always higher than that in the second stage, no matter it is of CB or PT. Possible explanations are as follows: (1) CB is not limited to PT. As favorable support for public transportation, the departure frequency of PT should be higher than that of CB. CB has the characteristics of flexibility and variation, and it provides a high level of services with a small percentage of the passenger. Therefore, the size of crowds should be less varied, and the function of this mode should be between PT and taxi; (2) When entering the market, both CB and PT will increase their departure frequency to win the number of passengers. In addition, in the second stage, they will continue to adapt to the market and adjust the departure frequency to meet the needs of passengers.

4.2. Quantity analysis of the First period

We consider two proportional constraints, the lower (K1) and upper (K2) limits of the number of passengers the bus company or the government wants. The economic connotation of the passenger quantity is rationalization operation on CB and PT, each of which has a market share. It is shown that three propositions in different stages have the proportion of quantity.

Proposition 1 shows the quantity proportion with passengers of CB and PT in the first stage. Now, we have Proposition 2.

Proposition 2.

(1) If \theta_1 < \theta < \theta_2 and \frac{p_a + p_b + S\theta}{S\theta} < \lambda < 1, q_{a,1} > 0, q_{b,1} > 0; (2) If \theta_1 < \theta < \theta_2 and f_{a,2}(\lambda) - f_{b,2}(\lambda) > 0, K1 < \frac{f_{a,2}(\lambda)}{f_{b,2}(\lambda)} < K2.

Where \theta_1 = \frac{1}{2} \left( 1 - m \left( \frac{\sqrt{(2(p_a - p_b)(p_b - S\theta) + 1)} - 1}{p_a - p_b} \right) \right)^2; \theta_2 = \frac{1}{2} \left( 1 - m \left( \frac{\sqrt{(2(p_a - p_b)(p_b - S\theta) - 2\lambda)} - 2\lambda}{p_a - p_b} \right) \right)^2.

Table 3

| Stage | K1 and K2 | \lambda |
|-------|----------|---------|
|       | Lower    | Upper   | Point  |
| Case 1 | K1 = 0.30 K2 = 0.35 | 0.60 | 0.78 | 0.69 |
| Case 2 | K1 = 0.55 K2 = 0.59 | 0.72 | 0.99 | 0.86 |
| Case 3 | K1 = 0.80 K2 = 0.83 | 0.98 | 1.00 | 0.99 |
| Case 4 | K1 = 0.05 K2 = 0.10 | 0.60 | 0.90 | 0.75 |
| Case 5 | K1 = 0.35 K2 = 0.59 | 0.60 | 0.73 | 0.67 |
| Case 6 | K1 = 0.65 K2 = 0.70 | 0.60 | 0.62 | 0.61 |
| Case 7 | K1 = 0.05 K2 = 0.10 | 0.60 | 0.78 | 0.69 |
| Case 8 | K1 = 0.10 K2 = 0.13 | 0.60 | 0.69 | 0.65 |
| Case 9 | K1 = 0.14 K2 = 0.16 | 0.60 | 0.64 | 0.62 |
Fig. 2. Cases 1–3 in the first stage.

Fig. 3. Cases 1–3 in the second stage.
Proposition 2 shows that the quantity of CB and PT passengers should be definite to satisfy the necessary discussion conditions. In addition, the quantity proportion is related to the level of service. When \( f_{K2}^2(\bar{\lambda}) - f_{K1}^2(\bar{\lambda}) > 0 \), it can be determined that the quantity proportion satisfies the limit of positive proportion. Taking CB as a reference, we explain this finding from three aspects: (1) In stage 1, CB will provide a high level of service and attract the passengers on PT. Since there are passengers with variety-seeking behavior, the number of PT passengers might be affected. This segment of passengers cannot choose control strategies, which will lead to a reasonable proportion. (2) For the bus company or government, the resources need to be configured hierarchically. With reference to the service level of CB, the service input of a certain proportion should be increased to improve the PT approach or to reach the service level of CB. (3) In order to achieve a positive quantity ratio, it is necessary to guide diversification to seek the passenger number proportion and service level, to make the results comparable.

Next, considering the quantity proportion in stage 2, we have Proposition 3.

Proposition 3. \( \quad (1) \) if \( \theta_3 < \theta < \frac{K1}{\lambda} \), \( \frac{\lambda (\theta_1 - \theta_2)}{\theta_1} < \lambda < f_2^2(\theta), q_{\theta_0} > 0 \) and \( q_{\theta_0} > 0 \); \( \quad (2) \) if \( \theta_3 < \theta < \frac{K1}{\lambda} \) and \( f_{K2}^2(\bar{\lambda}) - f_{K1}^2(\bar{\lambda}) > 0 \), \( K1 < \frac{q_{\theta_0}}{q_{\theta_2}} < K2 \);

Proposition 3 shows the quantity proportion with passengers of CB and PT in the second stage. The second stage shows similar characteristics to those in the first stage. In the second stage, quantity proportion satisfies the limit of positive proportion in the extensive range of variety-seeking choice. However, the maximum service level input of PT is lower than that in the first stage. When \( f_{K2}^2(\bar{\lambda}) - f_{K1}^2(\bar{\lambda}) > 0 \), the limit of the quantity proportion can be determined. Similarly, the most likely scenario is that PT will provide a high level of services in the second stage based on the operation status in the first period. CB and PT need to speed up the transformation of service operation modes and rationally adjust the service level. Proposition 3 (2) looks like Proposition 2 (2). The two expressions of the necessary conditions for \( K1 \) and \( K2 \) conservation are also given.

