Study on the Influencing Factors of Public Acceptance of Autonomous Vehicles in Chongqing Municipality

--Empirical analysis based on binomial logistic regression models

Xunyu Tao, Chenhao Lu, Shaoyicheng Zhu, Yushu Gao*

Army Logistics Academy, 20 Light, North Road, University City, Chong Qing, China 400000

* Corresponding author: gys568@qq.com

Abstract. elf-driving cars are an important part of the national development strategy and are formally proposed for development in the 13th Five-Year National Science and Technology Innovation Plan and the 13th Five-Year National Strategic Emerging Industries Development Plan. Exploring the public's willingness to accept self-driving cars will help drive the national plan forward. Chongqing, a "mountain city" with significant location, policy, consumption and market characteristics, is a "touchstone" for self-driving car testing and application, and a breakthrough to break the bottleneck in the self-driving car market. Therefore, this project takes the permanent residents of nine districts and counties in Chongqing Municipality as the survey object, takes the public acceptance willingness of self-driving cars and its influencing factors as the theme, and adopts the logistic regression model to study the influence of five variables, such as the perceived ease of use, the perceived usefulness, the perceived risk, the original trust, and the behavioural attitude, on the public acceptance willingness of the self-driving cars and their significant degree, and we find that the self-driving car's safety, usefulness, and manoeuvrability have a significant effect on the public acceptance willingness, safety causes general public concern, usefulness is the focus of public attention, and manoeuvrability affects the public's level of trust. Based on this, we can provide statistical data to automobile manufacturers and government departments, so that we can make targeted suggestions and countermeasures.

Keywords: autonomous driving; public acceptance willingness; logistic regression model

1 Introduction

Self-driving car is an intelligent car that realises unmanned driving through the computer system, as a product of the deep integration of the automobile industry and new generation information technology such as big data, it has become an important direction for the development of the current global automobile industry's intellectualisation and network connectivity. Self-driving cars not only have a revolutionary impact on road traffic, but are also a major breakthrough in the new era of human beings' expan-

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sion of free space, integration of things and integration of intelligence.[1] The car is a breakthrough in the new era.

Technological advances are bringing connected and self-driving cars (CAVs) into the evolving transport system, and exploring public acceptance and adoption of these technologies can help drive advances in self-driving technology[2] . Individual psychological and physiological attributes, socio-demographic attributes, ethical and legal responsibilities and level of vehicle safety, level of vehicle automation and related attributes, travel-related attributes, and environmental factors have been demonstrated to be the key categories of factors that influence the public's acceptance of automated vehicles·[3] . Currently, automated driving technology in China is still in the development stage, and studies have shown that Chinese users' attitudes towards automated driving are still positive.[4] The study also indicates that Chinese users' attitude towards autonomous driving is still positive.

However, different regions have different impacts on the development of self-driving cars due to differences in terrain, economy, population and other factors. Chongqing is surrounded by mountains and water, with many steep slopes, the special geographical conditions limit the use of bicycles, electric cars and other small vehicles, creating a huge market space for automotive products. Whether it is the main city roads or the surrounding districts and counties in Chongqing, the road conditions are more complex, the terrain is more typical, and the requirements for autonomous driving are more demanding. As a result, public acceptance of self-driving cars is somewhat typical and representative.

Based on this, this paper visits 640 permanent residents in 9 districts and counties of Chongqing Municipality, and based on the 637 questionnaires recovered, accurately portrays their demand characteristics and analyses the factors influencing the acceptance willingness of the consumer groups in Chongqing Municipality through the Logistic Regression Model, so as to provide traction for the development of the industry.

2 Data collection and sample generalisation

2.1 Overview of the study area

In October 2022, the General Office of the Chongqing Municipal People's Government issued the Chongqing Automatic Driving and Telematics Innovation and Application Action Plan (2022-2025), which specifies the main goals for the development of Chongqing's intelligent networked new energy vehicle industry cluster by 2025: to build a leading intelligent networked ecology in the country, and to create a basic platform to support the development of the industry as a High-quality prototype, the first in the country to carry out large-scale, multi-scene demonstration applications, vehicle, road and cloud integration of sensing, decision-making, control and other services in the demonstration area to achieve full coverage.

