

Perceived risk of crime on driverless public bus and ride-pooling services in China

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ABSTRACT

Driverless vehicles are expected to improve traffic safety and efficiency in the future. If the autonomous driving technologies are successfully developed, they are anticipated to be applied not only to private vehicles but also public buses, taxis (including ride-pooling services). Such driverless vehicles may cause passengers to be concerned about crimes on such driverless public transportation. Thus, this study explores users' acceptance of driverless public buses and ride-pooling services and how the individual characteristics affect their perceived risks of crime occurrence and victimization, and willingness to use these modes. To achieve this objective, 1,090 questionnaires were collected from China. The survey shows that approximately 43% of the respondents answered that the possibility of crime is high, 39% stated they do not want to use driverless public buses or ride-pooling cars, and 30% think that the possibility of being a victim is high. Three random parameters ordered probit models are estimated. The results show that: (1) people believe a driverless vehicle is more dangerous than a conventional one in terms of crime; (2) females are more concerned about crime occurrence; (3) respondents are more concerned about crime occurrence at night; (4) people have significant concerns about crime occurrence on a driverless public bus than on a ride-pooling car; and (5) region, travel time, income, education level, and safety measures have significant effects on the perceived risk of crime.

1. Introduction

Crime related to public transportation is a pressing social issue as it directly affects people's daily mobility (Heidensohn, 1989). Recent statistics reveal a concerning increase in various crimes related to public transportation, affecting both developed and developing countries. For instance, in the developed country like United States, the crimes on public transportation have exhibited an average growth rate of over 1.01 (United States Department of Transportation, 2021). More specifically, the subway crime in New York, United States, spiked by 30 % in 2023 (Fola Akinnibi and Gregory Korte, 2023). In the United Kingdom, the monthly crime rate of London overground increased from 6.6 to a peak of 17.9, nearly a threefold increase (London Datastore, 2022). In Canada, major crimes in the Toronto transit system rose by 3 % in 2022 compared to 2019 (Yousif, 2023).

Crime on public transportation is also a serious issue in developing countries like India, Pakistan, and China. According to statistics from the National Crime Records Bureau in India, the number of crimes related to the public transportation has reached 2,766 in 2021, surpassing the

figures from 2020 (National Crime Records Bureau, 2022). It is also worth noting that the fear of crime has deterred over 30 % of individuals from using public transportation, with many being previous victims of such crimes (Gupta, 2020). Likewise, Pakistan has witnessed a substantial increase in crimes related to public transportation over the last three decades (Newton, 2015). A survey conducted in Pakistan revealed that 89 % of women reported experiencing harassment while traveling on public transportation (Tabassum and Suhail, 2022). Like other developing countries, China has also experienced a significant rise in transportation-related crimes. For instance, Beijing, China, has witnessed a rise in bus pickpocketing (Ding and Zhai, 2021). It is worth noting that violent crimes are predominant on public transportation in countries like the United States and the United Kingdom (Lydall, 2023), while sexual harassment poses a significant challenge in countries with more crowded public transportation, such as India and Japan (Asia Media International, 2019; Memon et al., 2022).

Currently, various countries are actively exploring the application of driverless technology to public transportation (Owens et al., 2018). For instance, in Europe, the Horizon Europe ULTIMO project is testing

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driverless buses with plans to deploy 45 driverless buses in three cities, namely Geneva (Switzerland), Kronach (Germany) and Oslo (Norway) by 2025 (Hall, 2023). In the United States, Lyft, a ride-hailing service company, has completed more than 100,000 driverless rider-hailing services in Los Angeles with people on real-world roads in 2020 (Holt, 2020). Waymo also received permission from the California Department of Motor Vehicles to deploy fully automated vehicles for shared services (J. Hawkins, 2022). Considerable progress has been made in developing driverless public transportation; however, certain critical issues, such as understanding users' attitudes toward driverless vehicles, remain to be addressed (Owens et al., 2018).

Users' attitudes toward driverless public transportation, such as public buses and ride-pooling services will play a key role in their successful adoption. Therefore, it is important to explore factors that negatively impact users' attitudes toward driverless vehicles. One such factor is the users' perceived risks of crime on public transportation, which can also hinder the acceptance of driverless public transportation (Roche-Cerasi, 2019). However, there is limited existing research on understanding users' perceptions regarding the crimes (security) of driverless public buses and ride-pooling services.¹

To fill this research gap, the present study explores users' crime perceptions concerning driverless public buses and ride-pooling services across a diverse sample of individuals. The study is carried out in China primarily because, despite being a developing country, China has made significant advancements in driverless technology. For instance, seven cities in China presently operate driverless buses on public roads, covering 54.6 km of routes. Notably, China achieved a milestone in April 2021 when its first level four driverless bus surpassed 15,000 km of operation. Moreover, China hosts the largest market for driverless vehicles, with a remarkable growth trajectory (Tencent News, 2021). For instance, in 2018, there were 0.3 million level two and three driverless vehicles in China, which is expected to surge to 1.5 million by 2025 (Market, 2019). This robust and vast market demand positions China as a promising candidate for widespread adoption of driverless technology, particularly within the realm of public transportation. Consequently, understanding users' acceptance and security concerns regarding the driverless public buses and ride-pooling services in China is essential. This understanding is crucial not only to capture the dynamics of users' acceptance and security perceptions regarding driverless vehicles in this extensive market, but it will also lay the groundwork to understand these aspects in other countries. To achieve this understanding, the study designed a scenario-based questionnaire in China, guided by the following research questions:

- (1) How do users perceive the risk of crime while traveling in these modes?
- (2) How do users perceive that they can be a victim of a crime while traveling in these modes?
- (3) How willing are users to use these modes in the future?

The contribution of this study is threefold: (a) it provides empirical evidence on the security (crime) concerns of users regarding driverless public buses and ride-pooling services. Evidence from the users' perspective is scarce in existing literature, but it is necessary in order to provide insights into the potential use of these modes as part of cities' transport systems; (b) it presents findings on how individual characteristics can affect perceived risks of crime occurrence and victimization; thus, allowing policymakers to have a better understanding of potential contributing factors, hence, proving more robust countermeasures; and

(c) it employs a random parameters model that allows to capture the heterogeneity across the users in their perceptions/responses.

2. Literature review

2.1. Perceived safety, perceived security, and perceived risk of crime regarding driverless vehicles

Perceived safety refers to an individual's subjective assessment of the likelihood of encountering harm or danger in a particular situation or environment. In the context of driverless vehicles, it involves evaluating the potential risks of crashes or injuries that may arise due to system failures, malfunctions, or other technical issues. Studies emphasize the significance of perceived safety in users' acceptance and intention to use driverless vehicles (Zhang et al., 2019). To mitigate this perceived safety barrier, various studies have analyzed the factors affecting it (Hulse et al., 2018). In this regard, several studies showed that socio-demographic factors significantly affect individuals' perceived safety of driverless vehicles (Greenblatt and Shaheen, 2015; Hussain et al., 2021; Nair and Bhat, 2021). For example, younger, high-income men tend to have more positive attitudes toward the safety of driverless vehicles (Faculty et al., 2020). In addition, users' trust in technology is another factor closely linked to driverless vehicles' perceived safety (Luger-Bazinger et al., 2021). Moreover, factors, such as death concerns, experience, familiarity with driverless vehicle tests, also directly or indirectly affect perceived safety (Pyrialakou et al., 2020; Tan et al., 2021).

In addition to perceived safety, perceived security is considered a significant factor affecting users' acceptance of driverless vehicles. Perceived security is the subjective assessment of the level of protection and safety from intentional harm or malicious activities. In the case of driverless vehicles, it encompasses concerns related to cybersecurity, data privacy, and protection against cyber-attacks (Liu et al., 2020). In this context, prior research (Manfreda et al., 2021) has concluded that socio-demographic characteristics are associated with varying levels of perceived security concerning hackers and privacy on driverless vehicles. Other existing research (Liu et al., 2020) has shown that due to the complexity of autonomous driving systems, assessing perceived security requires consideration of additional factors, categorized into themes such as awareness, education, safety, responsibility, legislation, and trust.