We further consider the quantity proportion in the first stage and the second stage. In the 1–2 stage, Proposition 4 shows the quantity proportion with passengers of CB and PT.

Proposition 4. \( \quad (1) \) if \( \theta_3 < \theta < \theta_5 \), \( \frac{\lambda (\theta_1 - \theta_2)}{\theta_1} < \lambda < f_2^2(\theta), q_{\theta_0} + q_{\theta_2} > 0 \) and \( q_{\theta_0} + q_{\theta_2} > 0 \); \( \quad (2) \) if \( \theta_3 < \theta < \theta_5 \) and \( f_{K2}^2(\bar{\lambda}) - f_{K1}^2(\bar{\lambda}) > 0 \), \( K1 < \frac{q_{\theta_0} + q_{\theta_2}}{q_{\theta_1} + q_{\theta_2}} < K2 \).

In Proposition 4, we can obtain two-stage operation results. The meaning of the parameters is consistent with that in the first and second stages. By comparison, the conditions that satisfy the requirements become stricter under the two-stage control. The possible reason is the dual influence of variety-seeking behavior. For individuals, there is selective substitution in the choice between CB and PT per unit time. Concerning group behavior, something similar could happen. In reality, a new traffic line will only be launched when CB reaches a specific scale. Therefore, in order to ensure that the number of passengers is positive, the result obtained is useful when the number of passengers with variety-seeking choices needs to reach a threshold.

According to the above analysis, we introduce \( K1, K2 \), the limits of quantity proportion. Further, we are interested in the constraint change of \( K1 \) and \( K2 \) as a condition influencing variety-seeking behavior ratio and service level. Therefore, Propositions 1–3 will be expanded to Inferences 1–3, and we have conditions of \( K1 \) and \( K2 \) in different stages. In stage 1, the number of passengers satisfies the constraints of \( K1 \) and \( K2 \), and we have Inference 1.

Inference 1:
In the first stage, we can have \( K1 \) and \( K2 \) conditions:

(1) \( \frac{[1+K1][1+K2]}{1-K1K2} > \frac{m(p_0 - p_2)}{(p_0 - p_2)(1-2\theta)+\sqrt{2m(p_0 - p_2)(1-2\theta)}} \);

(2) \( \frac{m(p_0 - p_2)(1-2\theta)}{(p_0 - p_2)(1-2\theta)+2m(p_0 - p_2)(1-2\theta)} < K1 < 1 \);

(3) \( 0 < K2 < \theta_4 \).

![Fig. 4. Cases 1–3 in the double stages.](image)
Inference 1 indicates the range of choice of K1 and K2 in stage 1. We can obtain the relationship between K1 and K2 from Proposition 1. This manner gets the input level of service from K1 and K2 to improve the efficiency of service input. Inference 1 (1) shows that the relationship between K1 and K2 should be larger than one fixed value. The economic significance of the proportional relationship is as follows: the ratio of the expected passenger limit ratio is higher than the unit benefit-cost ratio. It means that the optimum proportion of the selected quantity satisfies a specific proportion limit. Similarly, we can have the quantitative proportional relationship in the second stage (Inference 2) and two-stage (Inference 3) respectively.

Inference 2:
In the second stage, we can have K1 and K2 conditions:

1. \(0 < f^2_{K1}(\theta) < f^2_{K1}(\theta)\);
2. \(0 < K1 < f^2_{K1}(\theta) < 1\);
3. \(0 < K2 < f^2_{K2}(\theta) < 1\).

Inference 3:
In the 1–2 stage, we can have K1 and K2 conditions:

1. \(0 < f^2_{K2}(\theta) < f^2_{K1}(\theta)\);
2. \(0 < K1 < f^2_{K1}(\theta) < 1\);
3. \(0 < K2 < f^2_{K2}(\theta) < 1\).

We have different levels of service according to different values with K1 and K2. On this basis, we can find the interactive relationship between the limit value of K1 and K2, the service level, and the passenger ratios with variety-seeking behavior. In addition, we have changes in customer surplus and social welfare. In the next section, we will investigate the change of factors according to numerical illustration and identify the management implications in different stages.

5. Numerical illustration

In this section, we consider the changes in parameters with K1 and K2 in different stages. On this basis, we have the range of service level, departure frequency, passenger number, customer surplus, social welfare, and the proportion of passengers with variety-seeking behavior. In addition, we discuss the managerial implications in different stages. The designed parameter scheme is shown in Table 3.