Chongqing Municipality is located in the transition zone between the Tibetan Plateau and the plains of the middle and lower reaches of the Yangtze River, and its attitude gradually decreases from the north and south ends towards the Yangtze River valley. The northern part of Chongqing stretches across the Daba Mountains, the eastern and southeastern parts of the city are distributed with the Wushan Mountains, the Seven Mountains and the Wuling Mountains, the southern part of the city is diagonally crossed by the Daloushan Mountains and other mountain ranges, the western part of the city is distributed with reddish square hills, the central part of the city mainly consists of parallel valleys with low mountains and hills spaced apart from each other, with an elevation difference of 2,723.3 metres, and the area of mountainous areas within the territory of Chongqing accounts for 76 per cent of the area, with 22 per cent of the area of hills, and river valleys and dams only account for 2 per cent[5] . Overall, the topography of Chongqing is characterised by many mountains, ridges and valleys, with the central and northwestern parts dominated by hills and low mountains, making it a typical mountainous city. Based on the reality of a mountainous city, Chongqing has developed a magical "mountain city traffic". The details are shown in Figures 1 and Figures 2.

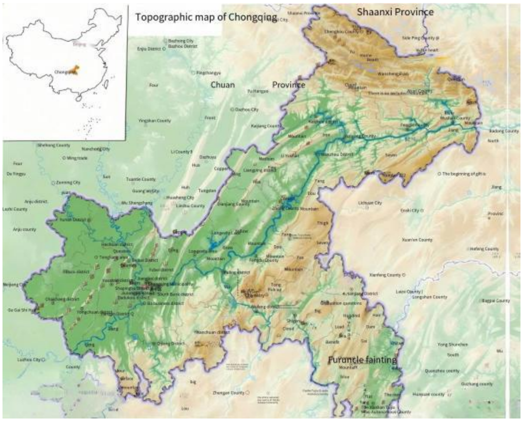

Fig. 1. Topographic map of Chongqing

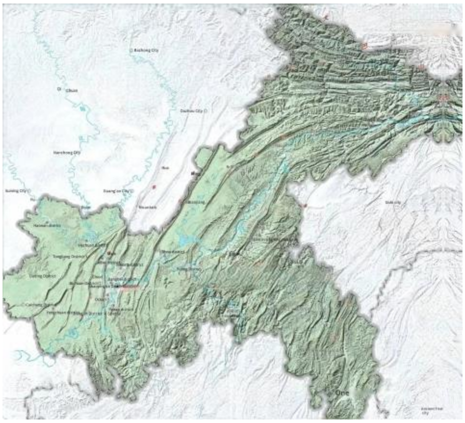

Fig. 2. Geomorphological map of Chongqing

The main city road network is intricate and complex, the traffic is three-dimensional, the main features are: ① the road is winding and sloping, vehicle detours, repeated starting situation; ② the city tunnels and bridges, traffic bottlenecks and jams, need to make decisions about how to deal with the nodes; ③ the road network of alternatives is poor, parallel diversion channel is less; ④ the road network of connectivity is poor, and some of the roads can not be interoperability. Characteristics of roads in the district and county include: ① narrow roads, poor accessibility; ② high and low ups and downs, high speed limit; ③ travelling alongside the mountains, steep and sharp curves, high driving danger.

2.2 Sample data collection

In this paper, we visited the permanent residents of nine districts and counties in Chongqing, including Shapingba District, Jiangbei District, Nanan District, Tongnan District, Rongchang District, Yongchuan District, Kaizhou District, Fengjie County, and Yunyang County. In terms of sampling method design, stratified sampling and three-stage unequal probability sampling were applied to tap the willingness of Chongqing residents to accept self-driving cars and their influencing factors.

