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Research Article

Urban Residents' Willingness to Choose and Pay for ADAS and Autonomous Driving Functions: Comparison of Two Cities in China

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ADAS and autonomous driving are booming. As technologies continue to innovate and mature, whether travelers understand, accept, and buy them will directly impact the technological development, popularization, and profitability of these products. This study analyzes the influence of urban residents' personal, family, and commuting characteristics on their willingness to choose and pay for ADAS and autonomous driving functions. Using the questionnaire survey data for Jiading and Meishan in China, Logit models are established for willingness to choose, and linear regression models are established for willingness to pay. Although Jiading and Meishan are similar in terms of city size and population, there are some differences in the influencing factors for willingness to choose and pay because of the differences in industrial structure, city culture, and residents' commuting habits. The results show that significant influencing factors vary for different levels of ADAS and autonomous driving functions. The findings of this research can provide a reference for city authorities, designers, and sellers of ADAS products or autonomous vehicles to identify potential buyers and promote related products.

1. Introduction

Advanced driver assistance system (ADAS) and autonomous driving technologies are constantly evolving. ADAS uses various sensors, such as cameras, radar, and GPS, to perceive the surroundings of vehicles, help drivers to detect potential dangers, with a potential to decrease reaction times, and improve safety through early warning and partial automatic control [1]. Autonomous driving technologies allow vehicles the capability of sensing their environment and moving safely with little or no human input [2].

The relationship between the two can be understood as different technical stages of vehicle driving automation system that achieve similar goals, that is, to reduce human driving and improve the safety and efficiency of automatic vehicle driving. ADAS is regarded as the primary stage and necessary prerequisite for autonomous driving. Society of Automotive Engineers (SAE) described vehicle driving automation systems that perform part or all of the dynamic driving task (DDT) on a sustained basis, providing a taxonomy with detailed definitions for six levels of driving automation. It ranges from no driving automation (level 0) to full driving automation (level 5) [2]. It can be considered that ADAS is included in levels 1 and 2, defined as driving mode-specific execution by one or more driver assistance systems of either (or both) steering and (or) acceleration/deceleration, while autonomous driving corresponds to levels 3–5, which means performance by an automated driving system respond to roadway and environmental conditions appropriately. From level 3 to level 5, the necessity for humans to take over driving gradually decreases.

ADAS and autonomous driving functions have played an increasingly important role in improving safe driving, reducing accident rates, and improving driver comfort. Like any emerging technology, ADAS and autonomous driving technologies will have to go through a long process for people to understand, evaluate, and adopt them [3].

There are three critical issues related to people's choice of ADAS and autonomous driving functions. First is the actual effectiveness of ADAS and autonomous driving functions. A research found that several people believe that autonomous vehicles are not as easy to use, useful, and credible as human driving vehicles [4]. Moreover, even if the same function is used by people with different characteristics, for example, different personalities and levels of driving operation, the actual effect will be different [5]. By comparing safety indicators, efficiency indicators, or driver psychological changes before and after the use of ADAS and autonomous driving functions, their effect can be evaluated [6, 7].

The second is that people can understand ADAS and autonomous driving for each function. People of different ages, genders, and personalities will have different interests in ADAS and autonomous driving, which will affect their choice of knowledge sources and their understanding [8, 9]. Simultaneously, drivers' understanding of ADAS and autonomous driving functions is not static [8]. It is affected by multiple factors, such as the advertisements they have seen as well as their initial judgment and acceptance [9]. After personally trying and using ADAS functions for a relatively long time, their willingness will gradually reflect the actual performance of ADAS [10]. Therefore, from this point of view, product designers have the responsibility to learn about users' demands, driving habits, and psychological characteristics and help in better understanding them [11]. Moreover, it is necessary for the drivers to understand these new functions as much as possible, especially if their vehicles are equipped with such functions [12].

The third issue related to people's choice after fully understanding these ADAS and autonomous driving functions is whether they highly value these functions and are willing to pay for their use. People's willingness to use and willingness to pay directly impact the promotion of ADAS and autonomous driving. If people are unwilling to use them or spend money, the development of these two new technologies will lose momentum. Therefore, identifying people who are willing to use them and promoting their popularity are an important issue. The structural equation model was used to study the attractiveness of different levels of autonomous vehicles to people [4]. Another research focused on the willingness of certain populations, such as teenagers and elders to accept ADAS [13, 14].

In terms of data sources, measured vehicle trajectory [15, 16], driving simulators [17, 18], traffic accident reports [19–21], and questionnaires are the most commonly used data acquisition methods. Questionnaire survey is especially helpful in understanding a driver's knowledge about ADAS or autonomous driving functions and their true feelings and attitudes [22, 27, 28].

Although there has been extensive research on how drivers understand and evaluate ADAS or autonomous driving functions [19], we are more concerned about, after learning that these functions are indeed effective in assisting human driving, whether people are willing to adopt and spend money on them. This research focuses on whether people are willing to buy these products, how much they are willing to pay, and what factors influence their willingness, by using questionnaire data from two cities. It should be noted that we did not conduct research based on the standard SAE taxonomy. To make it easier for respondents to understand the meaning of autonomous driving, we simplified the SAE taxonomy. We omitted level 0 and merged level 3 and level 4. Therefore, only four levels, levels 1–4, are used to classify autonomous driving in this study.

The remainder of this paper is organized as follows. The next section introduces the questionnaire data and conducts descriptive statistical analysis. Section 3 builds models to evaluate the influencing factors. Section 4 analyzes the results of the linear regression models and Logit models and attempts to explain the underlying reasons. Finally, conclusions and recommendations are given in the last section.