5.1. Analysis of the First stage

According to Table 3, we have Fig. 2 which discusses the change of parameters of service level, departure frequency, passenger number, customer surplus, and social welfare in stage 1. In this stage, the influence of K1 and K2 in different cases is clearly seen. Specifically, K1 and K2 mean the lower and upper limits of the proportion of the number of CB passengers to the number of PT passengers. The departure frequency of PT is increasing with the input of service level and the proportion of passengers with variety-seeking behavior. On the contrary, the number of passengers is declining with the change of two factors. The departure frequency of CB is declining, and the number of passengers is increasing with two factors. Customer surplus and social welfare are declining with the combined action of the departure frequency and the stock of passengers.

The potential cause is passengers with variety-seeking behavior. In this part, the bus company or government loses control with the choices of this segment of passengers. The high proportion of passengers with diverse seeking behavior leads passengers to move and try other ways of getting around. In this case, it will react to bus service with K1 and K2 the bus company or government wants, and reasonably adjust the level of service. However, the effect of PT’s service input is weakened or even inefficient when there is a high proportion of passengers with variety-seeking behavior. The managerial implication is as follows: In the first stage, the service input of PT may not make much sense when the passengers with variety-seeking behavior take a certain proportion (e.g., 0.36 < \(\theta < 0.41\)). In this case, PT should keep the original service level to obtain high customer surplus and social welfare. CB should keep reasonable departure frequency to ensure the diversified choices of passenger service experience. For the bus company or government, it is necessary to reasonably design the proportion of customized operation market, strengthen market guidance, and reduce the impact of blind entry into the CB market on consumers’ sense of gain.

5.2. Analysis of the second stage

We analyze the features according to Fig. 3. In the second stage, CB and PT are different from in the first stage under different values of K1 and K2. Specifically, the departure frequency of the bus would not be significantly affected. The departure frequency and passenger numbers of PT are increasing with service level. Moreover, the passenger number of CB shows different features. Specifically, the number of CB passengers is increasing with the level of service when the range of proportion of variety-seeking passengers is narrow. For example, in case 1 in the second stage, CB passenger is 0 when the proportion of passengers with variety-seeking behavior is between 0.14 and 0.19, and the service of PT is 0.75. After that, the number of passengers is rising. Similarly, CB passenger is 0 when the proportion of passengers with variety-seeking behavior is between 0.13 and 0.14 or between 0.13 and 0.15, and the service of PT is 0.67 or 0.61, respectively. It can be discovered that in the second stage, the proportion of passengers with variety-seeking behavior will be affected by the level of PT service which will have an

| The sensitivity analysis of several parameters in different stages. | 0.5 | 0.7 | 0.9 | 1.0 |
|---|---|---|---|---|
| m | \(\theta\) (min. max) | \(0.429, 0.458\) | \(0.400, 0.441\) | \(0.372, 0.425\) | \(0.359, 0.417\) |
| The first stage | K1 (min. max) | \(0.275, 0.497\) | \(0.272, 0.495\) | \(0.274, 0.500\) | \(0.275, 0.497\) |
| | K2 (min. max) | \(0.0, 0.833\) | \(0.0, 0.831\) | \(0.0, 0.836\) | \(0.0, 0.837\) |
| | \(\beta\) (min. max) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) |
| The second stage | K1 (min. max) | \(0.188, 0.500\) | \(0.162, 0.500\) | \(0.137, 0.500\) | \(0.125, 0.500\) |
| | K2 (min. max) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) |
| | \(\beta\) (min. max) | \(0.0, 0.696\) | \(0.0, 0.719\) | \(0.0, 0.743\) | \(0.0, 0.736\) |
| Two stages | K1 (min. max) | \(0.250, 0.500\) | \(0.217, 0.500\) | \(0.183, 0.325\) | \(0.166, 0.245\) |
| | K2 (min. max) | \(0.0, 0.718\) | \(0.0, 0.668\) | \(0.0, 0.324\) | \(0.0, 0.171\) |
| | \(\beta\) (min. max) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) | \(0.6, 1\) |
impact on the number of passengers on CB and has a specific inhibitory effect. In addition, the impact of customer surplus and social welfare is different from $K_1$ and $K_2$. For instance, it is evident to the proportion of passengers on CB. Those changes have an impact on the service level of PT. Interestingly, when a high proportion of services is invested (e.g., Case1), the customer surplus is at a lower level. In this situation, social welfare maintains a high level. Obviously, reasonable service input will influence the changes of customer surplus and social welfare.

The main underlying reason for the effect is $K_1$ and $K_2$, the proportional value with limits. The bus company or government loses control with the choices of passengers with variety-seeking behavior. Now, a scheme between a service provider and a customer regulates service offering from aspects of reliability, timeliness, and responsiveness. In this way, the bus company or government aims to increase the number of passengers by improving bus services, as long as the conditions satisfy the operating requirements. The higher the expected ratio, the higher the level of service required. The perceived value passengers feel from PT is similar to that from CB when it is reasonable with $K_1$ and $K_2$. At this point, the PT transfers a part of passengers from CB, and the market share is balanced. With a high level of service, the passenger numbers on PT will increase. When a certain level of congestion is reached, it may cause a decline in consumer experience, offsetting the positive effect of improved service level. In general, the high level of service input will increase the perception of society.

