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How to promote sustainable travel behavior in the post COVID-19 period: A perspective from customized bus services

Linghui He a,c, Jian Li a,b,c,* , Jianping Sun c

a Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University, Shanghai 201804, China
b College of Transportation Engineering, Tongji University, Shanghai 201804, China
c Institute for Urban Risk Management, Tongji University, Shanghai 200072, China

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A B S T R A C T

The Corona Virus Disease 2019 (COVID-19) has influenced the daily life of urban residents worldwide. In the post COVID-19 period, the proportion of public transport commuting trips decreased, whereas that of car commuting trips increased. As a sustainable travel mode, customized bus services have been promoted to ensure the public health security during commuting in this period in many cities in China and other countries. This study focused on the promotion of sustainable travel behavior in the post COVID-19 period from the perspective of customized bus services. A total of 664 respondents from Shanghai, China participated in this study to provide revealed preference (RP) and stated preference (SP) data related to the customized bus services in the post COVID-19 period. The mode choice model was established based on the hypothetical scenarios to estimate the commuters’ intention to shift to the customized bus services, determine the mode preference of different groups, and suggest potential policies. The results showed that the preference for customized buses decreased with the increasing fare for one journey, the travel time, and the availability of a one-way ticket, and middle-class commuters had a higher preference for commuting by customized bus. The measures for the short and long term in the post COVID-19 period were proposed. The results of this study can help governments adopt policies to promote customized bus services not only in the post COVID-19 period but also during regular daily life.

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1. Introduction

The Corona Virus Disease 2019 (COVID-19) pandemic, which represents the most significant disruption that people have experienced in recent history, has a significant impact on human mobility. The international community and governments have to consider various policies on travel restrictions to inhibit the spread of the novel Coronavirus (Cheng et al., 2020, Linka et al., 2020). Once the COVID-19 pandemic is under control, government departments ask people to resume work and production to avoid more serious social problems.

During the COVID-19 period, the travel behavior of urban residents has changed due to the influence of the virus and travel restriction measures, especially in public transportation. Travel by public transport increases the risk of being exposed to
the virus, and the increase in private vehicles has exacerbated urban traffic congestion. In Shanghai, China, the passenger flow of the metro during the COVID-19 period (February 2020) was 27% that of the corresponding period one year before the pandemic (Wu et al., 2020). In the post COVID-19 period (the end of March 2020), the passenger flow of the metro reached 80% of the working days before the Chinese New Year, according to the Shanghai Transport Operation Monthly Report. Also, in other countries around the world, it has been proved in some studies that some of the travelers who usually commute by public transport shift to using motor vehicles (Shakibaei et al., 2021, Campisi et al., 2020). It is expected that the number of public transport users may decrease, and many may change using to private vehicles in the post COVID-19 period. The increase in the private motorized transport may have an unsustainable impact on urban transport, environment and residents’ life. Therefore, it is necessary to discuss how to promote sustainable travel behavior in the post COVID-19 period.

As a transport policy in post COVID-19 world, customized bus services have been promoted to prevent cross-infection on the way to work in a large number of Chinese cities, such as Shenzhen, Jinan, and Beijing (Wang et al., 2020b). Customized bus is not a new transportation concept, and it has been developed in Europe and America since the 1970s (Liu and Ceder, 2015). In 2013, China’s first customized bus line was officially opened in Qingdao. (Ke et al., 2017). A customized bus service in the regular period is a demand-responsive public transport service using bus-like vehicles and serve the similar group people living closer to each other, having the similar destination, and departing at the similar time for work (Li et al., 2019). After several years of development, the travel volume of customized buses remained low, and many residents were not aware of it. A customized bus service in the post COVID-19 period has several more features than that in regular daily life. The service targets the similar group people in one vehicle, and it guarantees all riders their seats and mutual isolation. To make it come true, the government and operators limit the vehicle load rate to less than 50%, and the passengers in the vehicles must wear masks and are forbidden to sit next to each other. The governments and operators check the body temperature of drivers and passengers in advance before each boarding. Since customized buses for the work resumption can meet the commuting demand in a sustainable way, current conditions represent an opportunity to increase efforts to promote this travel mode. Compared with walking, cycling or other forms of public transport, customized bus services can not only meet the needs of distance commuting while the post COVID-19 period, but also reduce the risk of cross infection due to its relatively fixed group of passengers and other features. This is especially important for densely populated cities. Therefore, it is crucial to examine what kind of policies are appropriate to attract people to commute by customized bus as a stable travel mode in the post COVID-19 period.

This paper establishes a commuting mode choice model that included the customized bus mode. The model considers the stated preference (SP) and revealed preference (RP) data collected in Shanghai, China. Also, the methods for user group segmentations are introduced. A survey was conducted in Shanghai to obtain the data. The survey data include the commuters’ socioeconomic and demographic characteristics, the travel behavior in the pre and post COVID-19 periods, as well as the mode shift to customized bus services under the hypothetical circumstances. We estimate the travelers’ intention to shift to customized buses based on a discrete choice model, and discussed the mode preference of different groups and potential policies. The findings provide recommendations for transport policy-making related to customized bus services to promote sustainable travel behavior in the post COVID-19 period.

The main focus of this study is to explore the significant impact of COVID-19 pandemic on travel behavior, and discuss how to promote sustainable travel behavior in the post COVID-19 period from a perspective of customized bus services. The study provides three contributions. First, we try to find the differences in travel behavior in the pre and post COVID-19 period. Second, we consider the user heterogeneity and study the preference of different groups to the customized bus services. Third, we provide constructive suggestions for managing the significant changes in travel behavior and guiding the development of customized bus services to avoid the unsustainable travel behavior.