2. Data

2.1. Case Cities: Jiading and Meishan. Considering the comparability between cities and availability of data, Jiading and Meishan were selected as case cities for this research. The two cities are similar in terms of city size and population, but there are clear differences in industrial structure, economic status, and residents' travel habits.

Jiading (district) is located in Shanghai, a municipality directly under the Chinese Central Government, and Meishan (city) is located in the province Sichuan. Both Shanghai and Sichuan are province-level regions, and Jiading and Meishan are prefecture-level regions. Figure 1 shows the location of Jiading and Meishan.

Jiading is in the northwest of Shanghai, where the under-construction Shanghai International Automobile City is located. Thus, a large number of automobile manufacturing and service industries are concentrated in the region. The automobile industry accounts for 65.9% of the gross industrial output of Jiading. It is also a national autonomous driving test area and one of the cities with the strongest automobile culture in China. Jiading, which is only 27 km from the main urban area of Shanghai, is closely connected to it, with a large number of commuters between them. Its core area is approximately 464 km^2, and the urban population is approximately 1.55 million.

Meishan, the capital of Sichuan, is in the southwest of Sichuan Province and is only 60 kilometers away from Chengdu, one of the ten largest cities in China. Similar to the relationship between Jiading and Shanghai main urban area, Meishan and Chengdu are also closely connected. They jointly established a national-level new area, Tianfu New Area. Currently, agricultural production and food processing are the largest industries in Meishan. The core area of

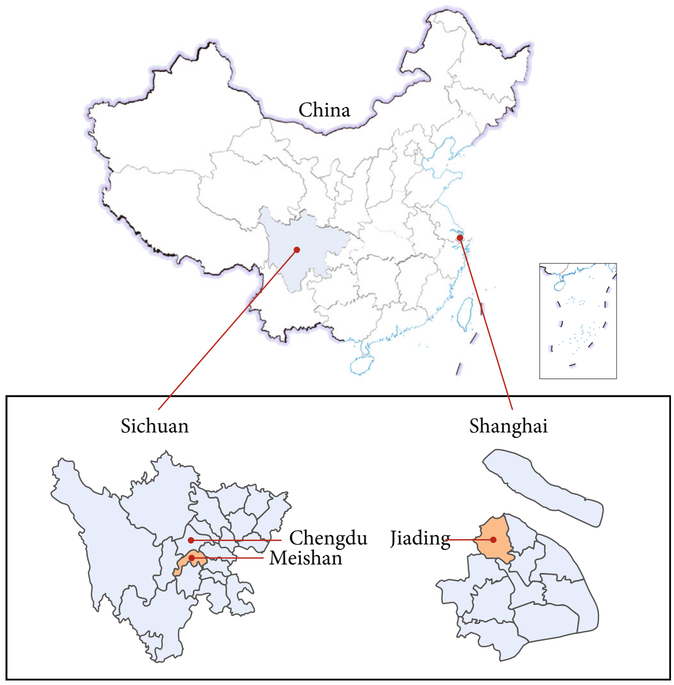

Figure 1: Location of Jiading and Meishan in China.

Meishan is approximately 386 km^2, and the urban population is 1.43 million.

Jiading and Meishan are significantly similar in terms of area, population, and relationship with neighboring metropolises (or main urban areas), which makes them comparable for this research. Moreover, their differences in industrial structure, city culture, and residents' commuting habits allow us to explore the potential differences in their attitudes towards ADAS and autonomous driving.

2.2. Data Preparation. The data was collected using a questionnaire survey conducted in Jiading, Shanghai, in June 2020, and Meishan, Sichuan, in September 2020. It was conducted online with the assistance of the local traffic management departments. The URL link of the questionnaire was posted on the official social media accounts of the traffic management departments so that any resident could fill it out. The access was restricted according to the IP address, so it could be ensured that all the respondents were locals. Before the formal survey, several rounds of test surveys were conducted to improve the questionnaire structure and design.

The questionnaire consisted of four parts. The first part was about commuting characteristics. Respondents were asked about commuting mode and commuting time. The second part was about family characteristics, where respondents were asked information about their family, including the number of vehicles, e-bikes, and bikes owned, as well as the types of vehicles owned. In the third part, personal characteristics including gender, age, education level, and wage were collected. We also enquired about respondents' most valued factors in travel, understanding of ADAS and autonomous driving functions, and the next vehicle they were willing to buy. The last part was about willingness, including willingness to choose and willingness to pay for ADAS and autonomous driving functions. We present the core part of our questionnaire in the appendix.

After verifying the quality of the respondents' responses to the questionnaire, we finally got 405 valid responses in Meishan, with each respondent answering each question. In Jiading, 316 valid questionnaires were obtained; among them, some respondents did not answer the last question about willingness to pay. It has been suggested that when discrete choice modeling is performed based on actual survey data, stable coefficient estimates can be obtained when the sample size reaches 300-500 [20], and it has also been suggested that the sample size can be relaxed to between 280 and 350 [21]. Accordingly, the sample in this study is sufficient to support the statistical modeling analysis.

2.3. Descriptive Analysis

2.3.1. Commuting Characteristics. We asked respondents about their primary commuting mode and the average time spent on a single commute. Table 1 shows the commuting mode characteristic, and Figure 2 shows the distribution of commuting time.

We conducted the Mann–Whitney U test (MWU test), and the results are shown in the table. They represent the difference between the two cities for a particular indicator. "True" means a significant difference (95% confidence interval). As shown, the results of the MWU test for both commuting mode and time are "True."