Apart from the above two crucial factors, perceived risk is another factor that plays a vital role in shaping users' attitudes toward driverless vehicles. Perceived risk of crime is an individual's subjective assessment of the likelihood of being a victim of crime, particularly in a given setting or activity. It involves evaluating the potential for criminal activities or harmful events to occur and impact one's safety and well-being. In the context of driverless vehicles, this could include concerns about theft, assault, and harassment that could happen while traveling in such modes. Existing research (Rader, 2004; Badiora et al., 2015) has shown that the perceived risk of crime significantly influences commuters' choices regarding a particular mode of transportation. However, in the realm of driverless vehicles, the perceived risk of crime has not been adequately explored. It is worth noting that any crime that occurs in the existing modes of transportation has the possibility to occur in driverless vehicles. Moreover, there is a warning indicator that, besides the existing crimes, new crime tendencies may arise in driverless vehicles (Newton, 2017). Given the serious issue of public transport-related crime, it is necessary to understand how the perceived risk of crime affects users' acceptance of driverless public buses and ride-pooling services.

2.2. Factors influencing perceived risks of crime

Most of the existing literature has attempted to explore the factors influencing people's perceived risk of crime in conventional (human-

¹ In this study, autonomous ride-pooling services refer to a kind of service in which a passenger shares a ride with an unknown passenger with comparable routes and schedules. It enables rides to serve more than one set of passengers, and the sharing between passengers is one-time, non-recurring, and unintended (Agatz et al., 2011; Zhu and Mo, 2022).

driven) public transportation. Among these factors, gender plays a prominent role. It is widely acknowledged that women exhibit a higher perceived risk of crime when using public transportation than men (Soto et al., 2022). Age is another key factor that plays a vital role in people's perception of crime on public transportation. For instance, young individuals tend to have a heightened perceived risk of crime, both while on the bus and waiting at the bus stop (Badiora et al., 2015). The level of education also plays a role in perceived risks of crime. People with higher education tend to perceive lower risks, whether using public or private transportation (Moen and Rundmo, 2006).

Transport mode is another important factor that significantly affects people's perceptions of crime. For instance, people reported higher perceived risk of crime in public buses (Alm and Lindberg, 2000). Similarly, people who less frequently use public transportation perceive a greater crime risk in such modes (Currie et al., 2010). The perceived risk of crime on public transportation is also influenced by the time of day. For example, nighttime is found to positively influence the perceived risk of crime (Orozco-Fontalvo et al., 2019). Traveling with unfamiliar passengers exacerbates negative feelings of concern for personal security, heightening the perceived risk of crime (Currie et al., 2013). The availability of onboard emergency measures like cameras and emergency buttons is another critical factor influencing perceived security against crime (Alm and Lindberg, 2000).

However, very few studies have explored the factors affecting the people's perceived risk of crime in the context of driverless public buses and ride-pooling services. In addition, there is limited literature investigating the factors influencing the peoples' willingness to use driverless public buses and ride-pooling services considering their concerns about crimes.

2.3. Variables selected in the scenario

Several studies have been identified to be associated with perceived risks of crime in public transportation. In this regard, factors, such as the presence of drivers, security measures (i.e., security officer, and CCTV (closed circuit television) / emergency button), travel time, are found to significantly influence the perceived risks of users. Thus, when structuring the scenarios for in this study, we carefully accounted for two key aspects: the presence or absence of driver, security measures (i.e., security officer, and CCTV / emergency button), and different travel times accounting for both day and night travel. In addition, travel distance is an important factor affecting users' assessment of the crime risk in public transportation; therefore, we incorporated this factor in the scenarios as long-distance and short-distance travel (Liu et al., 2022).

The perceived risk of crime associated with sharing a ride with a stranger is a challenge, which also may affect the widespread adoption of driverless vehicles. Thus, to explore users' perceived risks of crime in hazardous scenarios, we included co-passenger in each scenario (Schuß et al., 2023). In the future, driverless technologies are expected to be applied to public buses and ride-pooling services; therefore, we incorporated the two modes of travel—driverless public bus and ride-pooling—in scenarios.

3. Method

3.1. Questionnaire survey design

3.1.1. Scenarios' design

In the current study, the scenarios were developed using a fractional factorial approach. A fractional factorial design is a type of full factorial design that is expressed using the notation l^k , where l is the number of levels of each factor investigated, and k is the number of factors investigated. However, in many experiments, variables have distinct levels, and the influence of higher-order interactions on experimental object redundancy must be considered. Therefore, the study employed the mixed-level fractional factorial design.

In this investigation, the fractional factorial design has three two-level and one four-level factor. To have a higher resolution, to take the levels of all of the factors in the original design and switch them, a complete foldover design was chosen (Ankenman, 1999). Based on this theory, a foldover design with sixteen runs was developed to investigate the perceived crime risk. Each scenario includes security measures, travel mode, time, and distance. The security measures include the presence/absence of security officers, CCTV / emergency buttons, and the presence / absence of a driver. Travel mode refers to buses and ride-pooling services, and time categories related to day and night. Travel distance is divided into short (travel time ≤ 30 min) and long (travel time > 30 min) distances. Keeping in view the fractional factorial design, the investigation requires a total of eight scenarios. The details of the scenarios are summarized in Appendix A.

3.1.2. Questionnaire design

A questionnaire survey approach is used to collect information on users' socio-demographic characteristics, daily travel behaviors, observation of criminal activity, perceptions of crime occurrence, victimization, and unwillingness to use driverless public buses and ride-pooling services. The questionnaire was designed based on an extensive review of the existing literature and the results of pre-conducted discussions. Before the formal survey, several pretests were conducted to improve the clarity of the questions in the questionnaire. In light of the pilot study results, the initial questionnaire was revised to ensure that the questions were clear, concise, and easily understood by the respondents. Moreover, the questionnaire was designed in the Chinese language to facilitate the survey's participants. A cover letter outlining the study's aims, a brief introduction to the driverless vehicles, and confidentiality assurance were included at the beginning of the questionnaire.

The questionnaire comprised two different sections. The first section of the questionnaire inquires the users about their: (1) socio-demographic characteristics (i.e., gender, age, average annual income, and level of education); (2) daily travel behaviors (i.e., frequently used mode of transportation, and frequency of using public buses and ride-pooling service); and (3) observation of criminal activity (theft/robbery, verbal, physical, or sexual harassment) while traveling.

The second section of the questionnaire consists of questions about the various scenarios (for details of scenarios, please refer to Appendix A) to record the respondents: (1) perceptions about the possibility of crimes occurring in the driverless public buses and ride-pooling services (*Do you think it is possible a crime would occur?*); (2) their willingness to use these modes (*Considering the given conditions, would you choose to ride on this vehicle?*); and (3) their perceptions of being a victim of a crime while traveling in these modes (*Considering the given conditions, do you think you can be a victim of a crime?*). Respondents must answer these questions under the two aspects (short and long travel). All the indicators were measured with a five-point Likert-type scale (i.e., extremely unlikely, unlikely, neutral, likely, and extremely likely) (Huang et al., 2012). It is important to highlight that for the third question, we converted "willingness to use" to "unwillingness to use" by reversing the points. The rationale behind this choice stems from the fact that the other two questions inquired about the magnitude of perceived crime occurrence and victimization, both of which are associated with negative perceptions.

In the questionnaire, the scenarios were shown to the respondents through a simulated picture depicting the perspective of a passenger. For each scenario, essential information such as travel distance, travel time, presence of a driver, presence of security measures (i.e., security officer, and CCTV / emergency button), travel mode, and co-passenger within the vehicle was provided in text format alongside the corresponding image. This combination of images and text had the advantage of helping respondents visualize the scenarios while simultaneously ensuring that they recall the important elements they needed to consider.

3.2. Sample collection

Online (internet-based) surveys are widely adopted in economic and social research because of their potential advantage of effective nationwide surveys (Zhao et al., 2021). The present study also conducted an internet-based survey for the sample collection. For this purpose, the questionnaire was designed using the platform “Wenjuanxing (<https://www.wjx.cn/>)”, which is specifically designed for conducting surveys. The link to the questionnaire was then shared on various popular social communication applications in China, such as QQ and WeChat. In addition, an offline (field) survey was carried out with the help of a team of experienced traffic safety researchers. To minimize the likelihood of missing information in the data, all the questions on the internet-based survey were marked as “mandatory,” whereas, in the field survey, the survey team members were responsible for ensuring that all questions were answered correctly. Both surveys were conducted between June 5, 2022, and July 1, 2022. It is also worth noting that all questions were recorded anonymously.