First of all, according to the distribution of administrative districts in Chongqing, it is divided into three parts for sampling, the first part is "central city", the second part is "main city new area", the third part is "northeast Chongqing Three Gorges Reservoir Area Town Cluster" and "southeast Chongqing Wuling Mountain Town Cluster". The first part is divided into "central city", the second part is "main city new area", and the third part is "Three Gorges reservoir area town cluster in northeast Chongqing" and "Wuling Mountain town cluster in southeast Chongqing". Then, a three-stage unequal probability sampling method was applied. In the first stage, PPS sampling was used to select districts and counties in each stratum as the primary sampling unit; in the second stage, simple random sampling was used to select streets in districts and counties as the secondary sampling unit; and in the third stage, systematic sampling was used to select residents in streets as the basic sampling unit. A total of 675 questionnaires were distributed, and 650 questionnaires were recovered, with 637 valid questionnaires.

2.3 Generalisation of sample data

Based on the 637 questionnaires collected, the sample information data was collated as shown in Table 1.

Table 1. Informative data of the sample

information	sports event	frequency	Percentage/per cent
distinguishing between the sexes	male	236	37
	women	401	63
(a person's) age	18-25	389	61

	26-35	159	25
	36-55	76	12
	55-65	13	2
length of experience as a driver	no driving licence	194	30.5
	0-1 year	218	34.3
	2-5 years	168	26.3
	More than 6 years	57	8.9
academic qualifications	High school and below	70	11
	three-year college	70	11
	undergraduate (adjective)	376	59
	Master's degree or above	121	19
incomes	Less than \$3000	169	26.6
	3,000-5,000 yuan	152	23.9
	5000-7500	113	17.7
	\$7,500-\$10,000	73	11.4
	More than \$10,000	130	20.4

3 Research methodology and analysis of results

In this paper, using perceived ease of use, perceived usefulness, perceived risk, original trust, and behavioural attitudes as independent variables, and public acceptance willingness of self-driving cars in Chongqing Municipality as dependent variables, a binomial logistic regression model is used to study the influencing factors of acceptance willingness and their degree of significance.

3.1 Definition of independent variables

The meanings of the independent variables are described in Table 2:

Table 2. Observation table for independent variables

endogenous variable	observed variable	Meaning
PR Perceived risk	PR1	System security/equipment failure
	PR2	emergency response capacity
	PR3	Criteria for determining responsibility for traffic accidents
	PR4	Not as good a driver as a human.

endogenous variable	observed variable	Meaning
	PR5	Taking away my driving pleasure
PU perceived usefulness	PU1	Allow drivers to perform other tasks while travel-
	PU2	Can reduce traffic congestion and travelling time
	PU3	Reducing the likelihood of traffic accidents
	PU4	Reduce driving fatigue
	PU5	Reducing air pollution
PEOU Perceived ease of use	PEOU1	Mastering takeover behaviour in autonomous
	PEOU2	Reconnect in case of system problems or emergencies
	PEOU3	Reconnect in case of system problems or emergencies
IT original trust	IT1	Trust in self-driving cars recognised by govern-
	IT2	Trusting traditional automakers to produce
	IT3	The use of self-driving vehicles is considered to
ATT attitude	ATT1	Prospective expectations
	ATT2	What self-driving cars feel like
	ATT3	The acceptance of self-driving cars is
BI willingness to accept	BI1	Planning to ride in a self-driving car in the future
	BI2	Planning to buy a self-driving car in the future
	BI3	Referring family and friends to self-driving cars

3.2 Modelling

Since willingness to accept takes values of 0 and 1, logistic regression models can be built to investigate five endogenous variables: perceived ease of use (G_1), perceived usefulness (G_2), perceived risk (G_3), primitive trust (G_4), behavioural attitudes (G_5) and the effect between willingness to accept (Y).

Binomial logistic regression model is a classification model represented by a conditional probability distribution P(Y|X) in the form of a parametric logistic distribution. Here the random variable X takes the value of a real number and the random variable Y takes the value of 1 or 0. In this study, X is a set of random vectors, i.e., X=(G1, G2,G3,G4,G5)',Y is the willingness to accept. We developed a binomial logistic regression model as follows:

$$\ln\frac{p}{1-p} = \alpha + \beta_1 G_1 + \beta_2 G_2 + \beta_3 G_3 + \beta_4 G_4 + \beta_5 G_5 \quad (1)$$

where p represents the probability of accepting willingness Y = 1 and 1-p represents the probability of accepting willingness Y = 0.