The distribution of commuting time between the two places shows obvious differences. Meishan is a small city, and most citizens work in the city. Jiading is a district of

Table 1: Commuting mode characteristic of the sample in the two cities.

Indicator	City Sample size Category	MWU test result	Meishan N = 405 Individuals	%	Jiading N = 316 Individuals	%
Commute mode [1]	Car	True	327	80.74%	207	65.51%
	Taxi	True	33	8.15%	43	13.61%
	Public transit	True	45	11.11%	181	57.28%
	Bike	True	98	24.20%	100	31.65%

[1]Respondents can select one or more answers.

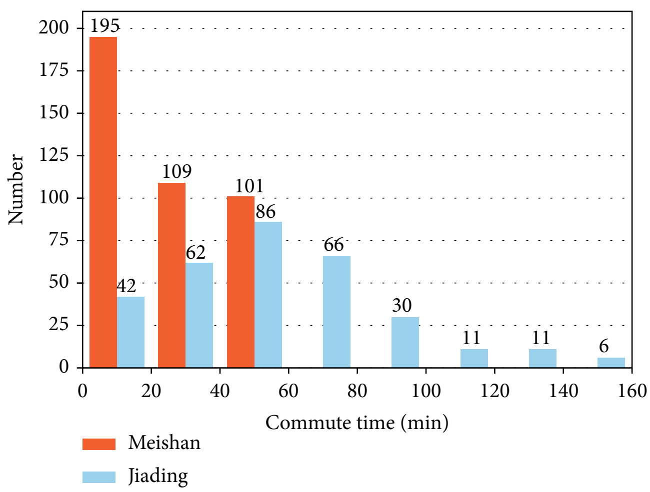

Figure 2: Distribution of commuting time of the sample in the two cities.

Shanghai, China's largest city, about 20 kilometers away from the center of Shanghai. Few citizens spend even 2–3 hours a day for commuting, which results in a relatively long average commuting time.

2.3.2. Family Characteristics. Family characteristics include the number of vehicles, e-bikes, and bikes owned by the household, as well as the type of vehicles owned by the household (petrol or electric, and whether ADAS or autonomous driving functions are available), as shown in Tables 2 and 3, respectively.

The number of households owning vehicles, e-bikes, and bikes in Meishan is generally higher than in Jiading. However, Jiading has a more significant percentage of households with electric cars, which is one of the positive results of being an international automobile city.

2.3.3. Personal Characteristics. Personal characteristics, as shown in Table 4, include gender, age, level of education, and wage. Moreover, it includes what they value most about travel, such as efficiency, convenience, reliability, comfort, economy, or environment. We asked whether they are aware of newer technologies, such as autonomous vehicle, shared travel, electric vehicle, and intelligent connected vehicle. We also asked about the type of vehicle they would like to purchase in the future (petrol, electric, or none of them).

In terms of the level of education and wage, Jiading has a higher average. It is also more obvious in Jiading in terms of the valuation of various factors about travel, familiarity with new technologies, and interest in purchasing new energy vehicles.

From the distribution of some factors of personal characteristics, we can also analyze the representativeness of the data for the commuting population in Meishan and Shanghai. Looking at the 2020 statistics for Meishan, the population aged 15-59 accounts for 61.26% of the city's resident population. In our sample, since our survey respondents are mainly workers, the number should be and is higher than that. According to the "Shanghai Youth Employment Status Report" released by the Shanghai Human Resources and Social Security Bureau in 2019, it shows that youths aged 16-35 account for about 48.7% of all workers. In terms of the average wage, Meishan announced an average wage of 5,572 yuan/month for urban employed people in 2020, while in Shanghai was 10,338 yuan/month. Our sample reflects the two numbers as 6,163 yuan and 10,845 yuan, respectively. Therefore, our sample is relatively consistent with the working age structure and the average wage in Meishan and Shanghai.

2.3.4. Willingness Characteristics. We asked respondents in the two cities if they would be willing to adopt several ADAS and autonomous driving functions, namely safety-related functions (such as identifying objects on the road and preventing collisions), economy-related functions (such as networking with traffic lights to smoothly pass intersections and reduce fuel costs), and convenience-related functions (such as assisting and reducing the burden of driving). Table 5 and Figure 3 show the willingness to choose ADAS and autonomous driving functions.

Respondents' interest in economy and convenience is more obvious, but the two cities show a slight difference. Although only 29.4% of Jiading respondents are willing to choose safety-related functions, it is still 10.4% higher than Meishan (19.0%). In contrast, about half of Jiading respondents (47.5% and 49.7%) are interested in economy-related and convenience-related functions, which is lower than Meishan (62.2% and 63.5%). This may indicate that people in different cities have different preferences for different ADAS and autonomous driving functions, and the willingness for them may not rise and fall simultaneously.

Moreover, we asked about the money (Chinese yuan) they are willing to pay for different levels of ADAS and autonomous driving functions: level 1 (driver assistance), level 2 (partial automation), level 3 (highly automation), and level 4 (fully automation). We will introduce the detailed definitions of different levels in the next section.

Table 2: Type of vehicle owned characteristic of the sample in the two cities.

Indicator	City / Sample size / Category	MWU test result	Meishan $N = 405$ Individuals	Meishan %	Jiading $N = 316$ Individuals	Jiading %
Type of vehicle owned [1]	No vehicle	True	26	6.42%	35	11.08%
	Petrol vehicle (normal)	True	218	53.83%	155	49.05%
	Petrol vehicle with ADAS	False	169	41.73%	117	37.03%
	Electric vehicle (normal)	False	21	5.19%	19	6.01%
	Electric vehicle with ADAS	True	13	3.21%	24	7.59%
	Electric vehicle with automation	False	6	1.48%	6	1.90%

[1]Respondents can select one or more answers.