The managerial implication is as follows: in the second stage, the departure frequency has no connection with the proportion of passengers with variety-seeking behavior. At this point, CB and PT should be concerned with the input level of service which can have an inhibiting effect on the proportion of passengers with variety-seeking behavior. In addition, the number of passengers is increasing with improved operation efficiency of service input. The high level of service may have no significant effect on customer surplus. Hence, we should keep a watchful eye on the input level of service with its positive effect on social welfare to maintain a reasonable service level for the increase and optimization of the overall social welfare. The bus company or government should rationally guide passengers’ demand in order to get a higher society benefit.

5.3. Analysis of the Double Stages

Next, we can analyze Fig. 4, and the descriptive characteristics are similar to those in the second stage from the dual-stage aspect. The departure frequency of CB is decreasing with the service level. It is also shown that the departure frequency of PT is increasing with the service level, which is different from the second stage. From the passenger number aspect, a certain proportion of passengers with variety-seeking behavior does lead to a passenger increase in CB. This phenomenon is more evident under the limitation ($K_1$ and $K_2$) of a small market share. At this point, the number of passengers on PT is much higher than that on CB. When the passenger proportion of CB is large (20%–30%), the above phenomenon is not apparent in the lowering of the diversification. When departure frequency and passenger number are combined, we can see that the changes in customer surplus are not apparent with the input level of service, and that the changes of tendency take on consistent character in different cases. In this situation, the level of customer surplus only influences the service level. Further, social welfare is influenced by the level of service input. Specifically, social welfare increases with the improvement of service level. Besides, the two-stage consumer benefit and social welfare show better performance than input of service in each separate stage.

A much higher possibility is that the input of service affects the proportion of passengers with variety-seeking behavior, which leads to the loss of passengers under the low level of service. Most of the time, this is due to the perceived value of passengers whose needs are not satisfied. The results show that some passengers are lost in the second choice. The high-level of travel experience, the flexibility of route, and the convenience of choice introduction of CB mode have become principal factors influencing the choice of passengers.

The implications are as follows: we can obtain a high level of customer surplus and social welfare from bus operation in the dual-stage. In this regard, if the bus company or government takes reasonable control over operational strategy (e.g., market share of CB and PT or level of service) in the dual-stage, it can weaken the adverse effect caused by the change in the proportion of passengers who choose diversification. In addition, the improvement of service inputs contributes to the improvement of customer surplus and social welfare when the company controls bus service operation in the dual-stage. Next, the customer surplus will not change significantly when service reaches a certain level. When we get this time point, we should consider increasing the level of service in order to get the maximum benefit to society.

According to an analysis of Figures, we have customer surplus and social welfare in CB and PT, which are shown in Proposition 5.

Proposition 5. (1) In this study, the customer surplus can be understood as the perceived value by passengers on the bus. In different stages, customer surplus is influenced by factors of service level, proportion of passengers with variety-seeking behavior, and proportion of constraints. These factors lead to similar customer surpluses in different conditions and stages.

(2) The value of social welfare varies with service level. The government hopes to get the maximum profit to make people produce a variety of social supports and satisfactions. Therefore, we need to consider the market proportion of the two modes of public transportation to achieve a balance between market share and social welfare when rationally planning travels ratio of the crowd to reach social optimum. From this point of view, the government has a high priority in the design of policies.

(3) When customer surplus is equal or similar, it is necessary to increase the input of service to improve social welfare.

5.4. Sensitivity analysis

In this section, we perform sensitivity analysis in which only the parameter of selection cost ($m$) varies in order to observe the impact of changes in $m$ on passenger choice. Considering the range of selection cost ($m$), we select $m = \{0.5, 0.7, 0.9, 1.0\}$ and keep other parameters of departure frequency, passenger number, customer surplus, and social welfare in different stages unchanged. We consider the sensitivity analysis from the perspectives of the main research and display the results in Table 4. From Table 4, we have the following observations:

(1) The increase in selection cost ($m$) will extend the range of relative values and narrow the range of absolute values of the variety-seeking behavior ratios ($\theta$). When $m$ is at a medium level, the range of $\theta$ is at a high level. In other words, there is a higher proportion of passengers that leads to a shift in the choice of bus modes. When $m$ is at a high level, the range of $\theta$ is at a medium-to-high level. Compared with the previous state, $\theta$ will decrease in the state in which the relative value range of variety-seeking behavior ratio will increases. For instance, the relative value of $\theta$ is 0.029 when the $m = 0.5$; the relative value of $\theta$ is 0.058 when $m = 1$. It is found that the relative value range of the variety-seeking behavior ratio will increase with the increase of $m$.

From the perspective of the economic phenomenon, this change indicates that when the cost of choice increases, passengers consider their revenue so that the probability of switching between different transportation modes will decrease. Namely, when the cost of paying passengers increases, they will choose the
way that maximizes its effectiveness, so the proportion of variety-seeking behavior will be reduced.

