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Using the Extended Unified Theory of Acceptance and Use of Technology to explore how to increase users' intention to take a robotaxi

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In recent years, many governments and companies have gradually launched robotaxi projects to help make transportation systems smarter, improve travel efficiency, and reduce travel costs. Robotaxi is a new mode of travel that replaces human driving with machines, freeing up social labour and enriching people's travel choices. This study employs the Extended Unified Theory of Acceptance and Use of Technology (UTAUT2) to understand the influencing factors of users' adoption and usage of robotaxis in China to facilitate the broader integration of robotaxis into urban transportation systems. This study surveyed the preferences of 2048 respondents and analysed the data through structural equation modelling. The results indicate that performance expectancy, hedonic motivation, and price value are the factors influencing users' behavioural intentions, while effort expectancy and social influence affect use behaviour. In contrast, habit is an important factor that affect both behavioural intention and actual use behaviour. Based on the findings, we have proposed practical strategies to improve robotaxi services and updated the UTAUT2 model in the context of robotaxi. We suggest that robotaxi operators can promote user acceptance and use by reducing the difficulty of use, improving the cost performance and the ride experience, and making appropriate publicity and guidance.

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Introduction

In recent years, the development of autonomous driving technology has garnered widespread attention and discussion, being recognized for its potential to transform the operational models of the transportation industry (Fagnant and Kockelman, 2014). The rapid iteration of sensor technologies, computer vision systems, and artificial intelligence algorithms has transitioned the concept of autonomous driving from the laboratory to public roads. Although autonomous vehicles can provide driving assistance to consumers, help reduce energy consumption, and curb the growth of private car ownership (Li et al., 2022), they still face many challenges in practical applications. For instance, issues such as reliability under adverse environmental conditions (Hussain et al. 2021), potential risks of cyber-attacks (Anderson et al., 2014), privacy and data protection (Brell et al., 2019), the establishment and applicability of laws and regulations (Bin-Nun et al., 2022), and the real contribution to environmental protection over their lifecycle (Onat et al., 2023) are difficulties that autonomous driving technology must overcome to achieve more mature applications and widespread market acceptance.

However, there are still a number of researchers still hold a positive view of autonomous driving technology. S. Liu (2022) argues that robotaxi - autonomous vehicles (AVs) operated by ridesharing companies - is an effective way to commercialize autonomous driving technology. Besides helping to realize the social and economic benefits expected from autonomous driving technology, robotaxis are also considered capable of changing the market landscape of mobility (Ambadipudi et al., 2017). Compared to personally owned autonomous vehicles, robotaxis offer a more economical and flexible choice (Kaddoura et al., 2020), not only lowering the barrier for consumers to experience autonomous driving technology but also providing possible solutions for urban transportation (Y. Zhou and Xu, 2023). Robotaxis also have the potential to reduce urban traffic congestion and parking demand (Litman, 2020), aligning with the current pursuit of sustainable transportation solutions (Chen and Yan, 2019). Currently, many companies, including Waymo, EasyMile, Apollo, and others, have begun trial operations of robotaxi projects in various locations around the world, including China, allowing consumers to personally experience robotaxis within pilot areas. However, the promotion of robotaxis still faces the same hurdles as autonomous driving technology itself, with robotaxis also confronting scepticism from consumers, businesses, and governments alike. Therefore, it is necessary to study the factors affecting user acceptance of robotaxis before they can be promoted on a large scale.

Consumer behaviour studies influenced by cultural, economic, or political factors from different countries may be subject to the potential impact of regional specificity. As Kaye et al. (2020) mentioned, the popularity and acceptance of highly automated cars show significant differences across various countries and regions. This means that limiting conclusions to a specific region could be more accurate. Given that robotaxis have entered widespread testing and operation stages in several cities in China, coupled with the difficulties and accessibility of our survey work, this study particularly focuses on Chinese consumers' perceptions and preferences towards robotaxis. At present, the development of autonomous driving technology is at a critical stage. In terms of business, many automakers continually launching vehicles with autonomous driving capabilities, with advanced autonomous features as a selling point. However, due to the high cost of these autonomous vehicles, many consumers cannot experience autonomous driving technology. Robotaxis provides an alternative and affordable solution to enable consumers to experience autonomous driving technology at a lower price, thereby enhancing people's understanding of autonomous driving technology. In terms of policy, the Chinese government is positively supporting the development of robotaxis and autonomous driving vehicles, providing substantive support in terms of policies, facilities, and funds. For instance, departments such as the National Development and Reform Commission, the Ministry of Transport, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the Office of the Ministry of Natural Resources have issued dozens of policies to promote the development of autonomous vehicles. The "Outline of the Strategic Plan for Expanding Domestic Demand (2022–2035)" issued by the Central Committee of Communist Party of China and the State Council mentions new consumption-related content such as "supporting the application of technologies such as autonomous driving". Therefore, under the strong influence of policy, exploring the factors affecting Chinese consumers' acceptance and use of robotaxis is an important topic that needs further exploration.