Table 3: Number of vehicles, e-bikes, and bikes owned characteristics of the sample in the two cities.

City / Sample size / Indicator	MWU test result	Meishan $N = 405$ Mean	Std.	Min	Max	Jiading $N = 316$ Mean	Std.	Min	Max
Number of vehicles owned	True	2.33	0.65	1.00	5.00	1.28	0.73	0.00	4.00
Number of e-bikes owned	True	1.93	0.80	1.00	6.00	0.87	0.94	0.00	5.00
Number of bikes owned	True	1.49	0.73	1.00	6.00	0.81	0.88	0.00	4.00

Table 6 and Figure 4 show the willingness to pay for different levels of ADAS and autonomous driving functions.

The difference between the two cities is evident. In Meishan, most respondents are only willing to pay less than 30,000 yuan for ADAS and autonomous driving functions, whereas in Jiading, relatively more respondents are willing to pay 30,000 to 50,000 yuan. Especially for level 4, Jiading respondents are even more willing to pay 40,000–50,000 yuan than those who are willing to pay 30,000–40,000 yuan. Therefore, people's willingness to pay in Jiading is on an average 54.99% higher than in Meishan.

Although people in Jiading are not as willing to pay for level 1 as in Meishan, their willingness to pay for levels 2–4 significantly exceeds Meishan. This may be related to the differences in income and enthusiasm for new technologies between cities.

3. Methodology

To find the influence of personal, family, and commuting characteristics on willingness to choose and willingness to pay, binomial Logit models and multiple linear regression models are established.

In the binomial Logit model, the choice probability for alternative i for person n is shown in Equations (1) and (2). The multiple linear regression model describes how the dependent variable y depends on the independent variables and the error term ε. Its general form can be expressed as Equation (3).

$$P_n(i) = \frac{e^{V_{\text{in}}}}{e^{V_{\text{in}}} + e^{V_{jn}}}, \tag{1}$$

$$V_{\text{in}} = \beta_1 X_{\text{in}1} + \beta_2 X_{\text{in}2} + \cdots + \beta_K X_{inK} = \beta' \mathbf{X}_{\text{in}}, \tag{2}$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon. \tag{3}$$

In Equations (1) and (2), V_{in} is the observed utility that person n obtains from alternative i; similarly, V_{jn} is the observed utility that person n obtains from alternative j. Each observed utility V_{in} is a function of a vector of independent observable variables $\mathbf{X}_{\text{in}}$, which include personal, family, and commuting characteristics in this research. β_0, $\beta_1, \beta_2, \cdots, \beta_K, \beta'$ are the parameters of the binomial Logit model. In Equation (3), $\beta_0, \beta_1, \beta_2, \cdots, \beta_k$ are the parameters of the multiple linear regression model, and ε is the random error term.

Because the variable representing the willingness to choose obtained from the questionnaire survey is a 0-1 variable, and the variable representing the willingness to pay is a continuous variable, binomial Logit models are established for willingness to choose, and multiple linear regression models are established for willingness to pay.

4. Results

In the last part of the questionnaire, respondents were asked the following question: what kind of ADAS or autonomous driving functions do they think are helpful and willing to pay for them? Respondents could select one or more answers from the following three options:

(i) Safety-related functions (such as identifying objects on the road and preventing collisions)

(ii) Economy-related functions (such as networking with traffic lights to smoothly pass intersections and reduce fuel costs)

(iii) Convenience-related functions (such as assisting and reducing the burden of driving)

Table 4: Personal characteristics of the sample in the two cities.

Indicator	City Sample size Category	Mann–Whitney U test	Meishan $N = 405$ Individuals	%	Jiading $N = 316$ Individuals	%
Gender	Male	True	302	74.57%	199	62.97%
	Female	True	103	25.43%	117	37.03%
Age (years old)	<20	True	5	1.23%	4	1.27%
	20–29	True	120	29.63%	63	19.94%
	30–39	True	161	39.75%	139	43.99%
	40–49	True	91	22.47%	77	24.37%
	50–59	True	28	6.91%	28	8.86%
	>60	True	0	0.00%	5	1.58%
Level of education	Junior high school or below	True	11	2.72%	3	0.95%
	High school	True	92	22.72%	34	10.76%
	Undergraduate	True	275	67.90%	216	68.35%
	Postgraduate	True	22	5.43%	58	18.35%
	PhD or above	True	5	1.23%	5	1.58%
Wage (yuan)	<5000	True	174	42.96%	39	12.34%
	5000-10000	True	169	41.73%	119	37.66%
	10001-15000	True	28	6.91%	70	22.15%
	15001-20000	True	17	4.20%	28	8.86%
	>20000	True	17	4.20%	60	18.99%
Factors considered valuable in travel [1]	Efficiency	True	258	63.70%	225	71.20%
	Convenience	True	219	54.07%	221	69.94%
	Reliability	True	51	12.59%	145	45.89%
	Comfort	True	83	20.49%	134	42.41%
	Economy	True	25	6.17%	67	21.20%
	Environment	True	23	5.68%	68	21.52%
Awareness about new technologies [2]	Autonomous vehicle	True	52	12.84%	235	74.37%
	Shared travel	True	54	13.33%	122	38.61%
	Electric vehicle	True	39	9.63%	112	35.44%
	Intelligent connected vehicle	True	43	10.62%	165	52.22%
Next vehicle willing to buy	No	True	96	23.70%	21	6.65%
	Petrol vehicle	True	104	25.68%	103	32.60%
	Electric vehicle	False	205	50.62%	192	60.76%

[1]Respondents can select one or more answers. [2]Respondents can select one or more answers or none of them.