(2) $K1$ and $K2$ are both influenced by the selection cost ($m$) and variety-seeking behavior ratios ($\theta$). Specifically, in the first stage, there is no obvious change in the proportion of $K1$ and $K2$ (e.g., the values settling a range). It can be found that the combined effect of the two parameters has a smaller impact on the limitation of the passenger ratio. In other words, the proportion limitation of the passengers that the government or the bus company hopes will not change significantly due to the increase in the cost of choice or the increase in the proportion of choice. In the second stage, $K1$ and $K2$ have different changes. For the lower value of $K1$, the choice range available is wider, which means $K1$ can be changed without affecting selection cost $m$ and variety-seeking behavior ratio. For higher value of $K2$, the value of range of choice increase with $m$ and $\theta$. Combining the results of $K1$ and $K2$, we can find that when a certain variation trend is satisfied, the change in the selected range in the second stage will have a greater impact than the first stage. The possible reason is the impact of selection diversification in the second stage. In the two stages, the changes in $K1$ show the same change characteristics as the second stage while the changes in $K2$ are opposite to the performance in the second stage. Specifically, $K2$ tends to decrease with the common influence of $m$ and $\theta$ because the first and second stages have a combined effect.

(3) For service level ($\lambda$), the changes in different stages are influenced by $m$, $\theta$, $K1$, and $K2$. Due to the complexity of the changes, Table 4 does not show the detailed results of changes in each parameter of service level. However, the parameter changes in each stage do not deviate from the original restrictions. It also shows that traditional bus companies should maintain a medium-high level of service to meet the operating needs of passengers if they want to achieve a specific proportion of passengers and a reasonable bus operational strategy.

(4) The results of numerical analysis and Table 4 combined, it can be found that when $m$ changes, the most significant impact is on the change in the level of diversified services. Therefore, in the discussion of $\theta$, the variation trends of departure frequency, passenger number, customer surplus, and social welfare will not change in each stage. Only the value of general level will change under the influence of different parameters. This change can be understood as a mathematical function figure moving up or down. From an economic point of view, the change only increases or decreases the degree of discussion of variables. It can be further explained that the changes in different parameters will not affect the discussion of the original results.

6. Managerial implications

In this section, we consider some managerial implications form two aspects. On the one hand, we obtain the research implications for the operational strategy of bus systems. On the other hand, we talk about the practical implications for CB and PT. On this basis, we can summarize the implications as follows.

6.1. Implications for research

From the research aspect, our research can enrich the studies on the topic of bus operation. The current studies focus on route optimization (Tong et al., 2017; kravchenko et al., 2017) or case study (Weng et al., 2018; Guo et al., 2019) in CB, and there is little application of passenger numbers in CB and PT. The results of the study can enrich the bus operational strategy and the research on CB related issues. Besides, the paper introduces on variety-seeking behavior into the research on CB, and we also consider that consumer behavior in passenger travels. These results can be used for reference in the study of the public transport system.

6.2. Implications for practice

In practice, the findings can be insightful in the bus operation. For instance, the emergence of CB will have an impact on the operation of PT. It is suitable to reasonably control the proportion of passengers on CB, and promote the improvement of PT service. In practice, in the city of Shenzhen, there were 1009 PT routes, and more than 1200 CB routes in 2018. The statistics show that CB routes account for about 62% of the city’s total bus routes. This proportion of CB exceeds the same type of data in other Chinese cities. In a city where it is generally accepted, CB mode will achieve better effects through enabling big data technology (7its, 2018). Therefore, we suggest that CB services level can be improved through technologies such as big data and Artificial Intelligence (AI) in reality. In addition, PT, is still one of the most important transportation modes for the public to travel and a symbol of a city’s development. It is necessary to improve the services in order to satisfy the needs of different groups of passengers. Besides, some passengers would like to try new modes. For this part, the government or bus company should establish a scientific public opinion guidance mechanism which can avoid rushing headlong into the mass of passengers and the impact on the existing transportation system of when new ways of public transportation are promoted. A rational plan of the proportion of passenger in different bus modes to form different levels of travel demands stratification. In addition, it is necessary to reasonably determine the level of services in PT in order to avoid insufficient or excessive investment and the adverse effects of promotion of customized public transport mode.

7. Discussion and conclusion

Recently, more and more cities have introduced the services mode of CB, which grants the variety-seeking passengers a choice. In consequence, when passengers choose a new type of bus, they may flood into the new mode of public transportation, which will hurt the existing bus operation system. How to balance the proportion of passenger numbers in different bus modes? What are the conditions for PT to improve the level of services in order to balance the passenger proportion, the best of customer surplus and social welfare? The previous studies focus more on the reasonable design or operation of the routes, and less on the balance of passenger numbers in operational issues in different stages. In this paper, we consider the reasonable proportion of passengers and bus operational strategy with the Hotelling model in different stages. Specifically, it is found that a reasonable input level of services enables the bus company or government to get the best of customer surplus and social welfare under different passenger proportions. The results also show the combined effects of the input level of services and variety-seeking behavior. Our concern is the proportion of passengers in different stages, namely, the first stage, the second stage, and the double stage. Moreover, we are interested in the impact of passenger proportion on customer surplus and social welfare in bus operation.