This paper is organized as follows: Section 2 reviews the literature. Section 3 introduces the methodology. Section 4 presents the survey and data. In Section 5, the model results and mode preferences of different groups are presented. Section 6 discusses the general findings and policy implementations. Conclusions and suggestions for future research are presented at the end of the paper.

2. Literature review

Customized bus services have been put into practice in many cities around the world. A number of researchers studied whether individual travel behavior and travel preference have changed with the emergence of customized bus services. In addition, since the travel behavior changed greatly under the influence of the COVID-19 pandemic, a number of previous studies have made much efforts for the impact of COVID-19 pandemic on travel behavior.

2.1. Research and practice of customized bus services

Customized bus services were developed in the 1970s and then rapidly spread throughout the United States, Singapore, and Europe. Customized bus services have provided rapid commuting services to residents traveling between city centers and suburbs (Liu and Ceder, 2015). Kirby and Bhatt (1974) proposed guidance for customized bus services, including identifying the potential users, recruiting drivers, actively revising routes, and scheduling vehicles. Meanwhile, a successful customized bus service is characterized by long-distance commutes, schedule reliability, convenient access, and guaranteed...
seating (Bautz, 1975). These early studies have laid the theoretical and practical foundation for the development of customized bus services.

Customized bus services started relatively late in China. Xu et al. (2013) discussed the service, advantages, and applicability of customized bus services in the 2010s, and summarized it as efficient, convenient, flexible, comfortable, and economical. In August 2013, two customized bus lines were first opened in Qingdao (Ke et al., 2017). Subsequently, customized bus services were promoted in other regions in China, and have been used primarily for commuting to this day. Currently, more than 30 cities have opened customized bus services in China, such as Beijing in 2013, Shenzhen in 2014, and Shanghai in 2016 (Wang et al., 2020a).

A number of studies were conducted to better understand route planning, vehicle scheduling, service quality, and other aspects of customized bus services. GPS or mobile phone data were used to design the specific routes and schedules for commuters (Cheng et al., 2019, Han et al., 2019), and a series of methods were used to determine how to provide a better service to the passengers’ experience, including the mathematical model formulation (Armant and Brown 2014) and the simulation and optimization tools (Ma et al., 2020). In addition, the service quality of customized bus lines was analyzed (Lu et al., 2015, Jiang and Zhuo, 2018), and usually used to study the behavioral intention to commute by customized bus and the factors influencing this demand. For instance, Zhang et al. (2017) captured the choices of mode and route/service with a logit-type formula and considered heterogeneous travelers with a discrete set of values of time. Cao and Wang (2016) selected Harbin, China as a case study and conducted a Stated Preference (SP) and Revealed Preference (RP) survey to measure the individual willingness to choose customized shuttle bus by logistic regressions.

These research and practice promoted the development of customized bus services, but it was still not the first choice for residents to commute long distances. The outbreak of the COVID-19 pandemic made a number of commuting modes threatened by the virus spread, which gave the customized bus services a new development opportunity. Therefore, under the influence of the COVID-19 pandemic, it is worth studying whether customized bus services can satisfy the individual commuting needs affected by the pandemic and their preferences for the customized bus services.

### 2.2. Research on impact of COVID-19 on travel behavior

The COVID-19 pandemic has greatly affected the travel behavior, and the relationship between viral outbreaks and travel behavior has become an interesting research topic. The number of relevant studies was limited before the COVID-19 pandemic. The previous researches focused on the impact of epidemics and pandemics including SARS (Severe Acute Respiratory Syndrome), MERS (Middle East Respiratory Syndrome) and H1N1 on travel behavior from city, region and international level (Kim et al., 2017, Zhang et al., 2005, Ruan et al., 2006, Bajardi et al., 2011).

With the outbreak of COVID-19, the number of studies on the impacts of the pandemic on mode choice and travel behavior is increasing rapidly. Table 1 shows that travel behavior changed during the COVID-19 pandemic took place in different regions all over the world. It shows the travel behavior affected by the COVID-19 pandemic was changing all over the world. This change lies not only in the travel mode choice, but also in the activity pattern.

Several fascinating conclusions have been drawn according to the previous studies related to the impact of COVID-19 on travel behavior, such as: 1) travel frequency dropped significantly with the implementations of preventive measures (Beck and Hensher, 2020, Zhang and Fricker, 2021, Muley et al., 2021); 2) differences of gender, education, life style, the number of positive cases, mobility restrictions and other elements had impact on the mode choice and travel behavior (Shakibaie et al., 2021, Bergantino et al., 2021); 3) travel restriction policies forced the majority of the residents to telecommute and practiced flexible office hours (Habib et al., 2021). 4) urban road congestion patterns under the COVID-19 pandemic included the stable and muting needs affected by the pandemic and their preferences for the customized bus services.

#### Table 1

| Study               | Study timeline                               | Region               | Study topic                                      |
|---------------------|----------------------------------------------|----------------------|-------------------------------------------------|
| Irawan et al. (2021)| March 2020 and April 2020                     | Indonesia            | Frequency of travel, Telesworking and e-learning, teleshopping and ride-hailing |
| Jiao et al. (2021)  | March 1st to July 16th, 2020 and July 16th to November 1st, 2020 | Houston (USA)       | Travel patterns and visit activity               |
| Neuburger and Egger (2020) | March 1st to 4th, 2020 and March 15th to 19th, 2020 | DACH region (Germany, Austria, and Switzerland) | Travel risk perception and frequency of travel |
| Beck and Hensher (2020) | March 30th to April 15th, 2020                | Australia            | Travel activity, Working from home, air travel and shopping |
| Zhang et al. (2021)  | April 30th to May 24th, 2020                  | All over the world   | Overall travel, public transport travel and private transport travel |
in the safety of bus, subway, taxi, taxi-hailing was not high (Tan and Ma, 2021). All these previous studies highlight that travel behaviors during pandemic situations could be remarkably different from the normal daily life.