Table 5: Willingness to choose different ADAS or autonomous driving functions.

Indicator	City Sample size Category	MWU test result	Meishan $N = 405$ Individuals	%	Jiading $N = 316$ Individuals	%
Willingness to choose [1]	Safety-related functions	False	328	80.99%	223	70.57%
	Economy-related functions	True	153	37.78%	166	52.53%
	Convenience-related functions	True	148	36.54%	159	50.32%

[1]Respondents can select one or more answers.

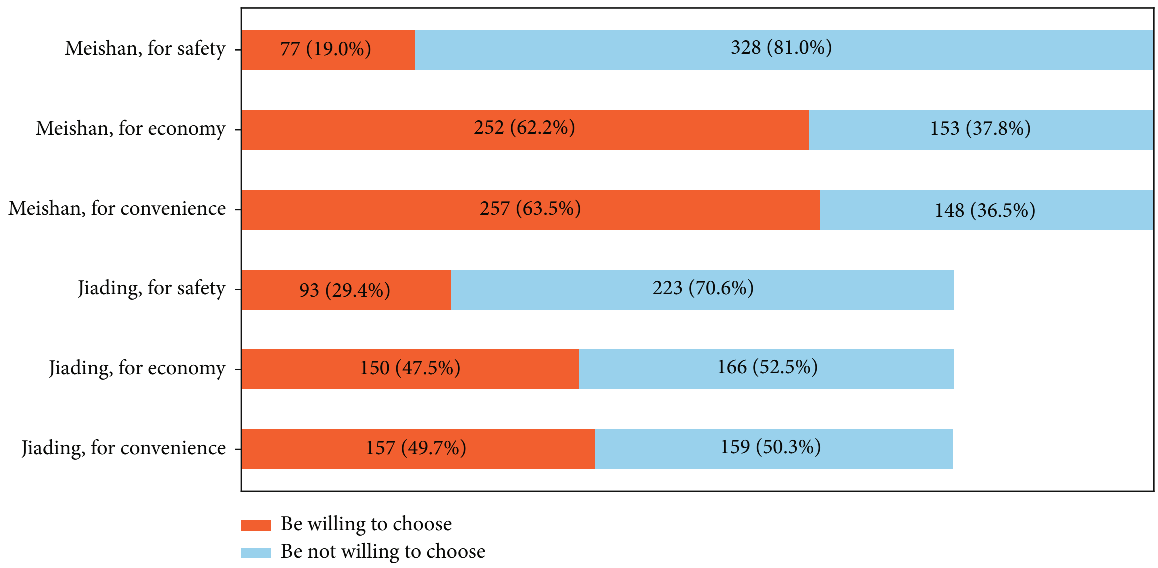

Figure 3: Willingness to choose different ADAS or autonomous driving functions.

Table 6: Willingness to pay for different levels of ADAS or autonomous driving functions.

City		Meishan				Jiading			
Sample size		$N = 405$				$N = 230$ [1]			
Indicator	MWU test result	Mean	Std.	Min	Max	Mean	Std.	Min	Max
Willing to pay for L1 functions	True	3248.60	4968.05	2000.00	50000.00	3097.56	5305.09	2000.00	30000.00
Willing to pay for L2 functions	True	3483.12	4270.79	2000.00	50000.00	4711.54	7212.36	2000.00	50000.00
Willing to pay for L3 functions	True	5164.83	6376.55	2000.00	50000.00	8332.02	11194.73	2000.00	50000.00
Willing to pay for L4 functions	True	7509.81	10468.30	2000.00	50000.00	13935.71	17702.70	2000.00	50000.00

[1] In Jiading, 316 valid responses were obtained, but only 230 respondents answered the last question about willingness to pay.