The main results are: (1) The departure frequency of CB is lower than that of PT. In the first stage, the departure frequency of the bus is influenced by the level of service and variety-seeking behavior. However, in the second stage, the departure frequency of the bus is influenced by the level of service only. (2) The proportionality of each fixed pair of passengers will have a positive influence on the improvement of service level. In particular, the improved service level of PT will inhibit the proportion of passengers with variety-seeking behavior in the second stage and the double stage. It also means that the number of passengers on CB will be increased only when the threshold of proportion of passengers with variety-seeking behavior is reached. (3) From the customer surplus and social welfare aspects, customer surplus in the first stage is more significant than on the second stage. Therefore, at this point, we consider adjusting services level to increase social welfare, which means
that CB and PT can reach a win-win situation. These findings have implications for both research and practical aspects of bus operation.

In reality, CB plays an important role. Its application scenarios include not only general public transportation operations, but also special transportation operations caused by important events. For instance, in order to fight against the COVID-19 in Wuhan, the bus companies used existing buses to operate in fixed locations and routes and at fixed time to reduce medical staff’s contact with other people on the road. In another example, to facilitate resumption of work, production, and schools, the “Schoolfellow” CB was launched in Fuzhou. This helps the resumption of classes for the third graders in high and senior high schools and speeds up the recovery process after the public medical event (Fuzhou News, 2020). Above all, it can be found that CB, with charter or reservation, can typically operate in case of contingency.

We discuss three future research directions to conclude this paper. Firstly, we consider the effects of variety-seeking behavior and level of services. In practice, the operation of CB may also require different techniques that can upgrade the bus, which requires a large capital investment. In case of the absence of regular attendance, it is difficult for CB to make profit. In this respect, how to balance the cost and benefit in CB and PT should be considered. Secondly, passengers with variety-seeking behavior do not consider the cost of the transfer, staying, or waiting when choosing the mode of public transportation. In addition, customer loyalty can also be considered as a future direction. Thirdly, how to use customized public transport in the new complex environment is also worthy of study.

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Appendix A

Proof of Proposition 1.

From the existing results, we can obtain the waiting time of CB and PT in different stages. In the first stage, the waiting time of CB and PT is:

\[ f_{a1} = \frac{2m}{(1 - 2\theta)(p_a - Sa)}; \quad f_{b1} = \frac{2m}{(1 - 2\theta)(p_b - Sa)} \]

In the second stage, the waiting time of CB and PT is:

\[ f_{a2} = \frac{2m}{p_a - Sa}; \quad f_{b2} = \frac{2m}{p_b - Sa} \]

According to the actual conditions, we can know that the waiting time of CB should be lower than that of PT. Therefore, \( f_{a1} < f_{b1} \) or \( f_{a2} < f_{b2} \). We can obtain the range of service level by the value of the waiting time. We make \( \frac{f_{a1}}{f_{b1}} > 1 \) and, can obtain \( \frac{\sqrt{p_a - Sa}}{\sqrt{p_b - Sa}} > 1, \) so \( \frac{\sqrt{p_a - Sa}}{\sqrt{p_b - Sa}} < \lambda < 1 \). In addition, we need to make sure that the square root is positive. According to this principle, we can get \( f_{a2} = \frac{2m}{(1 - 2\theta)(p_a - Sa)} > 0, \) and it is equivalent to \( 0 < \theta < \frac{1}{2} \).

We make \( \frac{f_{a1}}{f_{b1}} = \frac{1}{\sqrt{1 - 2\theta}} > 1 \). Therefore, \( f_{a1} > f_{a2}; \) \( f_{b1} > f_{b2} \).

Proof of Proposition 2.

Since the calculation results are complicated, we illustrate the Proof process in algebraic form.

Firstly, we consider the passenger numbers \( (q_1 > 0) \) and service level \( (\frac{\sqrt{p_a - Sa}}{\sqrt{p_b - Sa}} < \lambda < 1) \). Through the two parameters, we can obtain the value of service level by the passenger numbers.

\[ q_1 = \frac{m - (p_a - p_b)(1 - 2\theta) - \sqrt{2m(1 - 2\theta)(\sqrt{(p_a - Sa)(1 - 2\theta)} - \sqrt{p_a - Sa})}}{2m} \]  \hspace{1cm} (A.1)

Next, we make \( t = \sqrt{(p_a - Sa)} \) and \( q_a = 0 \). The result is:

\[ t = \frac{(1 - 2\theta)\sqrt{2m(p_a - Sa)}}{\sqrt{2m(1 - 2\theta) + (p_a - Sa)(1 - 2\theta)(p_a - p_b)(1 - 2\theta) - m}} \]  \hspace{1cm} (A.2)