The previous researches related on customized bus services and impact of viral outbreak on travel behavior requires improvement. First, the COVID-19 outbreak has a more significant impact on travel behavior than other previous public health events. It is unclear whether the preferences of commuters change when the customized bus services are promoted during the COVID-19 pandemic. Second, in the process of using survey data for research, the travel-related attributes (e.g., travel distances, times, and costs, etc.) are generally recalled by the respondents, which may make the results biased and inaccurate. Third, most of the current researches focus on the change of travel behavior under mobility restriction, but ignore the opportunity of promoting sustainable travel behavior. For these reasons, in this study, we investigate travel behavior in the post COVID-19 period with a focus on customized bus services to guide policies on sustainable travel behavior. The survey data were collected in the post COVID-19 period and the travel attributes were obtained from a map service on the Internet to ensure high accuracy. Moreover, the policy recommendations proposed in this paper can promote the use of customized buses by commuters in normal daily life in the future.

3. Methodology

This study obtains the RP and SP data from a survey. RP and SP data both have advantages and disadvantages. The RP data reflect the travelers’ preferences and their behavior but cannot reflect their attitudes toward modes that do not exist or that are not familiar to the respondents (Li et al., 2019). The SP data use several hypothetical scenarios with key attributes. They can capture individual behavior and perception more accurately to analyze the impact of a new alternative (Hensher and Bradley, 1993). Combining the RP data with the SP data provides an improved understanding of the new mode and the mode shift.

In this study, the Multinomial Logit (MNL) model (Domencich and McFadden, 1975) and the Nested Logit (NL) model (Ben-Akiva, 1973) with a scale parameter are used. The MNL model suffers from the independence of irrelevant alternatives (IIA) leading to equal cross elasticity, meaning that any alternative draws equally from all the others (Ben-Akiva and Lerman, 1985, Al-Garawi and Kamargianni, 2021). Compared with the MNL model, the NL model relaxes the identically and independently distributed (IID) assumption among the different alternative modes by allowing for correlation to exist among certain alternatives (Ben-Akiva and Lerman, 1985, Al-Garawi and Kamargianni, 2021). In this study, the NL model can also be used to determine whether the customized bus services have the same features as other traditional travel modes. In the NL model, the probability of choosing a customized bus service is defined as:

\[
Pr(CB) = Pr(CB|MD) \cdot Pr(MD)
\]

where \(MD\) is a nest that includes the customized bus service and one traditional travel mode (TM), and \(CB\) represents the customized bus service. After normalizing the nested scale parameter from the top, Equation (1) is rewritten as:

\[
Pr(CB) = \frac{\delta_{CB} \cdot \exp(\mu \cdot V_{CB})}{\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})} \cdot \frac{\exp\left(\frac{1}{\mu} \ln \left[\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})\right]\right)}{\exp\left(\frac{1}{\mu} \ln \left[\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})\right]\right) + \sum_{n} \exp(\delta \cdot V)}
\]

where \(V_{mode}\) is the deterministic utility function for the customized bus service (CB), one traditional mode in the nest (TM), which is one of the walking, bicycle, bus, metro, and car mode; \(\delta_{mode}\) is a binary variable indicating the availability of a travel mode. Not all travel modes are always available for all respondents. \(\mu\) is the scale parameter of the nest normalized from the top; it should be greater than or equal to 1. The inverse of the scale parameter ranges from 0 to 1 in this case (Bierlaire, 1998). If \(\mu\) is estimated to be 1, the choice model follows an MNL structure. \(n\) represents the number of travel alternatives, except for the customized bus service and the one traditional mode in the nest. The choice probability of the other nested travel alternative is:

\[
Pr(TM) = \frac{\exp(\mu \cdot V_{TM})}{\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})} \cdot \frac{\exp\left(\frac{1}{\mu} \ln \left[\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})\right]\right)}{\exp\left(\frac{1}{\mu} \ln \left[\exp(\mu \cdot V_{TM}) + \delta_{CB} \cdot \exp(\mu \cdot V_{CB})\right]\right) + \sum_{n} \exp(\delta \cdot V)}
\]

Therefore, the nested structure of the MNL model and NL model can be supposed to be like Fig. 1.

In the RP data, the customized bus service is not an available option, which means \(\mu = 1\) and \(\delta_{CB} = 0\). The model of the other nested traditional modes has an MNL structure:

\[
Pr(TM) = \frac{\exp(V_{TM})}{\exp(V_{TM}) + \sum_{n} \exp(\delta \cdot V)}
\]

The MNL model is used to estimate the choice probability of the other traditional modes based on the RP data similar to Equation (4). In the model, the RP and SP values are joined together for estimation. In this study, the criteria for determining the selection between the MNL model and the NL model for analysis are as follows:

...
(i). If the results of t-test for μ are significant, the MNL model is rejected and the NL model is accepted.

(ii). Using a likelihood ratio test for IIA, we compare the preliminary results, which are equivalent to a model in which μ equals one, and the final results, which allow μ to be unrestricted. If twice the difference in the log likelihoods for producing a chi squared test calculated by Equation (5) is larger than the critical value for the degree of freedom, the MNL model is rejected.

\[
LRT = 2 \times (LL_{NL} - LL_{MNL})
\]  

where LRT is the likelihood ratio test value, LL_{NL} is the log likelihood of the NL model, and LL_{MNL} is the log likelihood of the MNL model.