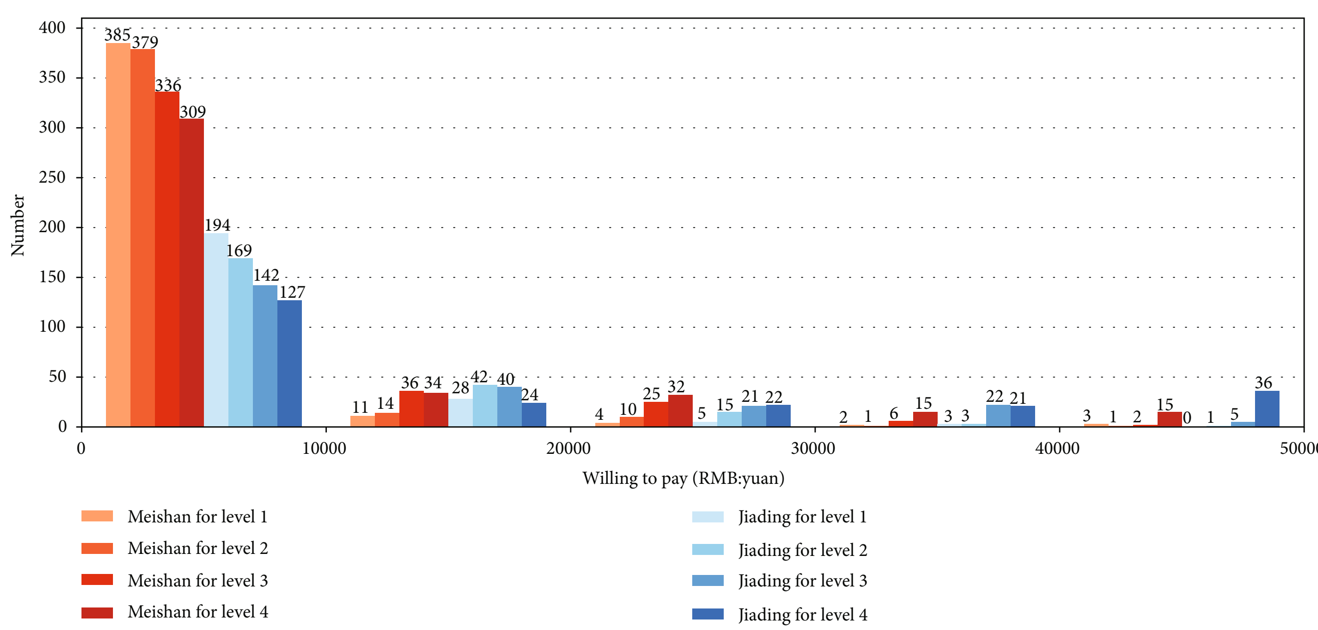

Figure 4: Willingness to pay for different levels of ADAS or autonomous driving functions.

Table 7: Logit model for willingness to choose different ADAS or autonomous driving functions.

City	Meishan				Jiading			
	Indicator with significant	Estimate	Std. E	*P*	Indicator with significant	Estimate	Std. E	*P*
	(Intercept)	1.2173	0.4195	0.00371**	(Intercept)	2.3755	0.9877	0.01617*
	Commuting characteristics				Family characteristics			
	Commute mode				Type of vehicle owned			
	Taxi	-1.1032	0.4329	0.01082*	Electric vehicle	2.1724	1.0712	0.04256*
	Family characteristics				Personal characteristics			
	Number of e-bikes owned	-0.3354	0.1636	0.04034*	Age	-0.4288	0.1452	0.00314**
Willing to choose safety-related functions	Personal characteristics				Awareness of new technologies of			
	Factors considered valuable in travel				Autonomous vehicle	0.7053	0.301	0.01911*
	Efficiency	0.5677	0.2777	0.04094*	Next vehicle willing to buy (base case: no)			
	Next vehicle willing to buy (base case: no)				Electric vehicle	0.8008	0.3012	0.00784**
	Petrol vehicle	0.8904	0.4023	0.02687*				
	Electric vehicle	0.893	0.3406	0.00874**				
	(Intercept)	-1.7205	0.5675	0.00243**	(Intercept)	0.6715	0.6262	0.28359
	Family characteristics				Personal characteristics			
	Type of vehicle owned				Gender (base case: male)	-0.6796	0.251	0.00678**
	Petrol vehicle	0.6615	0.2273	0.00361**	Age	-0.2905	0.1298	0.02522*
Willing to choose economy-related functions	Personal characteristics				Awareness of new technologies			
	Age	-0.2558	0.1232	0.0379*	Autonomous vehicle	0.8107	0.2803	0.00382**
	Wage	0.2689	0.1097	0.01424*	Electric vehicle	0.5577	0.2587	0.03108*
	Factors considered valuable in travel				Next vehicle willing to buy (base case: no)			
	Reliability	0.8162	0.3174	0.01012*	Electric vehicle	0.5204	0.2479	0.03579*
	(Intercept)	-1.398413	0.5129	0.0064**	(Intercept)	-0.267	0.2833	0.345851
	Personal characteristics				Commuting characteristics			
	Factors considered valuable in travel				Commute mode			
Willing to choose convenience-related functions	Efficiency	0.568549	0.246792	0.02124*	Taxi	1.008	0.3775	0.007585**
	Economy	1.206847	0.463733	0.00926**	Bike	0.7504	0.2778	0.006906**
	Next vehicle willing to buy (base case: no)				Next vehicle willing to buy (base case: no)			
	Electric vehicle	1.204794	0.239356	$4.8E-07$***	Electric vehicle	0.9131	0.2512	0.000278***

Table 8: Linear model for willingness to pay for different levels of ADAS or autonomous driving functions.