A total of 1,006 respondents filled out the questionnaire. To ensure that the pieces of information collected in the responses are valid, the following two filtering criteria were used: (1) excluding responses where the time spent on each item was less than 100 s (Huang et al., 2012); and (2) removing responses with consistent or repetitive options in half or complete questionnaire (Curran, 2016). Consequently, 164 out of the 1,006 responses were removed from the sample as they were suspected of being reported inappropriately. Thus, a total of 842 responses remained in the final sample (effective rate: 83.69 %).

3.3. Explanatory Analysis: Descriptive statistics

Table 1 summarizes the respondents' socio-demographic characteristics, daily travel behaviors, and observation of criminal activity. Regarding gender, 55.34 % of the participants were female. Concerning the respondents' age and education level, 72.33 % were under 30 years old, and 80 % had a bachelor's degree or above. It is important to note that while a significant portion of our respondents were young and highly educated, the sample remains valuable. A noteworthy aspect is that a majority (60 %) of the respondents reported using public transportation, emphasizing the relevance and potential insights the sample can offer in the context of this study. Respondents with an annual household income of 50,000–100,000 Chinese Yuan (~7,000–14,000 US Dollars) had the highest proportion (26.48 %), while those with an annual household income of 200,000–250,000 Chinese Yuan (~28,000–35,000 US Dollars) had the lowest proportion (5.94 %).

Concerning the respondents' daily travel behaviors, the sample reflects the majority of transport users in China, with rail transit or subways being the most common mode of transportation. In addition, in the available sample, the proportions of the respondents who use public buses and ride-pooling services as their most frequent modes of transportation were 14.73 % and 9.62 %, respectively. Moreover, respondents who do not use the bus at all (i.e., zero times per week) had the highest share (31.24 %), while those who use it more frequently (i.e., six times per week) had the lowest share (1.31 %). On the other hand, respondents who use ride-pooling less frequently (i.e., once per week) have the highest proportion (26.84 %), while those who use it more regularly (i.e., six times per week) have the lowest proportion (0.71 %).

When it comes to the respondents' observation of criminal activity while traveling, 42.28 % of the respondents reported that they had observed at least one type of crime while traveling. More specifically, the most prevalent crime type reported was verbal harassment (31.35 %), followed by physical harassment (23.40 %) and theft or robbery (14.61 %). In terms of prior experience with driverless vehicles, 25.89 % of respondents reported that they had a prior experience with driverless vehicles.

Table 1

Descriptive statistics of the respondents' socio-demographic characteristics, daily travel behaviors, and observation of criminal activity while traveling.

Variables	Description	Frequency	Proportion (%)
Gender	Female	466	55.34
	Male	376	44.66
Age	Older (Over 30 years old)	609	72.33
	Younger (Less than or equal to 30 years old)	233	27.67
Annual household income (1,000 Chinese Yuan = ~140 US Dollars)	Less than 50,000	151	17.93
	50,000–100,000	223	26.48
	100,001–150,000	198	23.52
	150,001–200,000	110	13.07
	200,001–250,000	50	5.94
Highest education level	Over 250,000	110	13.06
	High school or lower	80	9.50
	Professional college (Associate bachelor's degree)	82	9.74
	Undergraduate (bachelor's degree)	365	43.35
	Master's degree or higher	315	37.41
Most frequently used mode of transportation	Motorcycle	36	4.27
	Rail transit/subway	299	35.51
	Public bus	124	14.73
	Ride-hailing	81	9.62
	Private car	146	17.34
	Rickshaw	4	0.48
	Taxi	25	2.97
	Walking / bicycle	105	12.47
	Other	22	2.61
How many days do you use the public bus every week	0	263	31.23
	1	172	20.43
	2	172	20.43
	3	94	11.16
	4	48	5.70
	5	55	6.53
	6	11	1.31
	7	27	3.21
How many days do you use the ride-hailing service every week	0	221	26.25
	1	226	26.84
	2	201	23.87
	3	106	12.59
	4	33	3.92
	5	35	4.16
	6	6	0.71
	7	14	1.66
Observed crime type while traveling ^a	Verbal harassment (e.g., jokes, catcalling, discriminative words)	264	31.35
	Physical harassment (e.g., unwanted touch, violence)	197	23.40
	Theft/robbery	123	14.61
	Sexual assault (rape)	29	3.44
	Other	39	4.63
	None	486	57.72
Have you experienced riding in a driverless vehicle	Yes	218	25.89
	No	624	74.11

^a respondent could choose multiple crimes if applicable or select “none” only.

3.4. Respondents' responses regarding mode and automation

This section presents the respondents' responses regarding the possibility of crime occurrence, victimization, and unwillingness to use the different modes (public buses and ride-pooling services) in the different scenarios (driverless and human-driven vehicles). To ensure effective data analysis, different strategies were used to handle the dependent variable. However, the most meaningful results were obtained by categorizing respondents' responses, including extreme unlikely, unlikely, and neutral as disagree, and likely, and extreme likely as agree. This categorization was based on the recognition that certain respondents might not be highly sensitive to dangerous scenarios and are uncertain

about their perceived risk of crime at the time of completing the questionnaire but could perceive real-life scenarios differently. Therefore, grouping the “neutral” responses with “unlikely” and “extreme unlikely” help to avoid overestimation of respondents’ perceived risk.

The descriptive analysis showed that approximately 42 % of respondents perceive that there is a possibility of a crime occurrence (i.e., likely and extremely likely) on driverless public buses, compared to 33 % for human-driven buses. In the case of ride-pooling services, 42 % of the survey participants agree that the probability of crime occurrence is higher, whereas only 27 % think the same for human-driven one. Similarly, around 32 % believe that there is likelihood of victimization on driverless public buses, compared to 20 % on human-driven buses. For driverless ride-pooling services, 31 % agree that there is risk of victimization, in contrast to only 19 % for human-driven ride-pooling services. In terms of willingness to use, 39 % of the respondents reported that they are either unwilling or extremely unwilling to use driverless public buses compared to 23 % for human-driven buses. This difference is more pronounced for ride-pooling services, where the proportion of the respondents who are likely or extremely likely unwilling to use driverless and human-driven ride-pooling services are 39 % and 19 %, respectively.

Pearson’s Chi-square test was used to determine the statistical difference in the respondents’ responses between different scenarios. As shown in Table 2, when comparing different modes of transportation (public buses and ride-pooling services), the results showed that the possibility of crime occurrence between driverless and human-driven vehicles is more significant in ride-pooling services. Although the difference in the respondents’ responses about being a victim of crime between public buses and ride-pooling is not substantial, a relatively higher proportion of people fear they may be victims of crime in driverless vehicles. Finally, regarding the unwillingness to use a mode, the survey participants are more likely to be reluctant to use driverless public buses and ride-pooling services than human-driven vehicles.

3.5. Statistical analysis

In this study, respondents are required to record their responses to questions about their perceptions of crime occurrence, victimization, and unwillingness to use driverless public buses and ride-pooling services in the different scenarios (for detail, please refer to sections 3.1.1 and 3.1.2) on a five-point likert scale (extremely unlikely, unlikely, neutral, likely, and extremely likely), which is ordinal in nature. Therefore, the study adopted the ordered probit model to investigate the factors influencing respondents’ perceptions of crime occurrence, victimization, and unwillingness to use driverless vehicles. To account for the possible heterogeneity across the survey’s participants in their responses and the means and variances of the random parameters, the ordered probit model’s counterparts, i.e., random parameter model and random parameters model with heterogeneity in means and variances, respectively, were also estimated.