This study poses the following research questions (RQs): RQ1: What are the factors affecting Chinese consumers' acceptance and use of robotaxis and how do they relate to each other? RQ2: How to improve Chinese consumers' acceptance and use of robotaxis? Following the proposed research questions, the objective of this study is to use UTAUT2 (the Extended Unified Theory of Acceptance and Use of Technology) to understand the influencing factors of users' adoption and usage of robotaxis in China. This study examined the influence of antecedent variables, including performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit, on behavioural intention and use behaviour. Additionally, this study also tested the moderating effects of experience, gender, and age on the influencing pathways in the model. In the following sections, we first sort out a list of factors that may influence consumers' adoption and usage of robotaxis based on relevant literature and theoretical research, and propose research hypotheses to construct the hypothetical model of this study. Subsequently, we conduct a quantitative survey of robotaxi users to assess the relationships among user perceptions, preferences, and behaviours. Then, we perform structural equation modelling analysis to reveal the potential relationships between constructs and present the research findings. Finally, we discuss and propose marketing and operational strategies from the perspective of robotaxi operators based on research findings. This study offers specific and actionable suggestions from two dimensions: the application and validation of UTAUT2, along with practical recommendations.

Literature review

Robotaxi. Robotaxi is a kind of autonomous vehicle based on the sharing business model, which aims to provide transportation services for users by using autonomous driving cars (M. Liu et al., 2022). Saeed et al. (2020) indicated that robotaxi will become the main business model of autonomous vehicles. Robotaxis, which play an important role in the transformation of non-ownership business models, can allow consumers to try them at an early stage and build trust for autonomous driving technology. Robotaxis is considered to benefit the sustainable development of the autonomous vehicle industry (Panagiotopoulos and Dimitrakopoulos, 2018), and help improve road safety, reduce traffic congestion, increase mobility, relieve parking problems, and release urban space (Dai et al., 2021; Duarte and Ratti, 2018; Yan et al., 2020). Martinez and Viegas (2017) mentioned that when using robotaxi service, customers need to accept a small detour from the original direct path and share part of the journey with others. They found that replacing private cars, buses and

taxis with well-functioning sharing models would significantly reduce vehicle travels, mileage, and carbon dioxide emissions of private vehicles.

At present, users may come into a few restrictions when using robotaxis. First, the number of operating vehicles of robotaxis in the current market is far lower than that of traditional taxis, and there is a fixed available duration and designated service area, so it may not be able to meet the full demand of huge user groups. Secondly, as autonomous vehicles are not yet popular, users may worry about unexpected failures of robotaxis on ride safety (Dai et al., 2021; Lim and Hwangbo, 2021a). Thirdly, robotaxi operators will give users a certain discount in the trial operation stage, but it is still uncertain whether users will give priority to robotaxi after the discount is cancelled. Ultimately, once the initial excitement of utilizing robotaxis diminishes, it remains uncertain whether users will continue to use robotaxis.

Theoretical framework. Both technological and psychological factors influence the public's acceptance of autonomous vehicles (Shariff et al., 2017). Research on autonomous driving technology and autonomous vehicles has been extensively conducted from multiple perspectives. Efforts have been made not only to enhance the safety of autonomous driving technology at the algorithm level (Fu et al., 2023; Xiao et al., 2022; Xu et al., 2023) but also to improve autonomous driving capabilities through vehicle data processing and interaction (Ding et al., 2023; Fang et al., 2022; Xiao et al., 2023; Zhang et al., 2021; Zhao et al., 2023), and to increase driving safety from the perspective of driver assistance (Xu et al., 2022; Xu et al., 2022; Xu et al., 2021; Xu et al., 2022). However, besides the improvements in the capabilities and safety of autonomous driving technology itself, the psychological factors that affect users' acceptance of autonomous driving technology and robotaxis also require attention. Li et al. (2022) highlighted factors such as perceived drawbacks, perceived benefits, attitudes, and environmental awareness regarding the adoption of robotaxis. M. Liu et al. (2020) introduced social influence and, based on the TAM model, discussed the impact on Chinese consumers' acceptance of robotaxis. Later, M. Liu et al. (2022) further incorporated governmental support, perceived trust, and social influence on the basis of TAM to further explore Chinese consumers' acceptance of robotaxis. It is found that existing literature discussing the factors influencing the acceptance of robotaxis is relatively limited. The UTAUT2 (the Unified Theory of Acceptance and Use of Technology) model used in this research provides a more comprehensive exploration of the factors affecting users' use of robotaxis. Furthermore, Madigan et al. (2016) used the UTAUT (the Unified Theory of Acceptance and Use of Technology) model to investigate people's acceptance of automated road transport systems. Yuen et al. (2020) employed the UTAUT2 model to investigate the factors affecting the Vietnamese public's acceptance of shared autonomous vehicles. The results of these studies have elucidated and contributed to the understanding of the possible behavioural patterns of users accepting or using autonomous vehicles. Therefore, this study intended to use UTAUT2 to understand the influencing factors of users' adoption and usage of robotaxis in China.

Research hypotheses

The extended unified theory of acceptance and use of technology (UTAUT2). UTAUT2 extends UTAUT (unified theory of acceptance and use of technology) to investigate the adoption and use of technology among consumers (Palau-Saumell et al., 2019). The UTAUT2 model added hedonic motivation, price value and experience and habit to the UTAUT model (Venkatesh et al., 2012). Since 2012, the UTAUT2 model has been widely used to analyse different types of users and organizations, as well as different types of technologies (Tamilmani et al., 2021). Therefore, this study adopts UTAUT2 model to investigate the use intention of robotaxi users. The hypotheses proposed in this study are shown in Fig. 1.