(iii). Although both criterion (i) and criterion (ii) reject the assumptions of the MNL model, if the μ value is very close to 1, we may still consider using the results of the MNL model instead of the NL model for analysis.

In Equation (2) to Equation (4), the deterministic part of the utility function for each travel mode i is defined as:

\[
V_i = z_i + \beta_i \cdot X_i
\]

where \( z_i \) represents the alternative specific constant (ASC) of mode i, and captures the average effect on the utility of all factors otherwise not included in the model. Based on the previous studies (Shen and Zhao, 2018, Mo, et al., 2018, Liu et al., 2021), \( z_i \) indicates the inherent preference for the travel mode. \( \beta_i \) is an unknown parameter to be estimated, and \( X_i \) represents a vector of the explanatory variables of alternative i.

Maximizing the log-likelihood is used to estimate the model parameters in Python Pylogit package in this study. The function is shown in Equation (7). The higher the value of the likelihood function, the more credible the model parameter is.

\[
LL(\beta; z) = \ln L = \sum_{i=1}^{N} (y_{in} \ln Pr_n(i) + (1 - y_{in}) \ln (1 - Pr_n(i)))
\]  

where N represents the number of the samples.

4. Data collection and analysis

4.1. Survey design

A survey was conducted to measure the indicators used in the models. The survey questionnaires were randomly distributed to commuters between July 3rd and 10th, 2020 in Shanghai, China. According to the Shanghai Municipal Health Commission, Shanghai reported its first case of COVID-19 on January 20th, and the infection cases have been emerging since then. During the pandemic, the government adopted different measures to control the viral spread. There have been few new cases since the end of April. Therefore, the time completing the survey can be considered to be in the post COVID-19 period in Shanghai. The survey was implemented in an online crowdsourcing platform that provided functions similar to “Amazon Mechanical Turk” (Wu et al., 2018). We collected 664 questionnaires, and 506 valid questionnaires with effective and completed replies were selected for further study.

At the beginning of the survey, the background about the post COVID-19 period and the customized bus services were introduced to the respondents. The post COVID-19 period was described as follows: it is the period that remarkable results in fighting epidemic diseases are achieved through the travel restriction measures implemented by governments, and the epidemic almost disappears and no longer affects the daily life. The customized bus services were described as follows: they are reserved through the mobile APPs and serve the similar group people living closer to each other, having the similar destination, and departing at the similar time for work. The service also guarantees all riders their seats, and the prize is between that of metro/bus and that of taxi/ride-hailing services. Further, we introduced the epidemic prevention measures in the customized buses. Body temperature of drivers and passengers is checked before boarding. When the first level response to epidemic situation is launched, passengers in the vehicles must wear masks and are forbidden to sit next to each
other. When the second or third level response to epidemic situation is launched, passengers in the vehicles also need to wear masks but can sit next to each other. Fig. 2, was showed to the respondents to present more details about the customized bus services in the post COVID-19 period.

The questionnaire consisted of three parts. In the RP part, we collected comprehensive commuting travel information, including the main commuting modes in the pre and post COVID-19 pandemic periods, and the number of companions. Geographical information on the respondents’ residence and work locations was obtained by using the intersections of two crossroads instead of asking for a specific address, which protected the privacy of the respondents (Li et al., 2019). In the SP part, we collected information on a possible mode shift to the customized bus services under four hypothetical scenarios using an orthogonal experimental design. Three attributes related to customized buses were offered in different combinations in the scenarios, as shown in Table 2. The first two attributes were related to the ticket price, and the last attribute was related to the operating speed and travel time. In the third part, we collected information on the commuters’ personal socioeconomic and demographic characteristics, including gender, age, occupation, degree, income, and car/bike ownership.

4.2. Sample description

4.2.1. Socioeconomic and demographic attributes

The descriptive statistics of the socioeconomic information based on the survey are shown in Table 3. There were slightly more female commuters (61.26%) than male commuters (38.74%). Most of the valid interviewees were in the age range of 26 to 34 and 35 to 45, accounting for 47.83% and 39.53% of the sample, respectively. As for the income of the interviewees, 39.53% and 39.92% of the interviewees had a monthly income of 5,000–10,000 RMB (equal to 706–1,412 US dollars) and 10,000–20,000 RMB (equal to 1,412–2,824 US dollars), respectively. Most commuters had a bachelor’s degree, and held a driving license. Over 60% of the respondents had at least one car or one bicycle.

4.2.2. Travel service attributes

The location information obtained by the intersections of two crossroads determined the residence and work locations of the respondents. As shown in Fig. 3, 24.51% of the interviewees lived in the Pudong New District, 8.89% lived in the Yangpu District, and 8.10% lived in Minhang District; 23.52% of the respondents worked in the Pudong New District, 10.47% worked in Xuhui District, and 8.70% worked in Jingan District.

![CUSTOMIZED BUS SERVICES](image)

**Advantage**
- **One person one seat**
  - No need to transfer
  - Run directly from origin to destination
  - Assure the seat
- **Environmentally friendly and cheap**
- **Exclusive lane**
  - Pass through the bus lanes in peak hours
- **Cheaper**
  - Far lower than the travel costs of private cars and taxis
- **Discount**
  - Receive a discount in the current period

**Price**
- **Different charging modes**
  - Example:
    - Less than 10 kilometers: 8 RMB for each person of each time
    - Between 10 and 15 kilometers: 8 RMB for each person of each time
    - Between 15 and 20 kilometers: 10 RMB for each person of each time
    - More than 20 kilometers: 3 RMB for each person of each time for every 5 kilometers increase

**Reservation**
- **Determine the routes**
  - Reservation and seat selection through the mobile APPs or Internet
  - Monthly fee or single fee
- **Complete payment**
  - Download QR code as a ticket
  - Scan the QR code on the mobile phone or the printed QR code on paper

*Fig. 2. Introduction to customized bus services in the post COVID-19 period.*
Commuting travel information can be obtained based on the origins and destinations of the respondents. Baidu Map provides a route planning service, which is also known as a direction application programming interface (direction API), to obtain these attributes. The direction API is a set of web service APIs in the representational state transfer (REST) architectural style; it provides route planning service in the form of HTTP/HTTPS.