The utility of a respondent ($n = 1, \dots, N$) choice from a set of i al-

ternatives can be expressed as follows (Hensher and Greene, 2003):

$$U_{in} = \beta_n X_{in} + \varepsilon_{in} \quad (1)$$

where X_{in} is a vector of observed independent variables, β_n is a vector of estimable parameters, and ε_{in} is the error term assumed to be the generalized extreme value distributed. The choice probabilities P_{in} can be written in an open form (Seraneeprakarn et al., 2017; Mannering et al., 2016; McFadden and Train, 2000):

$$P_{in} = \int_{\beta_n} L_{\beta_n}(\beta_n) g(\beta_n/\Omega) d\beta_n \quad (2)$$

$$L_{\beta_n}(\beta_n) = \frac{\text{EXP}(\beta_n X_{in})}{\sum_{i=1}^I \text{EXP}(\beta_n X_{in})} \quad (3)$$

where $g(\beta_n/\Omega)$ is the density function of β , and Ω is a vector of parameters of the density function (mean and variance). As noted by Seraneeprakarn et al. (2017), the density function $g(\beta_n/\Omega)$ determines β , which accounts for fluctuations/variations in the effect X on the participants’ choice probabilities. It should be noted that some elements of the vector β can be fixed across the sample of respondents, and some may vary across respondents (Seraneeprakarn et al., 2017). Also, heterogeneity in both the means and variances of random parameters can be accounted for as follows (Seraneeprakarn et al., 2017):

$$\beta_{in} = \beta + \delta_{in} Z_{in} + \sigma_{in} \text{EXP}(\phi_{in} \psi_{in}) \omega_{in} \quad (4)$$

where ω_{in} is the disturbance term, and Z_{in} captures the heterogeneity in the mean of random parameters with estimable parameters in vector δ_{in} . The heterogeneity in the standard deviation (σ_{in}) of random parameters is captured by ψ_{in} , with estimable parameters in vector ϕ_{in} . (Seraneeprakarn et al., 2017) indicate that with the absence of statistically significant variables in the vector ψ_{in} , the model would be a mixed (random parameters) logit model with heterogeneity in the means of the random parameters. On the other hand, if the vectors ψ_{in} and Z_{in} do not have statistically significant variables, then the model has no heterogeneity in the mean or variance of the random parameters.

In the present study, the parameters of the proposed models are estimated based on the simulated maximum likelihood approach with 1000 Halton draws (Bhat, 2001; McFadden and Train, 2000; Train, 2009). The statistical software NLOGIT5 is used for model estimation. The Akaike information criterion (AIC) was used to evaluate the data fitting performance of the competing models (Fabozzi et al., 2014). In addition, several distributions, including triangular, gamma, uniform, Weibull, and normal, were investigated; however, the estimated results revealed that none of these distributions were statistically superior to the normal distribution. As a result, the normal distribution was selected for modeling the random parameters, which is consistent with prior research (Fountas et al., 2021; Islam et al., 2020; Pervez et al., 2022a, b; Waseem et al., 2019).

Table 2

Chi-square test in response regarding mode and automation.

Description	Mode	Automation	Agree (%)	Disagree (%)	Chi-square	p-value
Crime may occur	Public bus	Driverless	2124 (42.0)	2928 (58.0)	62.290	< 0.001
		Driver present	554 (32.9)	1130 (67.1)		
	Ride-pooling service	Driverless	2124 (42.0)	2928 (58.0)	120.652	< 0.001
		Driver present	455 (27.0)	1229 (73.0)		
Being a victim of crime	Public bus	Driverless	1578 (31.2)	3474 (68.8)	69.914	< 0.001
		Driver present	347 (20.6)	1337 (79.4)		
	Ride-pooling service	Driverless	1463 (29.0)	3589 (71.0)	66.722	< 0.001
		Driver present	317 (18.8)	1367 (81.2)		
Unwillingness to use	Public bus	Driverless	1958 (38.8)	3094 (61.2)	137.445	< 0.001
		Driver present	388 (23.0)	1296 (77.0)		
	Ride-pooling service	Driverless	1787 (35.4)	3265 (64.6)	149.285	< 0.001
		Driver present	327 (19.4)	1357 (80.6)		

4. Results

To explore the factors affecting the respondents' perceptions of crime occurrence, victimization, and unwillingness to use driverless vehicles, the present study developed three random parameters ordered probit models for each dependent variable separately. To further investigate the heterogeneity in the means and variances of the random parameters, the study employed the random parameters model with heterogeneity in means and variances but could not get significant results. Thus, the results and discussions presented in the subsequent sections are based on the random parameters model.

4.1. Factors affecting Respondents' perceived risk of a crime occurrence

This section explores the factors influencing the respondents' reported perceived risk of crime occurrence in driverless public buses and ride-pooling services. The model's results (refer to Table 3) revealed that compared to the respondents in Northeast China, respondents from the North, Northwest, and Southern regions of China declared a higher possibility of crime in driverless public buses and ride-pooling services. On the same note, respondents in the Southwest and East regions also reported a higher chance of a crime in driverless public buses and ride-pooling services. The results showed that females perceived a higher likelihood of crime in driverless public buses and ride-pooling services.

Table 3

Model estimation results for perceived risk of crime occurrence, perceived risk of being victim of crime and unwillingness to use.

Category	Variable	Perceived risk of crime occurrence Coefficient (p-value)	Perceived risk of being victim of crime Coefficient (p-value)	Unwillingness to use Coefficient (p-value)
–	Constant	–0.773** (<0.001)	–0.120** (0.002)	–0.746*** (<0.001)
–	Std. dev.	0.673*** (<0.001)		
Region	Northeast region	Reference		
	North region	0.175*** (<0.001)		
	Northwest region	0.220*** (<0.001)		
	Southwest region	–0.331*** (<0.001)		
	East region	–0.079*** (<0.001)		
	Std. dev.	0.543*** (<0.001)		
	Southern region	0.450*** (<0.001)		
Age	Std. dev.	0.368*** (<0.001)		
	Older (Over 30 years old)	Reference		
	Younger (Less than or equal to 30 years old)			–0.100*** (<0.001)
Gender	Std. dev.			1.123*** (<0.001)
	Male			
	Female	0.617*** (<0.001)	0.300*** (<0.001)	0.871*** (<0.001)
Highest education level	Std. dev.	0.247*** (<0.001)	0.187*** (<0.001)	0.680*** (<0.001)
	Higher education (Undergraduate and higher)	Reference		
	Lower education (Lower than undergraduate)			–0.409*** (<0.001)
Annual household income	Std. dev.			0.832*** (<0.001)
	Higher income (Income more than 100,000 CNY)	Reference		
	Lower income (Income less than or equal 100,000 CNY)		–0.249*** (<0.001)	
If observed crime type while traveling	Std. dev.		0.854*** (<0.001)	
	No	Reference		
	Yes (crimes include theft/robbery, verbal, physical, or sexual harassment)	0.248*** (<0.001)		0.502*** (<0.001)
Driving automation	Std. dev.	0.233*** (<0.001)		0.391*** (<0.001)
	Driver is present	Reference		
	No driver	1.012*** (<0.001)	1.296*** (<0.001)	0.930*** (<0.001)
Security measure: security officer	Std. dev.	0.626*** (<0.001)	0.777*** (<0.001)	0.872*** (<0.001)
	Security officer is present	Reference		
	No security officer	0.989*** (<0.001)	0.845*** (<0.001)	0.904*** (<0.001)
Security measure: CCTV/emergency button	Std. dev.	0.457*** (<0.001)	0.496*** (<0.001)	0.651*** (<0.001)
	CCTV/emergency button is present	Reference		
	No CCTV/emergency button	0.693*** (<0.001)	0.716*** (<0.001)	0.603*** (<0.001)
Travel mode	Std. dev.	0.596*** (<0.001)	0.640*** (<0.001)	0.667*** (<0.001)
	Ride-pooling service	Reference		
	Bus	0.042** (0.009)	–0.027** (0.087)	0.075*** (<0.001)
Frequency of bus per week	Std. dev.	0.355*** (<0.001)	0.414*** (<0.001)	0.448*** (<0.001)
	Frequency of public bus per week: Zero	Reference		
	One to two times			0.348*** (<0.001)
Frequency of ride-hailing per week	More than three times			0.223*** (<0.001)
	Frequency of ride-hailing per week: Zero	Reference		
	One to two times		–0.310*** (<0.001)	
Travel time of day	Std. dev.		0.710*** (<0.001)	
	More than three times		–0.116*** (<0.001)	
	Reference: Day	Reference		
Travel distance	Night	0.258*** (<0.001)	0.316*** (<0.001)	0.151*** (<0.001)
	Std. dev.	0.607*** (<0.001)	0.656*** (<0.001)	0.551*** (<0.001)
	Short travel (≤30 min)	Reference		
Threshold parameters	Long travel (>30 min)	0.389*** (<0.001)	0.225*** (<0.001)	0.302*** (<0.001)
	μ_1	1.686*** (<0.001)	1.689*** (<0.001)	2.050*** (<0.001)
	μ_2	2.583*** (<0.001)	2.712*** (<0.001)	3.262*** (<0.001)
	μ_3	4.301*** (<0.001)	4.005*** (<0.001)	5.254*** (<0.001)

than males. Also, the indicator “female” produces a random parameter (as shown in Fig. 1b), implying that 99.9 % of females believe crimes are more likely to occur in driverless public buses and ride-pooling services. Regarding the experience of observing a criminal activity, it was found that respondents who had previously observed a crime had a higher perception of a criminal incident than those who had not. See Table 4.