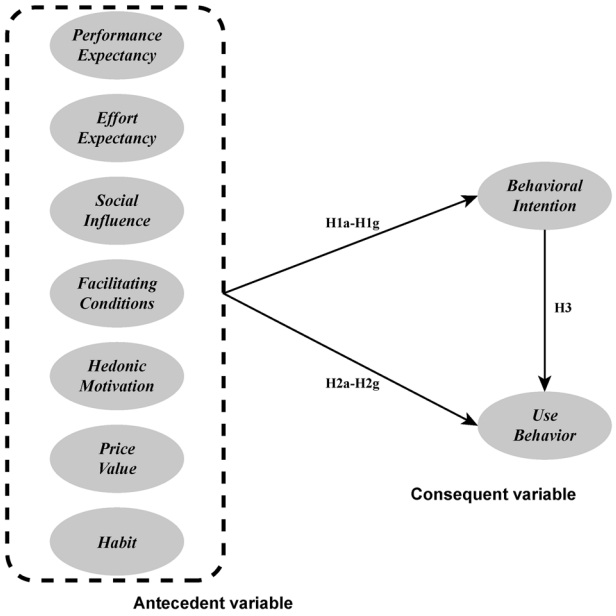

Fig. 1 Research framework.

Performance expectancy. Performance expectancy (PE) is defined as the degree to which users expect to use a certain technology to help them improve their work efficiency (Sewandono et al. 2023). In other words, it refers to the effectiveness of a technology that a user chooses to use when performing a particular task (Wang et al., 2020). Performance expectancy is regarded as one of the core predictors of the UTAUT model (Palau-Saumell et al., 2019). Therefore, the perception of travel efficiency may have an impact on users' decision to take robotaxi.

Effort expectancy. Effort expectancy (EE) refers to the convenience of consumers when using related technologies (Gursoy et al., 2019), which is used to measure the effort that individuals need to pay when using the system (Wu et al., 2022) and the degree of relaxation of users when using technology (Wang et al., 2020). Factors such as the hailing process, system operation, available duration, and location of robotaxi may lead to different feelings of convenience for users, which will further affect their continuous usage of robotaxi as a public transportation tool.

Social influence. Social influence (SI) refers to the technology that important family members or friends of users think they should use (Muangmee et al., 2021). Social influence is an important factor influencing the using behaviour of new technologies (Muangmee et al., 2021), and was proved to have a positive impact on users' intentions to use new technologies (Sair and Danish, 2018; Sathye et al., 2018). Existing studies show that young groups with a certain level of education have a higher possible acceptance of robotaxi (M. Liu et al., 2022). Therefore, social influence is one of the factors that need to be paid attention to and discussed when exploring robotaxi users' behaviour.

Facilitating conditions. Facilitating conditions (FC) refers to the consumer perception of resources and support (Palau-Saumell et al., 2019). Robotaxi is a newly launched transport tool, and

users unfamiliar with it might approach the use of this innovation with scepticism, which may affect the intention to use. Facilitating conditions can reflect the individual's perception of control over their behaviour (Palau-Saumell et al., 2019).

Hedonic motivation. Hedonic motivation (HM) is defined as the happiness and enjoyment of users when using robotaxi (Yuen et al., 2020). Hedonic Motivation is regarded as a good predictor in ride-hailing service (Yuen et al., 2020) and bike-sharing service (Chopdar et al., 2022). Studies have shown that hedonic motivation is an effective predictor of users' acceptance of autonomous vehicles (Kapser and Abdelrahman, 2020). After the pleasant and fresh experience stage of robotaxi, it is worth discussing and observing whether consumers will choose robotaxi for pleasure or pay more attention to travel efficiency and other more practical issues.

Price value. Price value (PV) is defined as a perceived measure of consumers' expected advantages and costs of an application (Palau-Saumell et al., 2019). Compared with buying autonomous vehicles, robotaxi users only need to spend the same price as ordinary taxis to get the experience of autonomous driving cars, which may lead to purchase behaviour. Research shows that consumers prefer services with good price value (Merhi et al., 2019). In particular, price value is one of the key points that determines whether users will adopt a new technology (Merhi et al., 2019). Therefore, for robotaxis, the impact of price value on consumers' usage intention and behaviour is worth attention.

Habit. In UTAUT2, habit (HT) is a user's behaviour toward the future, which can be understood as a perceptual structure experience reflecting prior results (Palau-Saumell et al., 2019). Habit is also the degree to which learning accumulatively develops into automatic behaviour through observation after using technology (Merhi et al., 2019). As a prior result that can reflect future behaviour performance, whether habits will affect users' intention to use robotaxis needs to be tested.

Behavioural intention. When users show behavioural intention (BI) in using innovative technology, they are about to adopt using behaviour (Chatterjee et al., 2021). Intention is the embodiment of the user's inclination. Behavioural intention cannot replace actual behaviour (Suhartanto et al., 2018), but it can reasonably and accurately predict consumers' future behaviour (Dean and Suhartanto, 2019).