The description of the travel service attributes is listed in Table 4. The objective was the commuting mode in the post COVID-19 period. In the RP part, the distance variable was used as the standard of the bus and metro access or egress. Using the distance variable provides a smaller bias because the commuters can use different modes with different travel speeds to get to the stations, such as walking or cycling (Duan et al., 2020). The average travel distance was 2.85 km for walking and 4.37 km for using a bicycle. The average travel distance for the non-motor modes was 3.99 km. In terms of the average travel time, travel by car was less than 30 minutes, whereas travel by bus was close to that by the metro (45 to 50 minutes). The access and egress distances of the metro mode were longer than those of the bus mode due to a denser distribution of bus stops than metro stations in Shanghai. The transfer distance and walking time of the metro mode were longer than those of the bus mode, which was also related to the number of stations and lines in Shanghai. In the SP part, the conditions for the customized bus service were set based on the fare for one journey, the charge type, and the operating speed. Since the customized buses run directly from the origin to the destination, the travel distance for the customized bus service was equal to the car travel distance. In this way, the travel time of the customized bus service could be calculated for each interviewee. In Scenarios 2 and 3, the travel times of the customized bus service (25.1 and 24.2 minutes) were close to that of the car mode (24.4 minutes). In the other two scenarios, the travel times were longer than the travel time of the car mode but slightly shorter than that of the bus and metro mode.

Table 2
Four hypothetical scenarios.

| Scenario | Fare for one journey | Charge type | Speed |
|----------|----------------------|-------------|-------|
| 1        | 6 RMB (fixed fare)   | Only monthly fee | 20 km/h |
| 2        | 6 RMB for less than 10 kilometers, 8 RMB between 10 and 20 kilometers and 10 RMB for more than 20 kilometers (tiered fare) | Monthly fee or single fee | 30 km/h |
| 3        | 6 RMB (fixed fare)   | Only monthly fee | 30 km/h |
| 4        | 6 RMB for less than 10 kilometers, 8 RMB between 10 and 20 kilometers and 10 RMB for more than 20 kilometers (tiered fare) | Monthly fee or single fee | 20 km/h |

Table 3
Descriptive statistics of the socioeconomic characteristics of the valid samples.

| Variable                  | Category value             | Sample size | Percentage (%) |
|---------------------------|----------------------------|-------------|----------------|
| Gender                    | male                       | 196         | 38.74          |
|                           | female                     | 310         | 61.26          |
| Age (years)               | 18–25                      | 33          | 6.52           |
|                           | 26–34                      | 242         | 47.83          |
|                           | 34–44                      | 200         | 39.53          |
|                           | 45–49                      | 31          | 6.13           |
|                           | 50–59                      | 23          | 4.55           |
|                           | ≥60                        | 0           | 0.00           |
| Education                 | senior high school or technical school | 18 | 3.56 |
|                           | bachelor's degree          | 412         | 81.42          |
|                           | master's degree            | 66          | 13.04          |
|                           | doctorate                  | 10          | 1.98           |
| Annual income (RMB)       | ≤36,000                    | 3           | 0.59           |
|                           | 36,001–60,000              | 27          | 5.34           |
|                           | 60,001–120,000             | 200         | 39.53          |
|                           | 120,001–240,000            | 202         | 39.92          |
|                           | 240,001–500,000            | 56          | 11.07          |
|                           | 500,001–1,000,000          | 14          | 2.77           |
|                           | >1,000,000                 | 4           | 0.79           |
| Driving license           | yes                        | 349         | 68.97          |
|                           | no                         | 157         | 31.03          |
| Car ownership             | 0                          | 167         | 33.00          |
|                           | 1                          | 295         | 58.30          |
|                           | 2                          | 37          | 7.31           |
|                           | ≥3                         | 7           | 1.38           |
| Bike/Motorbike ownership  | 0                          | 140         | 27.67          |
|                           | 1                          | 225         | 44.47          |
|                           | 2                          | 104         | 20.55          |
|                           | 3                          | 37          | 7.31           |
4.2.3. Mode split and mode shift

The mode split of the five travel modes in the RP data and the mode shift to the customized bus service in the SP data are displayed in Table 5. The mode split in the RP data include the commuting modes in the pre and post COVID-19 periods. The proportion of the car mode with less infection risk increased, and the proportion of public transport with more infection risk decreased. The results show that the mode choice was still affected by the pandemic six months after the outbreak. Regarding the intention to shift to customized bus service, users who commuted by car were the most willing to shift to this service in all four hypothetical scenarios. The reason may be that the customized bus service represents relatively low infection risk,
little change in the travel time, and relatively low cost. In contrast, commuters who traveled on foot and by bicycle were the least willing to shift to customized bus service, because the non-motorized modes had relatively low infection risk, and a customized bus provided no advantage for short-distance travel. These findings were partly different from those of a previous study (Li et al., 2019). In the previous study, commuters using rail and bus were the most willing to shift to the customized bus mode, and commuters using non-motorized transport were the least willing to shift to customized bus service. It indicates that customized bus services attracted car commuters in the post COVID-19 period, while they were more attractive to public transport commuters in normal daily life. This difference might be because commuters were at a lower risk of being infected by the virus during the car commuting than public transport commuting. Also, commuters focused on the travel speed and travel time. In Scenarios 2 and 3, where the travel speed was the same but higher than those of the other two scenarios, a customized bus service attracted more commuters that used traditional travel modes.