The results indicated that the absence of a driver increases respondents' perception of crime occurrence in driverless public buses and ride-pooling services. The variable also results in a random parameter (as shown in Fig. 1f), suggesting that the absence of drivers would increase the respondents' perception of crime occurrence by 94.70 % in the aforementioned driverless modes. The absence of a security officer and CCTV/emergency button elevates respondents' perceived probability of crime in driverless vehicles. Also, both the indicators for security officer and CCTV/emergency button in the estimated model have random effects (refer to Fig. 1g, h), indicating that in the above-mentioned driverless modes, the absence of a security officer and CCTV/emergency button would raise the respondents' perception of crime risk by 98.48 % and 87.75 %, respectively.

The results indicated that the risk of crime occurrence is higher in driverless buses than in ride-pooling services. Regarding the time of day, the study found that nighttime increases the respondents perceived risk of crime in driverless vehicles. Finally, regarding the travel duration, long-distance travel increases the respondents' reported possibility of crime.

4.2. Factors affecting Respondents' perceived risk of victimization

This section presents the factors affecting the survey participants' perceived risk of being a victim of crime in driverless public buses and ride-pooling services. Regarding gender, females perceived that they were more likely to be the target of criminal activity. Also, the parameter follows a normal distribution (as illustrated in Fig. 2a), implying that 94.57 % of females believe they are more likely to be victims of crimes. The study found that respondents with lower incomes had the perception that they were less likely to become victims of crime while using driverless public buses and ride-sharing services.

Regarding automation, respondents declared that they are more likely to be victims of a crime without drivers. The estimated parameter for “No driver” is random (as shown in Fig. 2d), implying that the absence of a driver tends to raise the perception of being a victim of crime in 95.23 % of respondents. When it comes to security measures, the results indicate that the respondents recorded risk perceptions increase in the absence of a security officer and CCTV/emergency button. Also, the parameters of these variables are randomly distributed (see Fig. 1e, f), showing that the absence of a security officer and CCTV/emergency button increases the likelihood of victimization in 95.58 % and 86.64 % of respondents, respectively.

Regarding the travel mode, it was found that buses negatively affect the respondents' perceptions of being victims of a crime compared to ride-pooling services. The model's results indicate that the frequency with which respondents use ride-pooling has a negative effect on their perceived risk of victimization in driverless ride-pooling services. For instance, respondents who use ride-pooling more regularly (more than three times a week) feel that they have a lower risk of being a victim of crime. The results revealed that nighttime and long-distance travel increases the possibility of survey participants' perception of being a victim of crime in driverless public buses and ride-pooling services.

4.3. Factors affecting Respondents' unwillingness to use driverless vehicles

This section reveals the factors influencing survey participants' unwillingness to use driverless public buses and ride-pooling services under different scenarios. The model results in Table 3 showed that younger respondents are more likely to use driverless public buses and ride-pooling services. The parameter for younger respondents is also

random (refer to Fig. 3a), indicating that 53.54 % of the young respondents are unwilling to use the above-mentioned modes of driverless vehicles. When it comes to gender, females were more cautious about riding in driverless public buses and ride-pooling services than males. As shown in Fig. 3(b), the estimated parameter for “female” is random, showing that 89.99 % of females are reluctant to ride in driverless public buses and ride-pooling services.

Regarding the respondents' levels of education, the research revealed that respondents with lower levels of education are more likely to be open to using driverless public buses and ride-pooling services. Concerning the respondents' experiences of observing a crime, it was found that those who had observed any crime in the past were significantly less willing to use driverless public buses and ride-pooling services than those who had not.

In terms of driving automation, when there was no driver present, respondents were more hesitant to use driverless public buses and ride-pooling services. Also, the indicator for no driver has random effects, with 85.69 % on the right side of zero (as shown in Fig. 3e), showing the unwillingness of respondents in the absence of a driver. The study found that the absence of a security officer and CCTV/emergency button also increased respondents' reluctance to use driverless public buses and ride-pooling services. From Fig. 4(f) and (g), it can be observed that the parameters estimated for the security officer and CCTV/emergency button are randomly distributed, indicating that the absence of these two measures increases the survey participants' unwillingness to use the driverless modes by 91.75 % and 81.70 %, respectively.

The study found that the respondents' riding frequency of public buses positively affected their unwillingness to use driverless public buses. For instance, respondents who use the public bus more often (more than three times per week) were more reluctant to use driverless public buses. Considering the perceived risks of crime, respondents were more reluctant to use driverless public buses compared to driverless ride-pooling. Respondents were more reluctant to use driverless vehicles at specific times (nighttime) and distances (long-distance travel).

5. Discussions

The present study investigates the acceptance of driverless public buses and ride-pooling services. In this regard, the questionnaire data analysis showed that individuals' perceived risk of crime occurrence and victimization in driverless vehicles (public buses and ride-pooling services) was higher than in human-driving vehicles. Detailed discussions on the estimated significant factors are provided in the following sections.

5.1. Perceived risk of crime occurrence

The perceived risk of crime occurrence significantly influences users' decisions regarding adopting driverless public buses and ride-pooling services. Therefore, to comprehensively understand how users' individual characteristics influence their perceived risks of crime occurrence in driverless modes of public buses and ride-pooling services, this study examined the various factors affecting this perception. In this regard, this study found that regional factors significantly affect individuals' perceptions of crime occurrence on driverless public buses and ride-pooling services. The result is consistent with the previous study's conclusion (Khan et al., 2022). The current research findings highlighted that women are more anxious about potential crime incidents in driverless public buses and ride-pooling services, which is an important and concerning issue. The conclusion might be attributed to women's physical vulnerability, making them more exposed to certain types of crimes, such as sexual harassment and assault on public buses and ride-pooling services (Schafer et al., 2006). The present study's results showed that individuals with previous experiences of observing criminal activity were more likely to perceive a higher prevalence of criminal activity on driverless public buses and ride-pooling services. This could