3.3 Selection of models

The difference between the actual predicted output of the model and the true output of the samples is called the "error", the error of the model on the training set is called the "training error", and the error on the test set is called the "generalisation error". ". Obviously, we want to get the model with small generalisation error. Therefore, we use the 10-fold cross-validation method, which divides the sample into 10 mutually exclusive subsets of similar size, each of which maintains the consistency of the data distribution as much as possible, i.e., each subset is obtained from the sample through stratified sampling. Then, the concatenated set of 9 subsets is used as the training set each time, and the remaining one is used as the test set, so that 10 sets of training and test sets can be obtained, and thus 10 times of training and testing can be performed, and the final return is the mean of the results of these 10 tests, and the test results are shown in Table 3.

Table 3. -fold cross validation table

No. of groups	Mean value of test error	Generalisation error mean
1	0.1999	0.4000
2	0.3000	0.4582
3	0.0999	0.3000
4	0.0500	0.2179
5	0.6000	0.4898
6	0.0600	0.3285
7	0.1052	0.3068
8	0.0526	0.2232
9	0.7000	0.6659
10	0.0336	0.3282

We choose the group of models with the smallest mean of generalisation error, i.e. Group 4, as shown in Table 4.

Table 4. Summary of results of Logistic regression analysis

Item	regression coefficient	standard error	z-value	Wald χ 2	p-value	OR value	OR 95% CI
perceptual usefulness	1.434	0.682	2.102	4.419	0.036	4.196	1.102 ~ 15.982

Item	regression coefficient	standard error	z-value	Wald χ 2	p-value	OR value	OR 95% CI
perceptual exposures	-2.973	1.244	-2.390	5.712	0.017	-5.103	0.004 ~ 0.586
perceptual easy use	3.237	0.676	4.789	22.932	0.000	25.457	6.768 ~ 95.759
original (document etc) trust	1.848	0.682	2.709	7.337	0.007	6.347	1.667 ~ 24.167
behaviour posture	3.104	0.657	4.724	22.314	0.000	22.280	6.147 ~ 80.757
intercept (the point at which a line crosses the x- or y-axis)	9.173	3.526	-2.602	6.769	0.009	0.000	0.000 ~ 0.104

Dependent variable: willingness to accept McFadden R-square: 0.591

As can be seen from Table 4, all five independent variables passed the significance test, indicating that there is a significant linear relationship between acceptance and perceived usefulness, perceived risk, perceived ease of use, original trust, and behavioural attitude. Among them, the effects of perceived usefulness, perceived ease of use, primitive trust, and behavioural attitude on willingness to accept are positive, and the effects of perceived risk on willingness to accept are negative.

The model can be expressed as:

$$\ln\frac{p}{1-p} = 3.327G_1 + 1.434G_2 - 2.973G_3 + 1.848G_4 + 3.104G_5 + 9.173 \quad (2)$$

3.4 Evaluation of the model

There are many metrics to choose from to evaluate the performance of the model, and in this study, we chose to examine the prediction accuracy and AUC value of the model, as shown in Table 5.

Table 5. Logistic regression prediction accuracy

		projected value		Predictive accuracy	Prediction error rate
		0	1		
real value	0	98	32	75.38 per cent	24.62 per cent
	1	19	488	96.25 per cent	3.75 per cent
aggregation				91.99 per cent	8.01 per cent

Table 5 shows that the overall prediction accuracy of the model is 91.99 per cent and the model fit is acceptable. When the true value is 0, the prediction accuracy is 75.38%; when the true value is 1, the prediction accuracy is 96.25%. The ROC graph of the model is shown in Figure 3.

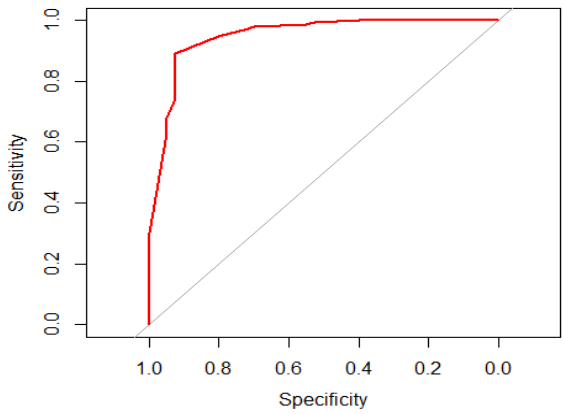

Fig. 3. ROC curve

The calculated AUC value was 0.9492, which is close to 1, indicating that the model fits well.