City	Meishan				Jiading			
	Indicator with significant	Estimate	Std. E	*P*	Indicator with significant	Estimate	Std. E	*P*
Willing to pay for L1 functions	(Intercept)	4211.3	877.4	2.25E-06***	(Intercept)	3475.9	2735.8	0.2053
	Commuting characteristics				Personal characteristics			
	Commute mode				Age	-763.7	368.9	0.0396*
	Car	-1316.6	641.7	0.0409*	Factors considered valuable in travel			
	Taxi	2840.9	888.5	0.0015**	Efficiency	-1841.5	818.1	0.0254*
	Public transit	-1927.3	840	0.0223*	Convenience	1649.3	775.6	0.0346*
	Personal characteristics				Economy	1977.5	891.5	0.0276*
	Factors considered valuable in travel							
	Comfort	1286.8	631.8	0.0423*				
Willing to pay for L2 functions	(Intercept)	2779.5	946	0.003495**	(Intercept)	11930.1	2301.4	$4.86E-07^{***}$
	Commuting characteristics				Family characteristics			
	Commute mode				Number of vehicles owned	1371.1	682.4	0.0457*
	Car	-1712.1	566.1	0.002651**	Personal characteristics			
	Taxi	2831	755.7	0.000206***	Gender (base case: male)	-2219	991.1	0.0261*
	Public transit	-1359.5	685.3	0.047965*	Age	-1071.2	520.4	0.0407*
					Factors considered valuable in travel			
					Efficiency	-2238.6	1041.7	0.0327*
Willing to pay for L3 functions	(Intercept)	3178.8	1885.3	0.09257.	(Intercept)	21074.4	3999	$3.22E-07^{***}$
	Family characteristics				Personal characteristics			
	Number of bikes owned	911.2	425.5	0.03285*	Gender (base case: male)	-4829.5	1495.5	0.00143**
	Personal characteristics				Age	-3200.3	774.7	$5.11E-05^{***}$
	Age	-1064.9	341.2	0.00193**	Next vehicle willing to buy (base case: no)			
	Level of education completed	1251.7	491.8	0.0113*	Electric vehicle	3689.3	1499.4	0.01463*
	Awareness of new technologies of							
	Shared travel	-2042.2	981.8	0.03817*				
	Next vehicle willing to buy (base case: no)							
	Electric vehicle	1508.3	667.2	0.02433*				
Willing to pay for L4 functions	(Intercept)	778.4	3060.2	0.799344	(Intercept)	31599.3	6268.2	$9.69E-07^{***}$
	Commuting characteristics				Family characteristics			
	Commute mode				Number of e-bikes owned	-2737.4	1165.7	0.019747*
	Taxi	4473.1	1860.8	0.016681*	Personal characteristics			
	Personal characteristics				Gender (base case: male)	-7807.7	2261	0.000665***
	Age	-1155.3	556	0.038348*	Age	-4994.2	1180.4	$3.42E-05^{***}$
	Level of education	2167.4	807.8	0.007597**	Wage	2218.5	896.2	0.014062*

Table 8: Continued.

City	Meishan				Jiading			
	Indicator with significant	Estimate	Std. E	*P*	Indicator with significant	Estimate	Std. E	*P*
	Next vehicle willing to buy (base case: no)				Next vehicle willing to buy (base case: no)			
	Electric vehicle	4428.7	1133.2	0.000109***	Electric vehicle	6860.6	2309.3	0.003301**

Based on the answers collected from Jiading and Meishan, Logit models for willingness to choose different ADAS or autonomous driving functions were established. Table 7 shows the results of the Logit models.

Respondents were also asked how much they were willing to pay for different levels of ADAS or autonomous driving functions. After reading the following descriptions of the different levels (from levels 1 to 4), the respondents were asked to give four amounts representing their willingness to pay, ranging from 2,000 RMB to 50,000 RMB.

(i) Level 1 (driver assistance): at this level, the vehicle can provide some driving assistance functions, but the driver can still handle acceleration and braking and still have to pay attention to the surrounding environment. Imagine that when getting too close to another vehicle on the highway, your vehicle will automatically brake

(ii) Level 2 (partial automation): at this level, the vehicle itself can perform all monitoring of the environment and can assist with steering or acceleration. Only a small part of the operation requires the driver to perform

(iii) Level 3 (highly automation): at this level, the vehicle can steer, brake, accelerate, monitor surrounding vehicles and roads, respond to events, determine when to change lanes, turn, and use signals. But the system will first notify the driver when conditions are safe, and then the driver can switch the vehicle to this mode

(iv) Level 4 (fully automation): at this level, autonomous driving does not require any human involvement, with no need to step on the accelerator, brake, or hold the steering wheel. The autonomous driving system controls all key tasks, monitors the environment, and recognizes various driving conditions, such as traffic jams

Based on the answers collected from Jiading and Meishan, linear models for willingness to pay for different levels of ADAS or autonomous driving functions were established. Table 8 shows the results of the linear models.

5. Discussion

From the results of the Logit and linear models, the two cities have similarities as well as different characteristics.

Regarding the influence of personal characteristics on willingness to choose and pay, in Meishan, only two factors of personal identity characteristics—gender and education level—affected people's choice on willingness to pay for ADAS and autonomous driving functions at only levels 3–4, whereas other personal characteristics or the influence on other levels were not clear. In Jiading, the influence of age on each level is obvious; gender becomes influential from level 2, and wage from level 4. The effect of age and gender (i.e., women compared to men) on willingness to pay is negative, whereas the effect of education level and wage is positive. However, a common observation is that age, gender, wage, and education level are generally more influential at higher levels.

One result worth mentioning is that the older the people are, the less they are concerned about economy-related functions that help them save gas or money, but they are less willing to spend money on ADAS and autonomous driving functions. Therefore, the elders have more savings than the young but lack the motivation to embrace new technologies. Similar conclusions have been obtained from acceptance studies of new technologies such as MaaS (mobility as a service) [10].

In Meishan, people's interest in travel efficiency, reliability, and economy positively affects their choices. Compared with this, Jiading is different in the sense that they understand related new technologies, especially autonomous driving and electric vehicles, which positively affects people's choices. In the two cities, people who are willing to buy electric vehicles seem to be more inclined to consider ADAS and autonomous driving functions. This suggests that we can promote related products from the perspective of publicity and knowledge dissemination. Simultaneously, we can screen potential users according to people's understanding and interest in such technologies.

Regarding the influence of family characteristics, such as the number and type of vehicles owned, there is no clear pattern of whether they significantly affect willingness to choose or pay for each function or level. Owning an e-bike in the family seems to weaken the willingness to choose and pay for ADAS and autonomous driving functions.

Regarding the influence of commuting characteristics, in Meishan, the commuting mode has an impact on the willingness to pay for lower-level (levels 1 and 2) ADAS and autonomous driving functions. Commuters using private cars and public transportation have a lower willingness, and commuters who use taxis have a higher willingness. There is no such phenomenon in Jiading. Perhaps in a city like Shanghai, commuters have chosen the best way to commute for themselves, and they will not change it easily, nor will it affect the purchase of ADAS and autonomous driving functions.