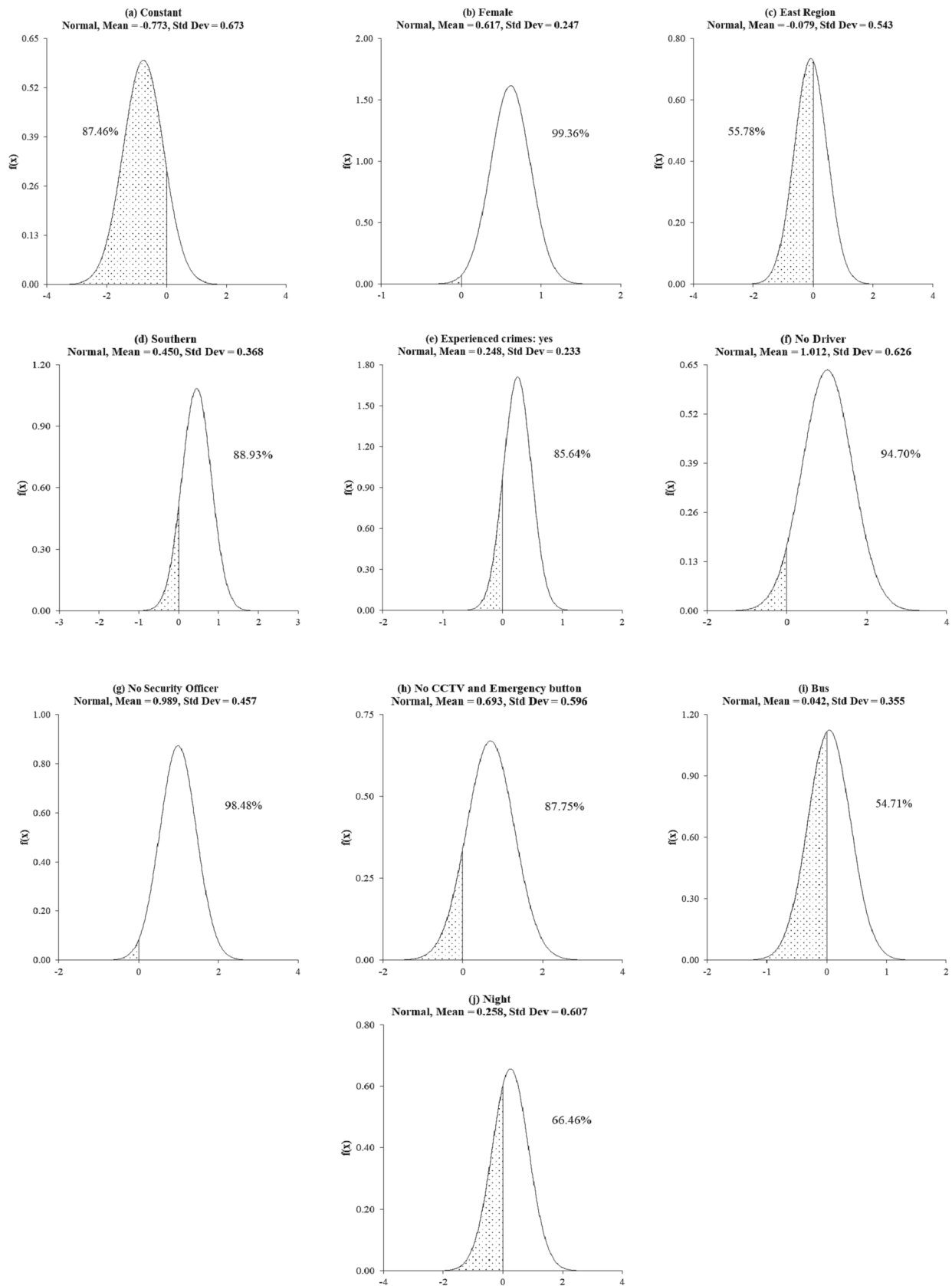


Fig. 1. Distributions of the random parameters for the possibility of crime occurrence.

Table 4
Scenarios used in the experiments from the passenger's perspective.

Scenario's picture	Scenario No	Scenario's variables
	Scenario 1 Short travel (≤30 min) Scenario 2 Long travel (>30 min)	Daytime, Public bus, No driver (automated), No security officer, Have CCTV, Have emergency button
	Scenario 3 Short travel (≤30 min) Scenario 4 Long travel (>30 min)	Nighttime, Ride-pooling, No driver (automated), No security officer, Have CCTV, Have emergency button
	Scenario 5 Short travel (≤30 min) Scenario 6 Long travel (>30 min)	Nighttime, Public bus, No driver (automated), No security officer, No CCTV, No emergency button

(continued on next page)

Table 4 (continued)

Scenario's picture	Scenario No	Scenario's variables
	Scenario 7 Short travel (≤30 min) Scenario 8 Long travel (>30 min)	Daytime, Ride-pooling, No driver (automated), No security officer, No CCTV, No emergency button
	Scenario 9 Short travel (≤30 min) Scenario 10 Long travel (>30 min)	Daytime, Public bus, No driver (automated), Have security officer, No CCTV, No emergency button
	Scenario 11 Short travel (≤30 min) Scenario 12 Long travel (>30 min)	Daytime, Ride-pooling, No driver (automated), Have security officer, No CCTV, No emergency button

(continued on next page)

Table 4 (continued)

Scenario's picture	Scenario No	Scenario's variables
	Scenario 13 Short travel (≤30 min) Scenario 14 Long travel (>30 min)	Nighttime, Public bus, With driver, No security officer, No CCTV, No emergency button
	Scenario 15 Short travel (≤30 min) Scenario 16 Long travel (>30 min)	Nighttime, Ride-pooling, With driver, No security officer, No CCTV, No emergency button

be explained by the fact that people who have observed criminal activity tend to have a less optimistic view of the benevolence of impersonal forces in their lives (Kanan, 2002; Quann, 2002); consequently, both direct and indirect victimization experiences can lead to an increased perceived risk of crime (Russo et al., 2013).

Despite driverless vehicles being considered a promising solution to improve road safety by eliminating human error, the current study's findings suggest that the absence of a driver raises the users' risk perception of crime occurrence in driverless public buses and ride-pooling services. This perception may be attributed to the belief that the driver's presence deters perpetrators; thus, reducing the risk crime (Welsh and Farrington, 2009), which is not the case in the above-mentioned driverless modes, resulting in higher crime risks among users in driverless modes. In addition, the present study found that security officers and CCTV/emergency buttons serve a similar purpose. Moreover, the presence of people, including drivers and security officers, can be more effective in enhancing passenger safety by assisting them immediately during a criminal incident (Salonen, 2018). Therefore, users' perceptions of security should be taken more seriously in the early deployment stages of driverless public buses and ride-pooling services. In this context, authorities should consider putting safety officers, CCTV/emergency buttons, or both on board, particularly in driverless public buses where passengers are exposed to one or more perpetrators/crimes. Considering the economic aspect, it is important to note that in the initial stages of implementing driverless vehicles,

having a security officer on board could significantly boost user acceptance. However, as the technology advances and users become more accustomed to driverless vehicles, the need for a safety officer diminishes. Ultimately, once the driverless technology is fully matured and widely accepted, these vehicles could prove to be more cost-effective in the long run, mainly due to reduced labor costs stemming from the absence of a need for safety officers on board.

The study highlighted that user expressed a heightened perceived risk in driverless public buses. This heightened perception could be attributed to the widespread use of public buses, leading passengers to perceive a higher likelihood of encountering perpetrators in the crowded and complex environment (Gerell, 2021). The study indicated that people perceive a higher risk of crime occurrence at night in driverless public buses and ride-pooling services. Heightened perception can be attributed to inadequate lighting during the night, which significantly amplifies the perception of potential criminal activities (Roche-Cerasi, 2019). The study revealed that longer travels on driverless public buses and ride-pooling services result in increased perceived crime risk. This is because, on such travels, users are compelled to spend more time in the vehicle, giving perpetrators more opportunities to plan and execute the criminal activity.

5.2. Perceived risk of victimization

Perceived risk of victimization plays a crucial role in the users'