From technology, efficiency, and the cognition perspective, factors such as performance expectancy, effort expectancy, facilitating conditions could influence robotaxi users at the early stage of robotaxi (Hooda et al., 2022). Performance expectancy is recognized as the main determinant of behaviour intention(Dwivedi et al., 2019; Wang et al., 2020). When users get good results using new technology, they are more likely to have behavioural intention and use this technology in the future (Chang et al., 2019). In the study of e-government field, performance expectancy has a significant impact on behaviour intention (Hooda et al., 2022). Hooda et al. (2022) stated that the effort expectancy has positive impact on behavioural intention, and the effort required by using new technology directly affects users' acceptance and implementation of the technology (Chang et al., 2019). The current call and usage mode of robotaxi does not require users to spend extra effort to learn, but the limited service area and duration of robotaxi may affect users' behavioural intention. Dai et al. (2021) reported consumers' positive perception of facilitating conditions can promote behavioural intention. Behavioural intention would be enhanced when users find they have the ability to control the technology or resources at their disposal (Chang et al., 2019). Therefore, users' experience and perception of robotaxis may have an impact on behavioural intention. From the economic perspective, robotaxis can provide the same safe, comfortable, and convenient travel experience as e-hailing cars and taxis, as well as higher cost performance, which may also be an important factor affecting users' behavioural intention. Price value plays a key role in whether users choose to use the new technology (Merhi et al., 2019). From the perspective of users' feelings and experiences, whether users' important relatives and friends support them, the pleasure they feel after experiencing robotaxi, and whether they can form the habit of using robotaxi remain to be tested. Social influence has a positive influence on users' intention to use new technologies (Sair and Danish, 2018; Sathye et al., 2018). Since robotaxi is still in its initial stage, the experience of family members and friends who have close trust with each other may attract potential users who have never experienced robotaxi due to their lack of understanding and trust in the technology. The experiment of online air ticket purchasing consumers shows that habit is an important factor affecting consumers' online purchase behaviour (Chang et al., 2019). Hedonic motivation is one of the most influential factors on behaviour intention in previous studies (Chang et al., 2019). However, after enjoying fresh fun, whether users will use robotaxi frequently, change it into habit and influence behaviour intention still needs to be studied and discussed.

Based on the above discussion, the following hypotheses are proposed: Hypotheses 1 (H1): performance expectancy (H1a), effort expectancy (H1b), social influence (H1c), facilitating conditions (H1d), hedonic motivation (H1e), price value (H1f), and habit (H1g) has a positive influence on robotaxi users' behavioural intention.

Use behaviour. Use behaviour (UB) refers to the actual behaviour of using a robotaxi, which can also be regarded as the actual frequency of using a robotaxi in a period of time (Jadil et al., 2021). In this study, use behaviour is defined as users' actual actions of taking robotaxi. Loureiro et al. (2018) mentioned that consumers' satisfaction with technology depends on their expectations on technology performance, so performance expectancy can help lead to stronger behavioural intention. Hooda et al. (2022) found that facilitating conditions have direct influence on use behaviour. This indicates that whether users have enough convenient experience may affect their adoption of robotaxis. Although using mobile phones to operate robotaxi software has no difference from those known to users, such as online ride-hailing, the current limited service-hour and range may still affect the actual adoption. In the initial stage of the development of autonomous driving technology, the main channels for consumers to understand robotaxi information mainly include official publicity and feedback from people with close and trusted relationships, such as their family and friends. Muangmee et al. (2021) argued that social influence should not be ignored when discussing the important factors that influence the behaviour of using new technologies. Whether users will list robotaxi as their first choice for travel and integrate it into their daily life habits depends on whether users enjoy robotaxi when using it and its cost performance. Kapser and Abdelrahman (2020) pointed out that hedonic motivation is an effective predictor of user acceptance of autonomous vehicles. Merhi et al. (2019) found that price value is an important factor for users when considering new technologies. Palau-Saumell et al. (2019) noted that habit is a user's tendency to transform habit into daily state spontaneously after using it.

Based on literature, we further proposed Hypotheses 2 (H2): performance expectancy (H2a), effort expectancy (H2b), social influence (H2c), facilitating conditions (H2d), hedonic motivation

(H2e), price value (H2f), and habit (H2g) has a positive influence on use behaviour.

In addition, Chang et al. (2019) argued that behavioural intention is the main determinant of predicting consumer use behaviour. This relationship may still exist when a user chooses to use a robotaxi. Hence, this study further proposes Hypothesis 3 (H3): behavioural intention has a significant positive influence on use behaviour.

Methodology

Our experiments informed consent was obtained from all participants and all methods were performed per relevant guidelines and regulations.

Sampling. In this study, an online questionnaire was used to investigate Chinese consumers' perceptions on robotaxis. We commissioned a professional survey company (Wenjuanxing, which is a well-known survey company in China) to conduct this survey for us. We submitted our designed questionnaire to the Wenjuanxing website and set our recruitment requirements. Respondents could browse our survey requirements on the Wenjuanxing platform and voluntarily choose whether to participate. The survey was conducted from January 2022 to March 2022. Consumers with and without robotaxi using experience were both surveyed to test the moderating effect of experience. Video introduction and text description of robotaxi were placed at the beginning of the questionnaire to let consumers know about the service. The participants were asked to answer the questionnaire after reading all the instructions. A total of 2048 users were investigated, and 1284 valid samples were retained after screening processes such as reverse question test, answer duration test, and logical test of feedbacks. The valid response rate was 62.695%. The participants were categorized into ten-year age intervals. The recruitment method is mainly voluntary registration, and some users with ride experience are invited to answer. A survey of several countries around the world shows that women are significantly more likely to take a taxi than men (W.-S. Ng and Acker, 2018). In our survey sample, the proportion of female sample is also slightly higher than that of male sample. All respondents in the survey were paid by digital payment after submitting the questionnaire. The demographic characteristics of the respondents are shown in Table 1.