In addition, we can obtain the optimal service level \( \lambda^* \). From the above analysis, we can know about the range of service level \( (\frac{\sqrt{p_a - Sa}}{\sqrt{p_b - Sa}} < \lambda < 1) \). Therefore, we can solve a set of inequalities with respect to the ratio of variety-seeking behavior. Finally, we obtain the result of \( \theta_1 < \theta < \theta_2 \). Where \( \theta_1 \) and \( \theta_2 \) are as follows:

\[ \theta_1 = \frac{1}{2} \left( 1 - m \left( \frac{\sqrt{2(p_a - p_b)(p_a - Sa) + 1} - 1}{(p_a - p_b)\sqrt{p_a - Sa}} \right)^2 \right) \]  \hspace{1cm} (A.3)

\[ \theta_2 = \frac{1}{2} \left( 1 - m \left( \frac{\sqrt{2(p_a - p_b)(p_a - Sa) - 1} - 1}{(p_a - p_b)^2(p_a - Sa)} \right) \right) \]  \hspace{1cm} (A.4)

Finally, we consider the proportionality coefficient \( K1 \) and \( K2 \) of passenger number. We have \( f_{a2}^2(\lambda) - f_{b2}^2(\lambda) > 0 \). On this basis, we have \( K1 < \frac{q_1}{q_1} < K2 \). Q.E.D.

Proof of Proposition 3.

This Proof is similar to that of Proposition 2. We have an expression for the service level by passenger number, which is \( \lambda^* \). From Proposition 1, the
range of service level is \( -\frac{p_b + p_a - S_1}{\sqrt{2}m} < \lambda < \frac{p_b + p_a - S_a}{\sqrt{2}m} < 1 \). In addition, we have \( \frac{p_b + p_a - S_a}{\sqrt{2}m} < \lambda ^* < 1 \). We calculate the value interval of the service level \( (-\frac{p_b + p_a - S_1}{\sqrt{2}m} < \lambda < \lambda ^*\) and the ratio of variety-seeking behavior \( (\theta_s < \theta < \frac{1}{2}) \). Finally, we consider the proportionality coefficient \( K1 \) and \( K2 \) of passenger number. We have \( f_{K2}^*(\lambda) - f_{K2}^*(\lambda ^*) > 0 \). On this basis, we have \( K1 < \frac{q_m}{\theta_s} < K2 \). Q.E.D.

Proof of Proposition 4.

Firstly, we calculate the expression of the service level \( (\lambda ^*) \) by passenger numbers \( (q_m + q_a) \). We have a range of service level in Proposition 1. In addition, the range of variety-seeking behavior ratio is obtained by solving inequality groups respectively. Correspondingly, the result is \( \theta_s < \theta < \theta_g \).

Finally, there are two restrictive parameters of passenger number \( (K1 \) and \( K2 \)) that should meet \( f_{K2}^*(\lambda) - f_{K2}^*(\lambda ^*) > 0 \). Q.E.D.

Proof of Inference 1.

We further consider the changes of \( K1 \) and \( K2 \). It is known from Proposition 2 that there is a proportional relation \( K1 < \frac{q_m}{\theta_s} < K2 \), and we can establish the inequality (A.5):

\[
\begin{align*}
K1 &< \frac{m + (p_a - p_b)(-1 + 2\theta) + \sqrt{2}m(-1 + 2\theta)}{\left(\frac{1}{\sqrt{2}m(p_a - S_1)(1 - 2\theta)} - \frac{1}{\sqrt{2}m(p_a - S_0)(1 - 2\theta)}\right)} < K2 \\
&< \frac{m + (p_a - p_b)(-1 + 2\theta) - \sqrt{2}m(-1 + 2\theta)}{\left(\frac{1}{\sqrt{2}m(p_a - S_1)(1 - 2\theta)} - \frac{1}{\sqrt{2}m(p_a - S_0)(1 - 2\theta)}\right)} < K2
\end{align*}
\]

(A.5)

Therefore, we have inequalities of the level of service \( (\lambda) \):

\[
\begin{align*}
p_a - \frac{2m(1 + K1)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K1)(p_a - S_0) - (1 + K1)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K1)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} < \lambda \\
p_a - \frac{2m(1 + K2)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K2)(p_a - S_0) - (1 + K2)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K2)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} > \lambda
\end{align*}
\]

(A.6)

(A.7)

We need to follow three constraints. Firstly, the upper bound of the constraint is higher than the lower bound of the constraint. Secondly, the upper bound of the constraint condition is lower than that of the original constraint condition. Thirdly, the lower bound of the constraint condition is lower than that of the original constraint condition.

\begin{enumerate}
\item Firstly, the upper bound of the constraint is higher than the lower bound of the constraint.

\[
\begin{align*}
p_a - \frac{2m(1 + K1)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K1)(p_a - S_0) - (1 + K1)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K1)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} < \lambda \\
p_a - \frac{2m(1 + K2)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K2)(p_a - S_0) - (1 + K2)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K2)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} > \lambda
\end{align*}
\]

(A.8)

We have the result \( \lambda ^* > \frac{m(p_a - S_0)}{m(p_a - S_0) - m(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K1)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} \).