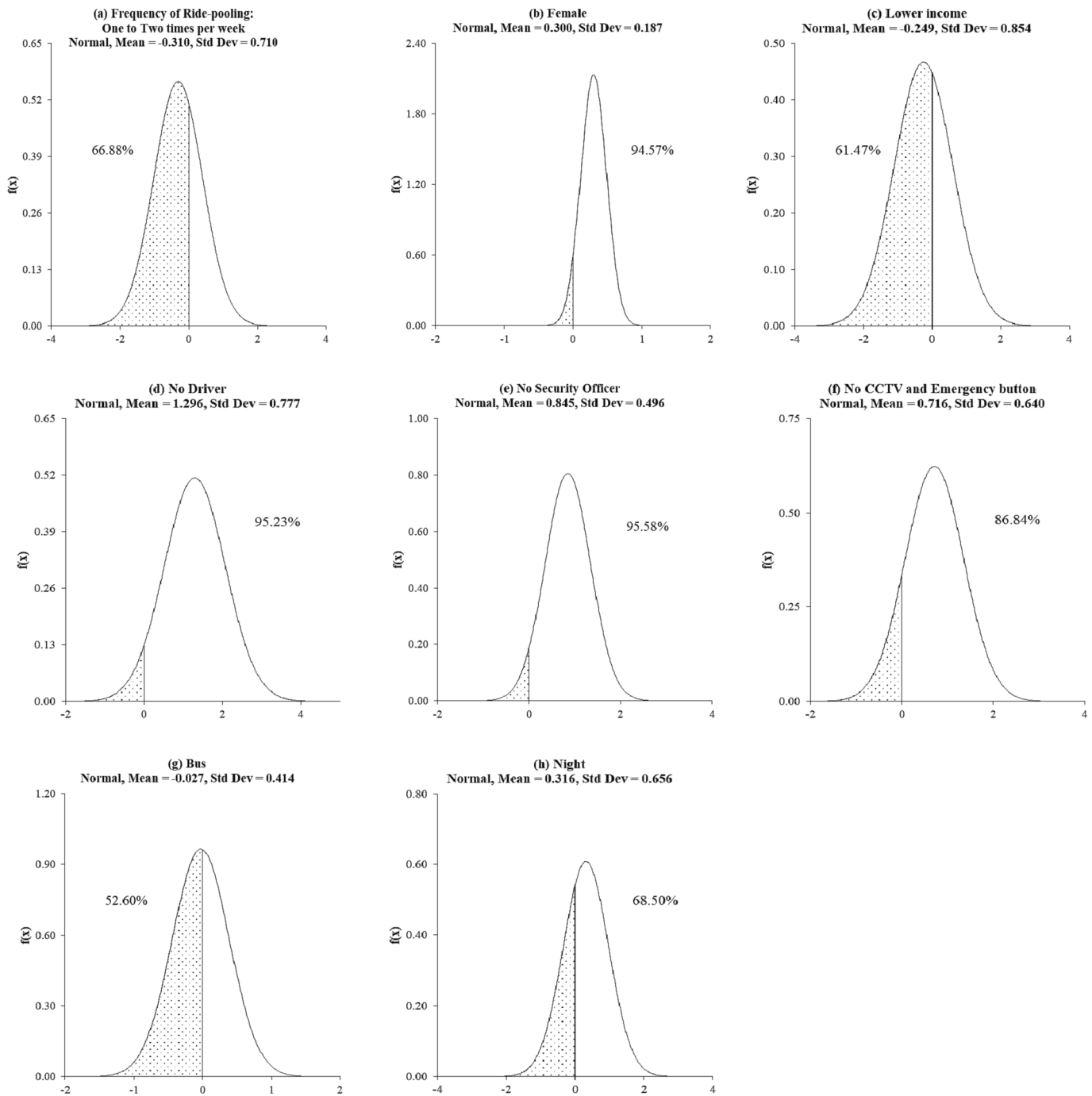


Fig. 2. Distributions of the random parameters for the possibility of being a victim of a crime.

security-related concerns regarding driverless vehicles. Therefore, to gain a comprehensive understanding of how users' individual characteristics impact their perceived risks of victimization in driverless modes of public buses and ride-pooling services, this study investigated the diverse factors influencing their perception of victimization. In light of this, the study's findings revealed that women are more likely to believe they become crime victims in driverless public buses and ride-pooling services. This vulnerability might stem from their comparatively weaker physique and self-defense capabilities, making them easier targets for potential perpetrators (Loukaitou-Sideris, 2014). The study's findings indicated that users with lower incomes believe they are less likely to be victims of crime. This perception could arise from that fact that they usually live in less secure environments and are more exposed

to crime incidents (Moody, Bailey, Zhao, 2020); thus, they have more experience in facing and dealing with criminal activities.

The present study's findings revealed that in the absence of a driver and security officer, users reported a heightened perception of victimization in driverless public buses and ride-pooling services (Schuß et al., 2023). This could be attributed to the passengers' belief that the presence of a driver or security officer enables timely intervention to avoid or mitigate the harm caused by perpetrators. Other security measures (i. e., CCTV/emergency buttons) serve a similar purpose. The emergency buttons allow passengers to control the vehicle and help them escape in time to avoid severe damage in the event of a crime (Schneble and Shaw, 2021). The majority of users believe that the presence of CCTV in place acts as a deterrent for potential offenders, effectively discouraging

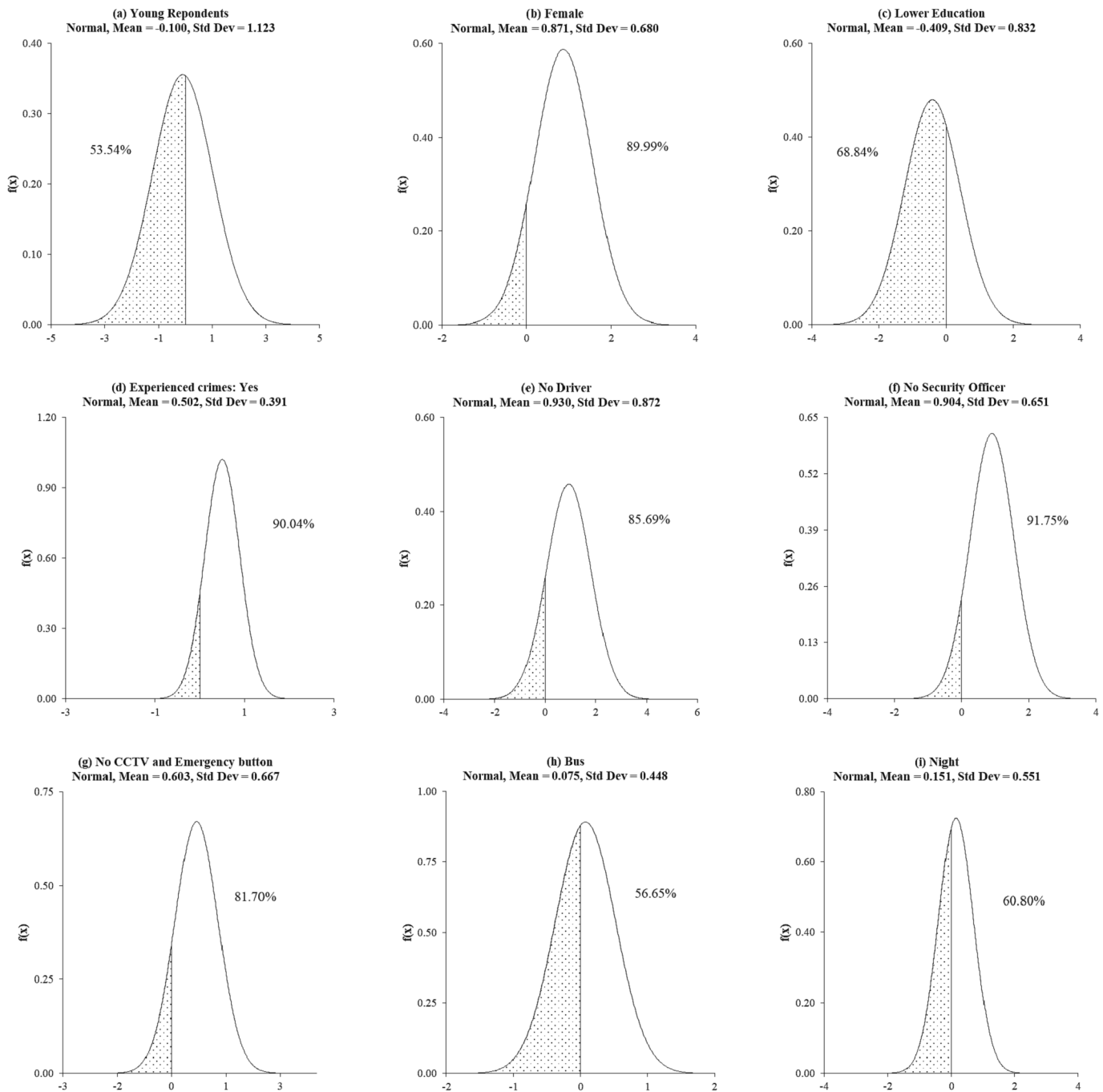


Fig. 3. Distributions of the random parameters for the unwillingness to use driverless public buses and ride-pooling services.

them from committing crimes (Roche-Cerasi, 2019).

Comparing users' perceived risk of victimization between driverless public buses and ride-pooling services, the study's findings revealed a higher perceived risk of victimization in public buses. This heightened perception is likely due to buses being typically congested, providing more opportunities for offenders to commit crimes. Also, public buses have fixed routes, which limit passengers' control over their journey, offering more opportunities for the perpetrators to commit crimes. In contrast, users who frequently use ride-pooling services reported a lower perceived risk of victimization. The regular use of ride-pooling services contributes to repeated exposure to services, resulting in increased satisfaction and confidence, reducing their perceived risk of becoming crime victims (Nguyen-Phuoc et al., 2020).

The present study also highlighted that respondent perceive a higher likelihood of being victims of crime while traveling at nighttime on driverless public buses and ride-pooling services. This perception aligns with the preference of offenders to commit crimes at nighttime (Ceccato and Loukaitou-Sideris, 2022). Finally, the study results indicate that users' have higher perceived risk of victimization during long distances travels. This might be because during long-distance travels, the difficulty in obtaining immediate help during a crime contributes to passengers perceiving themselves as more likely to be victims of crime, which can also lead to a heightened perception of the risk of victimization in driverless public buses and ride-pooling services.

5.3. Unwillingness to use

People's willingness to use driverless public buses and ride-pooling services is the most direct indicator of their acceptance of such modes of transportation. Thus, the present study explored the various factors affecting the users' willingness to use driverless public buses and ride-pooling services. In this context, the study's findings showed that found that young people are more willing to use driverless public buses and ride-pooling services. This may be because young people tend to live in urban life exposure to more information about driverless technology (Ceccato and Uittenbogaard, 2014).