The possible reason for the difference between the two cities is that Jiading has a stronger car culture and is more tolerant towards new technologies. Even autonomous driving test vehicles are often seen on the roads in the city, so residents have a general understanding of ADAS and autonomous driving. Moreover, compared with Meishan, Jiading has a higher economic and average education level of residents, which may positively affect their willingness to purchase ADAS and autonomous driving products.

6. Conclusions

The biggest roadblocks standing in the path of mass adoption may be psychological, not technological [22]. This study analyzes the influence of urban residents' personal, family, and commuting characteristics regarding their willingness to choose and pay for ADAS and autonomous driving functions. The results show that significant influencing factors vary for different cities and levels of ADAS and autonomous driving functions.

The findings of this research can help city authorities, designers, and sellers of ADAS products or autonomous vehicles to identify potential interested persons or users and promote the popularization of related ADAS and autonomous driving functions or vehicles. For example, designers should develop strategies for people of different ages, gender, wage, and education level. In the case of the elderly, we found that they are less concerned about economy-related functions that help them save gas or money, so they should be attracted from other aspects, such as ride comfort, health monitoring, and assistive functions. Also, different strategies are needed in different cities. If sellers want to market level 4 autonomous driving cars, men with high salaries are more likely to be attracted in Shanghai, while in Meishan, it is people with high education. There should also be different strategies for different levels of products. Commuters who use taxis in Meishan are more willing to buy lower-level (levels 1 and 2) cars so that sellers can market precisely accordingly.

Because the data of this research comes from questionnaire surveys, a large-scale survey needs to be supported by the government. Currently, the sample size of this research only includes two cities. In the future, more data will be collected from more cities to verify the results.

Appendix

We present the core part of our questionnaire here; due to government requirements, we cannot show the complete questionnaire, but all questions related to this study are here.

1. What is your main mode of travel for commuting? You can choose one or more options.

A. Car

B. Taxi

C. Public Transit

D. Bike

E. Others

2. Please select a most representative weekday and fill in the following blanks.

Your departure time from your place of residence is: ________;

The time you arrive at your workplace/school is: ________;

The time you leave your workplace/school is: ________;

Your arrival time at your place of residence is: ________.

3. What is the type of vehicle your family owns? You can choose one or more options.

A. No vehicle

B. Petrol vehicle (normal)

C. Petrol vehicle with ADAS (such as adaptive cruise control and lane keeping)

D. Electric vehicle (normal)

E. Electric vehicle with ADAS (such as adaptive cruise control and lane keeping)

F. Electric vehicle with automation (such as self-driving on the highway)

4. Your family owns _____ vehicle(s), _____ e-bike(s), and _____ bike(s).

5. Please select the main factors that you value when commuting. You can choose one or more options.

A. Efficiency: less time consuming

B. Convenience: easy to access

C. Reliability: low delay

D. Comfort: a comfortable ride

E. Economy: save money

F. Environment: protect the environment

6. Are you aware of the following emerging smart travel modes? You can choose one or more options.

A. Autonomous vehicle

B. Shared travel

C. Electric vehicle

D. Intelligent connected vehicle

E. None of above

7. What vehicle would you like to buy in the next ten years if the price were not a consideration?

A. Petrol vehicle

B. Electric vehicle

C. None of above

8. Your gender:

A. Male

B. Female

9. Your Age:

A. Under 20

B. 20-29

C. 30-39

D. 40-49

E. 50-59

F. 60 or above

10. The highest-level education you have obtained:

A. Junior high school or below

B. High school

C. Undergraduate

D. Postgraduate

E. Ph.D. or above

11. Your monthly income:

A. Under 5000 yuan

B. 5000-10000 yuan
C. 10001-15000 yuan
D. 15001-20000 yuan
E. 20000 or above

12. What ADAS or autonomous driving functions do you think are helpful and willing to pay for them? You can choose one or more options.

A. Safety-related functions (such as identifying objects on the road and preventing collisions)

B. Economy-related functions (such as networking with traffic lights to smoothly pass intersections and reduce fuel costs)

C. Convenience-related functions (such as assisting and reducing the burden of driving)

13. How much are you willing to pay for different levels of ADAS or autonomous driving functions? Please give four amounts ranging from 2,000 RMB to 50,000 RMB.

Level 1 (driver assistance): At this level, the vehicle can provide some driving assistance functions, but the driver can still handle acceleration and braking and still have to pay attention to the surrounding environment. Imagine that your vehicle will automatically brake when getting too close to another car on the highway.

Level 2 (partial automation): At this level, the vehicle can perform all environmental monitoring and assist with steering or acceleration. Only a small part of the operation requires the driver to act.

Level 3 (highly automation): At this level, the vehicle can steer, brake, accelerate, monitor surrounding vehicles and roads, respond to events, determine when to change lanes, turn, and use signals. But the system will notify the driver when conditions are safe, and then the driver can switch the vehicle to this mode.

Level 4 (fully automation): At this level, autonomous driving does not require human involvement, with no need to step on the accelerator, brake, or hold the steering wheel. The autonomous driving system controls all critical tasks, monitors the environment, and recognizes various driving conditions, such as traffic jams.

Level 1 (driver assistance): ________ yuan;
Level 2 (partial automation): ________ yuan;
Level 3 (highly automation): ________ yuan;
Level 4 (fully automation): ________ yuan.

Data Availability

The raw data of questionnaire results used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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