Questionnaire design. The scale and items used in this study is based on rigorous results that have been verified in previous studies. Likert's 5-point scale was used for the measurement. Among them, performance expectancy (3 items), effort expectancy (4 items), social influence (3 items), facilitating conditions (4 items), hedonic motivation (3 items), price value (3 items), habit (3 items), behavioural intention (3 items) and other items are all derived from the research of Venkatesh et al. (2012). And the three items included in 'use behaviour' are from the research of Ramírez-Correa et al. (2019). All item content is tailored to focus on the robotaxi. After the questionnaire was finished, we sent it to four experts familiar with the topic of this study for pretest. The questionnaire items were modified according to the suggestions on the way of expression and inquiry content of the experts. The final version of questionnaire used is showed in Appendix A.

Results

IBM SPSS software was used for reliability analysis and exploratory factor analysis of the collected data. And IBM Amos software was used for confirmatory factor analysis and structural equation modelling. The results showed that after deleting item EE1 and item FC4, the reliability and validity of all the constructs reached the suggested standards. Hence, we deleted those two items. The following content shows the data analysis results after the deletion.

Table 1 Demographic characteristics of the respondents.

Sample	Category	Number	Percentage (%)
Gender	Male	522	40.654
	Female	762	59.346
Age	Under 22	115	8.956
	23–30	558	43.458
	31–40	424	33.022
	41–50	100	7.788
	Over 51	87	6.776
Experience	Yes	237	18.458
	No	1047	81.542
Marital status	Married	883	68.769
	Unmarried	401	31.231
Monthly Income	Below 4000	183	14.252
	4001–6000	285	22.196
	6001–12000	515	40.109
	12001–18000	207	16.121
	18001 or more	94	7.321
Education	Junior high school or below	13	1.012
	High school or secondary school	79	6.153
	Undergraduate or college	1027	79.984
	Institute including above	165	12.850
Occupation	Civil servant	144	11.215
	Clerk	553	43.069
	Worker	172	13.396
	Public service agency	144	11.215
	Student	131	10.202
	Self-employed	140	10.903
Area	Eastern China	775	60.358
	Central China	200	15.576
	Western China	246	19.159
	Northeast China	62	4.829
	Hong Kong, Macao, and Taiwan in China	1	0.078

Reliability analysis. The results of reliability analysis are shown in Table 2. The results show that the corrected-item-to-total correlation (CITC) values of all items are over 0.5, which shows that the scores of all the items included in different constructs can be seen concentrated in a similar range (Zijlmans et al., 2019). The Cronbach's alpha value of all the constructs was greater than 0.7, and the Cronbach's alpha of single construct could not get a better value after deleting any item, indicating that the data had good internal consistency (Jansen et al., 2021). Therefore, the collected data has good reliability and is suitable for further analysis.

Exploratory factor analysis. Principal component analysis and varimax rotation method were chosen to conduct exploratory factor analysis (see Table 3). The results of Kaiser–Meyer–Olkin (KMO) test were greater than 0.5, and the results of Bartlett's sphericity test were less than 0.05. These indicate that the items have strong partial correlation, and rejects the null hypothesis that the correlation matrix is an identity matrix, which means that the collected data is suitable for factor analysis (Jahrami et al., 2022). The results of exploratory factor analysis showed that the commonality value of each item was greater than 0.5 in each construct, indicating that each item was correlated with other

Table 2 Results of reliability analysis.

Construct	Item	CITC	Cronbach's Alpha If Item Deleted	Cronbach's Alpha	Mean	Standard deviation
PE	PE1	0.613	0.731	0.789	3.561	0.958
	PE2	0.637	0.705		3.576	1.040
	PE3	0.639	0.702		3.714	1.003
EE	EE2	0.577	0.663	0.748	3.558	0.977
	EE3	0.576	0.663		3.619	0.998
	EE4	0.574	0.667		3.645	1.062
SI	SI1	0.613	0.676	0.769	3.046	1.109
	SI2	0.630	0.657		3.153	1.077
	SI3	0.563	0.731		3.275	1.086
FC	FC1	0.614	0.649	0.759	3.463	1.061
	FC2	0.627	0.633		3.500	1.046
	FC3	0.532	0.739		3.721	0.947
HM	HM1	0.718	0.808	0.856	3.921	0.934
	HM2	0.732	0.795		3.734	0.921
	HM3	0.735	0.792		3.776	0.904
PV	PV1	0.586	0.671	0.756	3.600	0.947
	PV2	0.607	0.647		3.644	0.951
	PV3	0.560	0.701		3.724	0.954
HT	HT1	0.642	0.787	0.821	2.639	1.181
	HT2	0.721	0.707		2.506	1.154
	HT3	0.663	0.765		2.221	1.161
BI	BI1	0.584	0.716	0.771	3.561	0.996
	BI2	0.620	0.676		3.390	1.067
	BI3	0.614	0.682		3.051	1.040
UB	UB1	0.809	0.863	0.903	3.107	0.879
	UB2	0.817	0.854		2.831	0.926
	UB3	0.801	0.869		3.062	0.954

Table 3 Results of exploratory factor analysis.