\item Secondly, the upper bound of the constraint condition is lower than that of the original constraint condition.

\[
\begin{align*}
-p_a + p_a + S_a - \frac{p_a - \frac{2m(1 + K1)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K1)(p_a - S_0) - (1 + K1)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K1)\sqrt{2m(p_a - S_0)(1 - 2\theta)}}} < \frac{m(p_a - S_0)}{m(p_a - S_0) - m(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K1)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} < K1 < 1
\end{align*}
\]

(A.9)

\item Thirdly, the lower bound of the constraint condition is lower than that of the original constraint condition.

\[
\begin{align*}
p_a - \frac{2m(1 + K2)^2(p_a - S_a)^2(1 - 2\theta)}{m(1 + K2)(p_a - S_0) - (1 + K2)(p_a - p_b)(p_a - S_1)(-1 + 2\theta) + (1 + K2)\sqrt{2m(p_a - S_0)(1 - 2\theta)}} < \lambda
\end{align*}
\]

(A.10)

We have the result \( 0 < K2 < \theta_s \). Q.E.D.

Proof of Inference 2 and Inference 3.

Due to the complexity of the formula, we omit these two proofs. The calculation process is the same as that in Proof of Inference 1. Q.E.D.

Explanation of data sources in Table 3.

In this section, we explain the numerical method of Table 3 and take Stage 1 as an example. According to the condition of Propositions and Inferences, we have the limit of the values for \( K1 \) and \( K2 \) and service level \( (\lambda) \). Therefore, we determine the specific value of each parameter. Firstly, according to the different minimums and maximums of \( K1 \) and \( K2 \), the values of Case 1 and Case 3 can be obtained, respectively. The midpoint of the minimums and maximums is the value of Case 2 \( (K1^\text{Case 2} = \frac{K1^\text{min} + K1^\text{max}}{2}) \). Secondly, the corresponding figure is derived according to the determined value, and the highest and lowest points of the service level value are read. Finally, the service level takes the midpoint to get the third point. Successively, we fill the values in Table 3 as figure data for departure frequency, passenger number, customer surplus, and social welfare in each stage.

The following is an explanation of the values in Table 3, taking the first stage as an example. Firstly, we determine the value of the constant \( (p_a = 8p_b = 6\alpha = 0.5\alpha = 10m = 1) \). In addition, we have \( \frac{8p_b}{3 - 2\theta} < K1 < 1 \) and \( 0 < K2 < \theta_s \). Therefore, we determine \( K1 \) in Case 1 and Case 3 which is \( K1 = 0.30 \) and \( K1 = 0.80 \) respectively. Next, according to \( K1 < K2 \) and the range of \( K2 \), we can determine the values of \( K2 \) in Case 1 and Case 3.
Calculating the midpoints in different cases of $K_1$ and $K_2$ respectively, we can get $K_1$ and $K_2$ in Case2. Finally, we draw figures of service level changes in different conditions based on different combinations of values, as is shown in Figure A1. In addition, we read the value of the corresponding service level according to figures. Q.E.D.

![Figure A1. Value of Service level](image)

**Statement of contribution/potential impact**

The customized bus (CB) is an innovative model of the public transport system, which has a positive role in relieving operation pressure with traditional public transport (PT) in China. However, there is a high proportion of customers with variety-seeking behavior. When this part of customers shows up in the public transportation system, people have various choices, such as PT to CB. The potential reason is the different consumption experiences brought by different modes of public transportation. Nevertheless, when a large passenger numbers crowd into CB, it may cause a decline in consumer experience and reduce the sense of social fulfillment. Therefore, in the application scenarios of CB and PT, if there are passengers with variety-seeking behavior, how to improve services to rationalize operational without rushing headlong into a mass.

Currently, the literature focuses on two aspects of research on CB, namely, route planning and case (or factor) study. There is little discussion of operational strategy or customer (or passenger) behavior. It is an important question (or gap) that should be focused on concerning CB because the changes in passenger or consumer behavior will have an impact on the operation of buses.

This study considers game model with two-period from the perspective of variety-seeking behavior and input of services. In addition, we have analytical solutions, implications, and proportion of passengers in different stages. The conclusion of this paper involves two basic questions of bus operation: (1) what is the interactive relationship between service level and variety-seeking behavior? (2) how to balance the impact of service input on customer surplus and social welfare at different stages.

Firstly, this study proposes an analytical framework to explore the impact of variety-seeking behavior and service input level on passenger ratios at different stages of CB and PT. In specific, the variation of departure frequency and passenger numbers of CB and PT were studied by Hotelling model. In addition, we have interactive relationship between service level and variety-seeking behavior under the changes of passenger numbers conditions. Therefore, we have proportion of passengers and the level of service input that the government or bus company expects.

Secondly, we obtain the changes of customer surplus and social welfare according to limit of proportion with passengers in different modes. At the same time, we propose different operation strategies of CB and PT to obtain reasonable level of service, and even achieve the best benefit to consumers and society.

Therefore, the contribution of this paper is introducing the idea of game into a CB operation scenario. The research results show the reasonable input level of services in different stages in order to rationalize the bus operations of CB and PT. In addition, the results can also make social welfare and customer surplus reach a higher level and provide references for bus operation.
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