5. Results

5.1. Model estimation results

The MNL model and the NL models were established. In the NL models, the customized bus mode was nested in the car, bus, and metro, respectively, to test whether the customized bus services had the similar features with these traditional travel modes. The nested structure of the models is shown in Fig. 4.

The summary statistics of the goodness-of-fit indicators are displayed in Table 6. According to the criteria for choosing MNL model or NL model for analysis, the scale parameters $\mu$ in the NL models were statistically insignificant at 95% confidence based on the t value statistic for $\mu$. The LRTs of the NL × car and NL × metro models were smaller than the critical value for one degree of freedom of 3.84, and the LRT of the NL × bus was larger than the critical value. The scale parameters $\mu$ in the NL models were all close to 1. Therefore, the NL model was not suitable to determine the effect of the customized bus, and the model almost had an MNL model structure (Shen and Zhao, 2018). The finding also showed that the customized

![Fig. 4. Nested structure of the models.](image)
bus mode differed from the traditional travel modes in terms of the travel time, travel distance, and other variables. Consequently, the estimation results of the MNL model were used in a follow-up analysis.

In the MNL model, different travel service attributes, which were the distances of accessing and egressing, travel time, travel distance, and transfer-related attributes, were included in the utility functions of all six modes. It was noted that not all attributes of travel service mentioned in Section 4 were significant, and the insignificant attributes were removed from the model. As shown in Table 7, the selected attributes had significant impacts on the mode choice, and the sign of the coefficients represented positive or negative effects. Most of the coefficients were significant with negative signs, except for the travel time of the metro mode. Since the metro mode have advantages for long-distance travel, it is understandable that the impact of the attributes was positive.

We first present the coefficients of the significant variables in the customized bus utility function. The coefficient of the customized bus fare for one journey was negative (-0.1141), indicating that commuters did not tend to choose the customized bus service when the fare increased. The coefficient was not highly significant; the likely reason was that the fare of the customized bus for one journey was fixed in some of the scenarios and did not change with the travel distance. As a new commuting mode that was introduced into the market, the fare of the customized bus was higher than that of the regular bus and close to or even higher than that of the metro. Thus, a higher fare discouraged the use of the customized bus service. At the same time, commuters were willing to pay for a monthly fee, possibly because it is preferable to repeated purchases. The travel time of the customized bus negatively affected the commuters’ mode choice probability (-1.3966); this factor had a stronger negative effect on the intention to commute by customized bus than the other factors. Also, commuters were sensitive to the travel time of the customized bus, similar to that of the bus mode (-1.4092).

Second, the coefficients of the travel service variables in the utility functions of the other travel modes are explained. The coefficients of the travel time of most modes were negative. The coefficient of the travel time by car was 2.41 and 2.16 times that of walking and taking the bus, respectively. The result indicated that the tolerance for the travel time by car was significantly lower than that of taking the bus or walking. The likely reason is that drivers need to concentrate on driving and prefer the less travel time. It was noted that the coefficient of the travel time by metro was positive (0.3046), but not significantly lower than that of taking the bus or walking. The likely reason is that drivers need to concentrate on driving and prefer the less travel time. It was noted that the coefficient of the travel time by metro was positive (0.3046), but not significantly lower than that of taking the bus or walking. The likely reason is that drivers need to concentrate on driving and prefer the less travel time.

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### Table 7

**Estimated results of the MNL model.**

| Mode       | Variable                               | Coefficient estimate | Standard error | t-statistic |
|------------|----------------------------------------|----------------------|----------------|-------------|
| Car        | Constant of car                        | -2.7558              | 0.266          | -10.354     |
|            | Car travel time (h)                    | -3.0451              | 0.343          | -8.873      |
| Walk       | Constant of walk                       | -3.1205              | 0.302          | -10.339     |
|            | Walk travel time (h)                   | -1.2657              | 0.128          | -9.872      |
| Bicycle    | Constant of bicycle                    | -2.3293              | 0.279          | -8.358      |
|            | Bike travel distance (km)              | -0.2716              | 0.019          | -13.939     |
| Bus        | Constant of bus                        | -2.5540              | 0.275          | -9.272      |
|            | Bus access distance (km)               | -0.3321              | 0.190          | -1.752      |
|            | Bus travel time (h)                    | -1.4092              | 0.147          | -9.603      |
| Metro      | Constant of customized bus             | -1.8228              | 0.192          | -9.473      |
|            | Metro egress distance (km)             | 0.3046               | 0.120          | 2.533       |
|            | Metro travel time (h)                  | -1.1243              | 0.338          | -3.331      |
|            | Metro transfer walking distance (km)   | -0.6717              | 0.074          | -9.097      |
| Customized | Constant of customized bus             | -1.1865              | 0.391          | -3.036      |
|            | Customized bus fare for one journey (RMB) | -0.1141          | 0.056          | -2.033      |
|            | Customized bus travel time             | -1.3966              | 0.181          | -7.711      |
|            | A one-way ticket is available          | -0.2445              | 0.111          | -2.205      |
distance of the metro had a larger influence than the travel time. An uncomfortable transfer environment may have made the commuters anxious and irritable, and these variables may be more likely to cause the commuters to shift to the private motorized mode.