Construct	Item	KMO test	Bartlett's Sphere Test	Communality	Factor Loading	Eigenvalue	Total Variation Explained
PE	PE1	0.706	0.000	0.685	0.828	2.110	70.327%
	PE2			0.711	0.843		
	PE3			0.713	0.844		
EE	EE2	0.692	0.000	0.667	0.817	1.997	66.558%
	EE3			0.666	0.816		
	EE4			0.664	0.815		
SI	SI1	0.693	0.000	0.697	0.835	2.052	68.393%
	SI2			0.715	0.846		
	SI3			0.639	0.799		
FC	FC1	0.682	0.000	0.702	0.838	2.025	67.505%
	FC2			0.716	0.846		
	FC3			0.607	0.779		
HM	HM1	0.734	0.000	0.766	0.875	2.329	77.645%
	HM2			0.781	0.883		
	HM3			0.783	0.885		
PV	PV1	0.691	0.000	0.675	0.821	2.015	67.179%
	PV2			0.697	0.835		
	PV3			0.643	0.802		
HT	HT1	0.708	0.000	0.702	0.838	2.211	73.704%
	HT2			0.784	0.885		
	HT3			0.726	0.852		
BI	BI1	0.698	0.000	0.661	0.813	2.059	68.630%
	BI2			0.702	0.838		
	BI3			0.696	0.834		
UB	UB1	0.755	0.000	0.839	0.916	2.517	83.906%
	UB2			0.847	0.921		
	UB3			0.831	0.912		

items within the same construct (Klein et al., 2022). After extracting the new factors, each construct can extract only one new variable with eigenvalue greater than 1, and the total variance explained is greater than 50%, factor loading was greater than 0.6 for all items. Therefore, the data is considered to meet the requirement of unidimensionality suggested in the previous study (Kohli et al., 1998).

Confirmatory factor analysis. Confirmatory factor analysis (CFA) is conducted to further examine the reliability and validity

Table 4 Model fit indices of confirmatory factor analysis.

Common indices	χ^2/df	RMSEA	GFI	AGFI	NFI	CFI	SRMR
Judgment criteria	<3	<0.08	>0.9	>0.9	>0.9	>0.9	<0.08
CFA results	2.848	0.038	0.955	0.941	0.954	0.969	0.032
CCLFM results	2.519	0.034	0.960	0.947	0.959	0.975	0.033

Table 5 Results of confirmatory factor analysis.

Construct	Items	Factor loading	t value	Standard error	*p* value	SMC	AVE	CR
PE	PE1	0.742	28.647	0.003	0.001*	0.551	0.555	0.789
	PE2	0.739	28.503	0.003	0.001*	0.547		
	PE3	0.753	29.189	0.003	0.001*	0.567		
EE	EE2	0.710	26.669	0.002	0.001*	0.505	0.498	0.748
	EE3	0.729	27.534	0.003	0.001*	0.531		
	EE4	0.677	25.089	0.003	0.001*	0.458		
SI	SI1	0.769	29.919	0.002	0.001*	0.591	0.527	0.770
	SI2	0.725	27.736	0.003	0.001*	0.526		
	SI3	0.682	25.615	0.003	0.001*	0.465		
FC	FC1	0.756	28.780	0.003	0.000*	0.572	0.519	0.763
	FC2	0.756	28.768	0.003	0.001*	0.571		
	FC3	0.643	23.480	0.003	0.001*	0.414		
HM	HM1	0.785	31.807	0.002	0.001*	0.616	0.664	0.856
	HM2	0.822	33.968	0.002	0.001*	0.676		
	HM3	0.837	34.861	0.002	0.001*	0.701		
PV	PV1	0.675	24.636	0.002	0.001*	0.455	0.509	0.756
	PV2	0.774	29.122	0.002	0.001*	0.599		
	PV3	0.686	25.152	0.003	0.001*	0.471		
HT	HT1	0.774	30.891	0.002	0.001*	0.600	0.607	0.822
	HT2	0.802	32.440	0.002	0.001*	0.643		
	HT3	0.761	30.180	0.003	0.001*	0.580		
BI	BI1	0.703	27.291	0.003	0.001*	0.495	0.528	0.770
	BI2	0.702	27.234	0.003	0.001*	0.493		
	BI3	0.773	30.964	0.002	0.001*	0.598		
UB	UB1	0.875	38.741	0.002	0.001*	0.766	0.759	0.904
	UB2	0.874	38.623	0.002	0.001*	0.763		
	UB3	0.864	37.938	0.002	0.001*	0.746		

*The level of significance is 0.05.

(see Table 4). Compared with the standards suggested by Hair et al. (2006), the model fit indices in this study reached the recommended standards they suggested, indicating that the model fit was good. In addition, this study adopts the calculating the common latent factor method (CCLFM) to conduct the common method bias test. The results show that the model fit indices of CCLFM is not significantly better than that of CFA after adding a deviation variable into the model. The decrease range of RMSEA and SRMR is less than 0.05, and the increase range of GFI, AGFI, NFI and CFI is less than 0.1, which indicates that there is no obvious problem of common method bias in the data of this study (S. B. Lee et al., 2016).