The findings suggest that women are less willing to use driverless public buses and ride-pooling services. This conclusion aligns with existing literature indicating that women tend to have greater concerns about crime occurrence, which also limit their use of public transportation (Liu et al., 2019). The study's results indicated that users with lower levels of education exhibit less willingness to use driverless public buses and ride-pooling services. The findings could be attributed to the fact individuals with higher education are more familiar with the concept of driverless vehicles, and more inclined to embrace new ideas and technologies. (Reid and Andresen, 2012).

The present research results highlighted that in the absence of drivers and safety officers, users' express reluctance to use public buses and ride-pooling services. This might be because passengers often have the belief that the presence of a driver or security officer would assist them in avoiding or at least mitigating the harm caused by offenders. On the other hand, when they are not present, passengers have the impression that they are more likely to become victims of crime. This is also consistent with the findings presented in the above sections of the study. Also, passengers are less willing to use driverless public vehicles when they lack CCTV/emergency buttons, as the absence of these security measures instills a sense of insecurity among passengers (Navas et al., 2022).

The findings also indicated that people are more hesitant to use driverless public buses, which can be explained in light of the present study's findings regarding the users' reported higher perceived risk of crime occurrence and being a victim of crime in the driverless public buses. One the same note, the findings revealed that regular bus passengers are less willing to use driverless public buses. The current research concluded that users declared hesitance to use the aforementioned driverless modes at nighttime. This could be because crime tends to be more concentrated during nighttime, leading to heightened concerns about personal security (Haboucha et al., 2017). Consequently, people exhibit reluctance in using these services during the night. Finally, users exhibit reluctance to use driverless public buses and ride-pooling services for long-distances travels. This can be interpreted through the findings that longer-distance travel requires more time spent inside the vehicle, consequently increasing the likelihood of encountering crime events. As a results passengers are less are less inclined to choose driverless cars for longer trips (Winter et al., 2019).

5.4. Comparison of factors in the three models

As shown in Table 3, some variables are significant in all three models. It is worth noting that the gender is significant for models of crime occurrence, being a victim of crime, and unwillingness to use. Security measures related factors (i.e., driving automation, security officer, and CCTV / emergency buttons) have significant effects on all the three dependent variables. Travel characteristics (i.e., mode, time of day, and distance) demonstrate a consistent impact across the three models. Having observed a crime was not significant in models of victimization, but it is significant in models of crime occurrence and unwillingness to use.

On the other hand, the results showed that respondents from different regions of China differ in their perceived risk of crime occurrence. Those who infrequently use ride-pooling services have an

aggravated perceived risk of victimization, while those who frequently use public buses are more willing to use driverless buses and ride-pooling services. The results also indicated that high income has a significant effect only on the perceived risk of victimization, and the age group has a significant effect on the respondents' willingness to use driverless buses and ride-pooling services.

5.5. Limitations of the study

The questionnaire data used in the study might be biased to some extent because of the high proportion of young and highly educated people in the sample. Some efforts have been made to control them by adding age and education variables in the models, but the limitation still exists and might affect the result. At the time of the questionnaire collection, China still suffered the serious COVID-19 pandemic and people were required to report on nucleic acid tests to go to public places, so their travel is greatly restricted. Therefore, most of the questionnaires were collected online. As a result, young and highly educated respondents are overrepresented because the internet is less familiar to older people. Still, those in the sample frequently use public transportation, ride-hailing service, and taxi (over 60 %). Thus, it is still reasonable to anticipate that the respondents are likely to use driverless buses and ride-pooling in the future.

China is one of the leading countries with advanced autonomous driving technologies and is operating commercial driverless taxis in major cities. It is expected that results on security issues on driverless vehicles are dependent on the familiarity of driverless vehicles, maturity of related technologies, and security level of a country. Thus, it is necessary to conduct the similar research in countries with different features.

6. Policy implications

Acceptance is essential to overcome the users' resistance toward driverless vehicles to facilitate the technological advancement of driverless vehicles. In the future transportation system, users' security concerns might affect their trust in and acceptance of driverless vehicles, regardless of their benefits. When it comes to public buses and ride-pooling services, security concerns are more crucial as they are shared by other people. Therefore, this study investigates users' perceptions of driverless public buses and ride-pooling services in terms of security by investigating their perceived risk of crime occurrence, being a victim of crime, and unwillingness to use driverless public buses and ride-pooling services. The study's findings suggest the following strategies that manufacturers, authorities, and other policymakers can take proactively to enhance the users' trust in driverless public buses and ride-pooling services.

First, specific user groups, such as females, are found to be more concerned about the security of driverless public buses and ride-pooling services. Therefore, driverless public buses and ride-pooling service providers should give these user groups more attention in the design and operation stages of these services. For instance, developing appropriate marketing strategies to elevate the security risks of these user groups toward driverless vehicles is recommended. Also, measures such as establishing female-only buses or assigning female passengers to female co-passengers in online ride-pooling services can be adopted. Second, users with prior experience of observing criminal activity are found to have a higher perceived risk toward driverless vehicles. It is also worth noting that the opinions of these users may have a far-reaching influence on the perceived risk of their friends and family. Thus, the policymakers should target these users with an openness to experience the security of the driverless public buses and ride-pooling services to build their trust in these modes, which will have a significant downstream effect on other users' (their friends and family) usage intention of the aforementioned modes of driverless vehicles.

Third, in-vehicle safety features significantly impact passengers'

perceived risk in driverless public buses and ride-pooling services. In the event of a crime, users prefer self-protection, and it is vital that they are aware that the in-vehicle safety systems (CCTV / emergency buttons) are operational. Therefore, it is suggested that emergency buttons should be placed where passengers can easily access them in an emergency. Fourth, it was found that driverless buses raise the users' security risks, possibly due to the fact that they can accommodate a higher number of passengers. In addition, it has been shown that on buses, crimes are more frequently committed by fellow passengers; thus, it is suggested that driverless buses should be designed as small-capacity mini-buses to reduce the likelihood of passengers being exposed to offenders.

Fifth, long-distance travel also increases users' perceived crime risk in driverless public buses and ride-pooling services, making them less willing to travel in these modes. In addition, long-distance travel is one of the most critical user demands. In this regard, the police department can open a special police channel for victims who are encountering crime, provide them with emergency help and promptly record criminal activity (Victoria Police, 2022). This initiative can apply both to short and long-distance travel. Other measures like using artificial intelligence to communicate with passengers and giving them security reminders several times throughout the travel are also effective and easier to achieve (Wang et al., 2019).

Finally, the role of media is critical in building users' trust in the security of driverless vehicles. Thus, to increase acceptance of driverless vehicles, efforts should focus on broadcasting the benefits and usefulness of driverless vehicles and ensuring that measures taken to improve the security of driverless vehicles reach users' minds adequately. In addition, with the help of government and developer partnerships, information campaigns and marketing channels can be established to raise awareness of safety and security in driverless vehicles.

7. Conclusions

The perceived risk of security toward driverless public buses and ride-pooling services is an essential factor in the adoption and acceptance of these services. The present study conducted a scenarios-based questionnaire to explore individuals' perceived risk of crime occurrence, being a victim of crime, and unwillingness to use driverless vehicles. The descriptive statistics showed that individuals' perceived crime risks are higher in driverless vehicles than in human-driving vehicles. The results of the random parameters models revealed that females have a higher perception of risk in terms of crime. Also, respondents are more concerned about crime in buses and during nighttime. Moreover, factors such as region, travel time, income, education level, and safety measures all significantly affect the perceived crime risk.

There is a correlation between the perceived security and desirable security, and exploring the risk perception of driverless vehicles is beneficial to understanding the desirable level of security of driverless vehicles (Nees, 2019). As a result, we were able to gain a greater knowledge of how security driverless vehicles are considered to be and how security people expect them to be. Furthermore, researchers may discover new ways to improve personal security in driverless vehicles. Thus, the findings indicate that the security of driverless vehicles could be improved not just from an engineering point of view but also from a psychological point of view by investigating the users' interests.

The results of the present study should be interpreted with several limitations in mind. First, the scenarios used in the study assumed that the co-passengers were unfamiliar and male. This may exacerbate gender differences in the perceived risk of the survey participants, especially women. Second, the role of a safety officer was not defined adequately in the questionnaire. Given that their role might change in the near future concerning driverless public buses and ride-pooling services, security officers' influence should be investigated further.

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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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