5.2. Mode preference of different groups

The alternative specific constants (ASCs) of the modes estimated by the MNL model represented the inherent preference for different modes (Shen and Zhao, 2018, Mo et al., 2018, Liu et al., 2021) as shown in Section 3. We normalized the ASC of the metro mode to zero, and compared the differences between the ASCs of the metro mode and other travel modes.

The ASCs were decomposed by integrating them with different characteristics of the respondents. We mainly focused on the mode preference of different groups, including the sociodemographic variables, such as personal income, age, gender, and education level, and travel variables, such as license holding, car and bicycle ownership, and the number of companions. Some variables were classified into different groups. Age was split into young (under 31 years old), middle-aged (between 31 and 36 years old) and old (above 36 years old) age groups. The categories were based on the quantile of the sample. Personal monthly income was divided into three groups: low income (under 5,000 RMB monthly), middle income (between 5,000 RMB and 10,000 RMB monthly), and high income (above 10,000 RMB monthly). The education level was classified as highly educated and not-highly educated. The other variables were dummy variables and were split into two groups.

The ASCs of the modes decomposed by the sociodemographic variables are shown in Fig. 5. In the models, all the coefficients were significant except for the ASCs of the low-income group. The number of respondents who earned less than 5,000 RMB monthly (equal to 706 US dollars) was too low to be used in the analysis. Therefore, this group is not presented in the following analysis. Fig. 5(a) to Fig. 5(d) show the mode preference based on the sociodemographic variables. The variables included age, income, education and gender. In Fig. 5(a), the preference coefficients show interaction with the age group. Young people were more willing to commute by metro and bus. Their intention to commute by customized
bus was relatively positive but lower than that to commute by metro, which may be because the fare of customized buses was higher than that of the metro. Middle-aged people preferred to commute by customized bus, and they were most likely to use customized bus service to commute in all age groups. Fig. 5(b) shows the preference of the groups with different levels of income. The middle-income group tended not to commute on foot, and they preferred to commute by public transit. Subjects in the higher income group showed a greater preference for the car mode. Compared with the middle-income respondents, the group with higher income seemed less willing to choose customized bus service as the commuting mode. Fig. 5(c) illustrates the preference coefficients by education level, showing a clear trend that the preference to use the customized bus service was correlated with the education level. People who were highly educated showed a strong preference (significantly higher than zero) to use customized bus mode. Fig. 5(d) shows the preference coefficients by gender. Female subjects, in general, showed a higher preference to use the customized bus service than male subjects. There was no significant difference in the males’ preference to different modes of commuting, but females were more averse to walking and cycling than males.

The ASCs of the modes decomposed by the travel variables are shown in Fig. 6. In the models, all the coefficients were significant. Fig. 6(a) to Fig. 6(d) show the mode preference based on the travel variables. Fig. 6(a) shows the preference of the groups with/without a license. The respondents without a license were more likely to commute by customized bus service, and their preference to the car mode was significantly negative. Those with a license were willing to commute by customized bus, but they also tended to commute by car. Fig. 6(b) illustrates the preference coefficients by car ownership. People with cars were willing to commute by car, but they were more willing to shift to customized buses than people without cars. This result may be because using customized buses makes the drivers less exhausted and greatly reduces the travel costs while ensuring health safety. Those without cars tended not to commute by car. Also, walking or biking to work is not an expected choice for them. Fig. 6(c) shows the preference coefficients by bicycle ownership. The respondents with bicycles were significantly more likely to use bicycles to travel to work, but a customized bus was also attractive to them. The respondents without bicycles did not like the non-motorized commuting modes. Fig. 6(d) shows the preference coefficients based on the number of companions. The commuters with companions preferentially chose the car mode because travelers can

![Fig. 6. Mode preference based on travel variables.](image-url)
share the cost and keep the benefit of driving. The commuters without companions were more likely to use the customized bus services than the commuters with companions.

In the post COVID-19 period, none of the groups of the respondents tended to commute by bicycle or on foot. The metro was the most preferred mode in most groups, likely because it was a relatively cheap commuting mode for long-distance travel. Also, in most groups, the respondents chose to commute by car as a second choice in the traditional travel modes. In addition to preferring the car mode in normal life, the public may show a preference for car travel to avoid the risk of infection. It is desirable to shift more car commuters to sustainable modes such as the customized bus service to promote the sustainable commuting mode and travel behavior. In most groups, many respondents were more willing to use customized bus service as the commuting mode than the traditional travel mode, which was conducive to policy-making.

6. Discussion

6.1. General findings

In Section 4 and Section 5, we have studied mode shifts brought by COVID-19 and the preference of different groups toward the customized bus services. The results of the survey and the model indicate that there are several options to promote the customized bus service in the post COVID-19 period. First, several respondents have changed their commuting modes, and the respondents who commuted by car in the post COVID-19 period were more willing to use a customized bus. Second, the customized bus mode differed from the traditional travel modes based on the results of the MNL model and NL models. Third, the travel time was a sensitive issue for the respondents, so travel time should be considered in policy-making for the governments and operators. Finally, the commuters who were middle-aged (31 to 36 years old), highly educated (master and doctoral degree), had a medium income, no license, and companions, and owned cars and bicycles tended to commute by customized bus. These groups should be targeted for policy-making.