The results of confirmatory factor analysis are shown in Table 5. The results showed that the factor loading of all items was greater than 0.6, and the square multiple correlation (SMC) was greater than 0.4, which reached the recommended standard in the study of Taylor and Todd (1995). The average variance extracted (AVE) and composite reliability (CR) of each construct are calculated according to factor loading. The AVE of each construct was greater than 0.4, and the CR was greater than 0.7, which indicated that the data had sufficient convergent validity (Mandhani et al., 2020).

Fornell–Larcker criterion was used to test discriminant validity, as shown in Table 6. The diagonal values in Table 6 are the square root of AVE for each construct, and the remaining values are Pearson correlation coefficients between the constructs. The results show that the square root of AVE for each construct is greater than its correlation coefficient with any other construct. The correlation coefficients between the constructs are all significant and less than 0.8, which is lower than the commonly used judgment standard (Provenzano et al., 2020). This indicates that there is linear relationship between these constructs, and there is no potential collinearity problem. The above indicates that the different constructs have discriminant validity (Fornell and Larcker, 1981).

Structural equation model. In this study, maximum likelihood estimation is used to establish the structural equation model. The calculations were performed with 2000 bootstraps and 95% confidence intervals. The model fit indices are shown in Table 7. The results showed that all the indices reached the recommended standards in previous studies and the model fit was good (Hair et al., 2006).

The calculation results of the structural equation model are shown in Fig. 2. In the figure, solid lines mark the influence paths that reach significant, and dashed lines mark the influence paths that do not reach significant. The results show that only performance expectancy, hedonic motivation, price value, and habit can have a direct and significant impact on users'

Table 6 Results of Fornell-Larcker criterion.

	PE	EE	SI	FC	HM	PV	HT	BI	UB
PE	0.745								
EE	0.518*	0.706							
SI	0.560*	0.470*	0.726						
FC	0.475*	0.595*	0.449*	0.720					
HM	0.498*	0.475*	0.448*	0.426*	0.815				
PV	0.438*	0.455*	0.434*	0.452*	0.488*	0.713			
HT	0.406*	0.321*	0.542*	0.355*	0.335*	0.384*	0.779		
BI	0.566*	0.475*	0.563*	0.479*	0.553*	0.517*	0.584*	0.727	
UB	0.503*	0.460*	0.585*	0.440*	0.437*	0.443*	0.652*	0.669*	0.871

*The level of significance is 0.05.

Table 7 Model fit indices of the structural equation model.

Common indices	χ^2/df	RMSEA	GFI	AGFI	NFI	CFI	SRMR
Judgment criteria	<3	<0.08	>0.9	>0.9	>0.9	>0.9	<0.08
Value	2.848	0.038	0.969	0.941	0.954	0.969	0.032

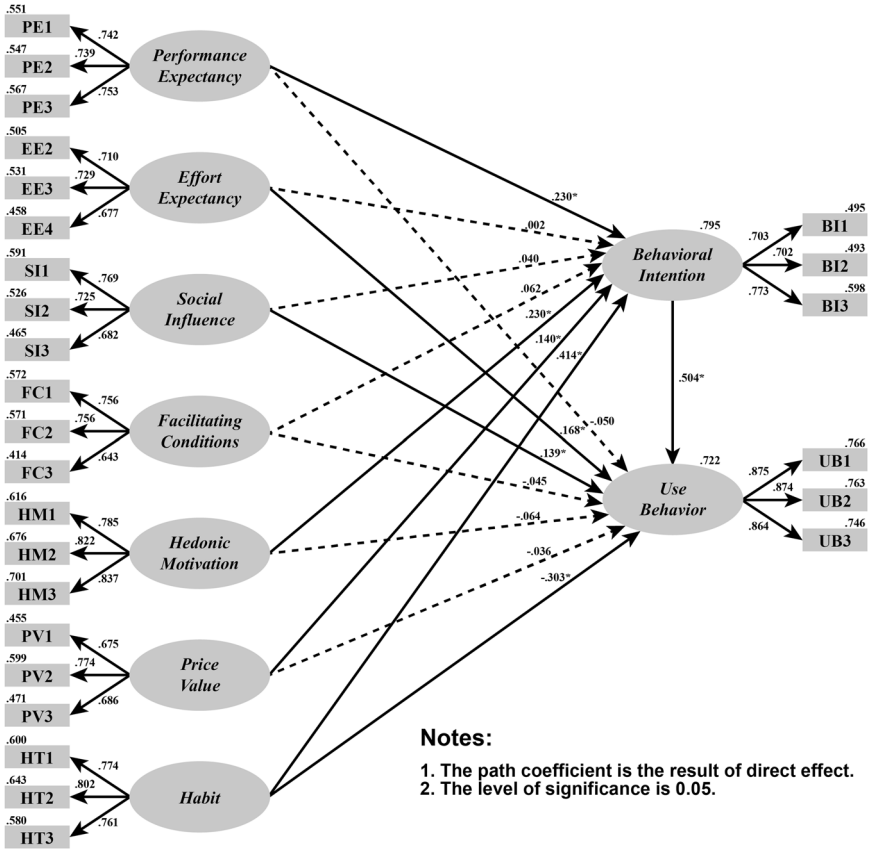

Fig. 2 Path analysis results.

behavioural intention. Effort expectancy, social influence, and facilitating the conditions will not affect behavioural intention. Therefore, H1a, H1e, H1f, and H1g proposed in this study are supported, while H1b, H1c, and H1d are not supported.