3.5 Analysis of the model

(1) Perceived usefulness

The perceived usefulness advantage ratio (OR value) is 4.196, meaning that for every 1 unit increase in perceived usefulness, the willingness to accept increases by 4.196 units. This is consistent with common sense that the function and usefulness of self-driving cars is always a public concern.

(2) Perceived risk

The Perceived Risk Advantage Ratio (OR value) is -5.103, which means that for every 1 unit increase in perceived risk, the willingness to accept decreases by 5.103 units. This indicates that the public generally believes that there is uncertainty and risk in the current self-driving cars, and the promotion of self-driving cars needs to further remove the risk hazards and improve their safety.

(3) Perceived ease of use

Perceived Ease of Use Advantage Ratio (OR value) is 25.457, which is the largest among the 5 variable advantage ratios. It means that for every 1 unit increase in perceived ease of use, the willingness to accept increases by 25.457 units. This suggests that the user scale of self-driving cars can be expanded exponentially by reducing the difficulty of operation. In order for self-driving cars to be widely promoted, it is extremely important to simplify the operation interface and lower the threshold of use, and only by making it easy for most people to operate can the degree of public acceptance be increased.

(4) Original trust

The raw trust advantage ratio (OR value) is 6.347, meaning that for every 1 unit increase in raw trust, the willingness to accept increases by 6.347 units. Compared to ordinary self-driving car manufacturers, manufacturers that have been recognised by the government or have a better reputation have a higher level of public trust and a stronger willingness to accept.

(5) Behavioural attitudes

Behavioural Attitude The dominance ratio (OR value) is 22.280, which is second only to perceived ease of use among the five variable dominance ratios. It means that for every 1 unit increase in behavioural attitude, the willingness to accept increases by 22.280 units. That is, the more positive and optimistic the public's attitude towards self-driving cars, the stronger the willingness to accept, which is also consistent with common sense. However, the change of behavioural attitudes cannot be achieved overnight, relying on the accumulation of word-of-mouth and habit penetration over a long period of time, which requires long-term investment and public opinion building by self-driving car manufacturers.

4 Conclusion

In this paper, the original data were collected through the method of questionnaire survey, and a binomial logistic regression model was established to further investigate the effects of five variables, namely, perceived ease of use, perceived usefulness, perceived risk, primitive trust, and behavioural attitudes, on the public acceptance willingness of self-driving cars and their degree of significance, which was analysed to obtain the following conclusions:

(1) The safety of self-driving cars has caused widespread public concern. Theoretically, self-driving cars can react faster than human drivers and can improve driving safety. However, at this stage, the development of self-driving technology is still immature, and there are uncertainties and risks in system safety and emergency response capabilities, which have caused widespread and high levels of public concern.

(2) The utility of self-driving cars is the focus of public attention. The public's perceived usefulness of self-driving cars has a great impact on their willingness to choose, as they attach more importance to whether self-driving cars can practically solve practical functions such as travelling difficulties, traffic accidents, and energy problems.

(3) The manoeuvrability of self-driving cars affects the level of public trust. In order to promote self-driving cars on a wide scale, it is extremely important to simplify the operation interface and lower the threshold of use, and only by making it easy for the majority of people to operate can the degree of public acceptance be increased. Enhancing the perceived ease of use and reducing the operating difficulty of self-driving cars will be a powerful means to increase public acceptance.

In general, the public generally expects the emergence of new technologies and is still positive and optimistic about the change of life by self-driving cars, but the change of behavioural attitudes cannot be achieved overnight, it is a product of long-term cultivation of the living environment and cultural atmosphere, and relies on a long period of word-of-mouth accumulation and habit infiltration, which requires self-driving cars to continuously carry out technological innovation and meet the needs of the public.

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