The above results show that commuters in Shanghai intended to travel by customized bus in the post COVID-19 period, and it is a good opportunity for the government and operators to attract commuters to take customized buses by providing high-quality services. Also, current conditions may increase the possibility of commuting by customized buses in the near future, which is beneficial to the sustainable travel behavior under the long-term impact of COVID-19. The general findings have important implications for policy making, and also provide reference to the governments and operators. Only implementing the travel restriction policies will lead to unsustainable travel behavior, and may also stimulate more social conflicts, which has been proved in many cities around the world. What kind of polices can ensure the necessary and sustainable travel under the premise of preventing the spread of the virus is an important issue that needs to be considered.

6.2. Policy implications

In the early stage of the COVID-19 outbreak, the governments tended to take travel restriction measures, such as lockdown, home quarantine, even stopping the entire traffic system, to prevent the viral spread. In the post COVID-19 period, the increase of unsustainable travel behavior should be avoided in the case of controlling the epidemic instead of focusing on the travel restriction measures. Therefore, as a sustainable travel mode, the policy implications from the perspective of the customized bus services are suggested as follows.

In the short term, the public health safety should still be the most important factor to be considered by the governments and operators at all levels. Although different passengers may have different risk perception to the pandemic, personal protective equipment and essential supplies for infection control should be placed in customized buses. The disinfectants, alcohol-based hand sanitizers and masks are essential supplies. Passengers can sit next to each other, but the vehicle load rate should be controlled to prevent the virus coming back. Wearing face masks is still a must because the virus is easy to spread in a confined space. The designed SP scenarios in our survey include these elements, and the results show that the public are willing to accept such customized bus services (Table 5), which means the public accepts these plans and restrictions.

In the long term, since car commuters in the post COVID-19 period are more willing to use a customized bus, and the travel time of customized buses is an important variable, the government should implement related policies to promote this transformation. The reasons why car commuters are willing to choose customized buses may be that they do not have to focus on driving and can relax on the way to work if the travel time does not change substantially. Therefore, it is necessary to ensure a relatively short travel time. The use of exclusive bus lanes is a conventional policy. In Shanghai, customized buses can run in bus lanes in peak hours, but this may not ensure that the travel time does not change. The reason is that all bus lanes in Shanghai are located on surface roads but not on expressways. Signal priority is a more important strategy in this case, and its integration with exclusive bus lanes will ensure stable travel times. Also, the entertainment devices can be incorporated into customized buses to relax the passengers.

Regarding the characteristics of each group, it is important to consider the preferences of commuters who are middle-aged (31 to 36 years old) or highly educated (master and doctoral degree) earn a medium income have no license or companions, and own cars and bicycles. Specific policies should be designed for these groups. Fare discounts and subsidies can be considered a starting point. Middle-aged residents with a medium income can be offered a fare discount of cus-
tomized buses at first if they have a car and agree not to drive to work. Also, residents with highly education can receive a similar fare discount. These policy recommendations are aimed at promoting the sustainable travel behavior in the post COVID-19 period. However, social equity should be considered in policy-making. Other commuters who are willing to take the customized buses but do not have these socio-economic characteristics (middle-aged, highly educated, earn a medium income, have no license and companions, and own cars and bicycles) still have the right to enjoy this service in the process of promoting this sustainable travel mode. Therefore, the incentives should set some restrictions and conditions, and can be implemented in pilot programs on some customized bus lines, or in locations where these people gather at work, such as colleges and universities, to test whether the policies can promote more residents to switch to customized buses. Then, based on the effects of the pilot programs, it is determined whether these policies will be implemented on a larger scale.

Thus, the key to successfully promote sustainable travel behavior in the post COVID-19 period should focus on the public health safety in the short term, and the exclusive bus lanes and signal priority in the long term. For each group with different characteristics, offering user-value-oriented services and providing related policies is a better way to encourage users to give up commuting by car.

7. Conclusions

This paper investigated how to promote sustainable travel behavior from the perspective of customized bus services in the post COVID-19 period. A case study of Shanghai, China was presented using data from July 2020. The commuting characteristics and the intention to commuting to choose a customized bus service were obtained from a questionnaire survey. The travel service attributes were derived from an Internet map service to improve model accuracy. RP and SP data were used to identify the influential factors affecting the travel choice for the customized bus mode in the post COVID-19 period. Also, the effects of commuter heterogeneity were investigated. The summary of the findings is presented below.

First, the MNL model was proved to be more suitable to explain the results than the NL model. Car commuters were the most willing to shift to a customized bus mode, whereas users walking to work were the least willing. The preference for the customized bus service decreased with the increasing fare for one journey, the travel time, and the availability of a one-way ticket. The travel time exerted a more negative effect on the intention to commute by customized bus than the other factors, and commuters showed a preference to pay for a monthly fee. Second, middle-aged users, or those who were highly educated, earned a medium income, had no license and companions, or owned cars and bicycles tended to commute by customized bus service. The results showed that most customized bus mode users were in the middle class, where people received good education, earned a medium income and own cars. Finally, several policies in the short and long term were proposed as improvement strategies. In the short term, the public health safety should still be the most important factor to be considered. In the long term, measures should be taken to ensure the stability of the travel time of customized buses. In addition, different strategies can be considered for different groups to encourage more commuters to shift to the customized bus service.

The results of this study help to promote sustainable travel behavior regarding customized bus services in the post COVID-19 period. In future research, more aspects of this topic can be investigated. First, regarding the fare of customized buses, the pricing strategy provided in this paper is relatively simple, and more refined fare systems could be designed for different groups in the post COVID-19 period. Second, with the pandemic evolvement, the travel-related measures will change, and the factors considered in the SP scenarios should also be adjusted. More data should be used to refine the model calibration and results. The factors related to the pandemic should no longer be the fixed conditions, but be the options for residents in the long term. Finally, more variables for user segmentation should be included to identify the locations where pilot policies can be implemented first and more about the social equity should be discussed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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