This study finds that effort expectancy, social influence, and habit can exert direct and significant impacts on use behaviour. And the influence of performance expectancy, facilitating conditions, hedonic motivation, and price value on use behaviour is not significant. Therefore, H2b, H2c, and H2g are supported, while H2a, H2d, H2e, and H2f are not supported.

It is worth noting that behavioural intention has been proved to have a direct impact on use behaviour, and path coefficient shows the effect is relatively robust, which indicates that behavioural intention may act as a mediating variable to link the path relationship between antecedent variable and behavioural intention, thus producing indirect effects.

In order to verify the specific situation of the mediating effect, this study examined the direct effect, indirect effect, and total effect among the constructs (see Table 8). The results show that the indirect effect on the influence relationship of performance expectancy, hedonic motivation, and price value on use behaviour reached significant. The direct effect of these variables on use behaviour is not significant, behavioural intention plays a full mediation role in the influence of these antecedent variables on use behaviour. In addition, the indirect effect of habit on use behaviour reached significant. Behavioural intention plays a partial mediation role in this relationship because habit itself has a significant direct effect on use behaviour.

However, after calculating the total effect, this study found that significant indirect effects alone could not bring about significant total effect results. That is, performance expectancy, hedonic motivation, and price value can only have slightly negative direct influence on use behaviour. Although the negative direct effect does not reach significant, it can offset the positive indirect effect. In short, these variables have no significant direct influence but significant indirect influence on use behaviour, the total effect is not significant. This study finds that habit shows more intense total effects under the same positive and significant direct and indirect effects, the insignificant indirect effects also help effort expectancy and social influence improve the total impact effect on use behaviour.

Like other studies on the UTAUT2 model, this study tested the moderating effects of experience, gender, and age on the path relationship of the model. The samples were grouped by experience with or without robotaxi, and by male and female. Due to the age of the respondents was divided into five intervals, the sample size in each interval was insufficient to support the test of the moderating effect. WeRide mentioned in their report that 48% of robotaxi users are 18–30 years old and 52% are over 31 years old (WeRide, 2020). This indicates that the age of 30 seems to be an appropriate age cut-off, so this study uses the age of 30 as the basis for age grouping. Additionally, we categorized income into three groups, combining those earning below 4000 and 4001–6000 as the low-income group, and those earning 12,001–18,000 and above 18001 as the high-income group, to test the moderating effects of income on different path relationships. We found that gender as a moderator variable showed significant moderating effect in the influence path of facilitating conditions on use behaviour. In terms of the comparison between different income groups, we discovered significant differences in the impact of hedonic motivation, habit, and behaviour intention on use behaviour (See Table 9).

To ascertain the specific mechanisms of the moderating effects, this study conducted a further test (see Table 10). Results showed

Table 8 Results of mediating effect.

Path	Direct effect		Indirect effect		Total effect	
	β	B-C Sig.	β	B-C Sig.	β	B-S Sig.
PE → BI	0.230	0.001*	/	/	0.230	0.001*
EE → BI	0.002	0.938	/	/	0.002	0.938
SI → BI	0.040	0.481	/	/	0.040	0.481
FC → BI	0.062	0.335	/	/	0.062	0.335
HM → BI	0.230	0.001*	/	/	0.230	0.001*
PV → BI	0.140	0.003*	/	/	0.140	0.003*
HT → BI	0.414	0.001*	/	/	0.414	0.001*
PE → UB	−0.050	0.389	0.116	0.001*	0.066	0.206
EE → UB	0.168	0.017*	0.001	0.938	0.170	0.014*
SI → UB	0.139	0.015*	0.020	0.467	0.159	0.007*
FC → UB	−0.045	0.426	0.031	0.315	−0.014	0.839
HM → UB	−0.064	0.135	0.116	0.001*	0.052	0.181
PV → UB	−0.036	0.483	0.070	0.004*	0.035	0.437
HT → UB	0.303	0.001*	0.209	0.002*	0.512	0.002*
BI → UB	0.504	0.002*	/	/	0.504	0.002*

*The level of significance is 0.05.

Table 10 Comparison results of path coefficients.

Moderating variable		Path	β	p
gender	male	FC → UB	−0.284	0.104
	female		0.046	0.355
income	high level	HM → UB	−0.257	0.039*
	low level		−0.009	0.982
	high level	HT → UB	0.062	0.910
	low level		0.392	0.010*
	high level	BI → UB	0.900	0.018*
	low level		0.286	0.028*

*The level of significance is 0.05.

Table 9 Results of moderating effect.

Path	Experience		Gender		Age		Income	
	CMIN	p	CMIN	p	CMIN	p	CMIN	p
PE → BI	1.102	0.294	0.179	0.672	0.994	0.319	0.971	0.324
EE → BI**	0.109	0.741	1.737	0.187	0.251	0.616	0.004	0.948
SI → BI**	1.368	0.242	0.185	0.667	0.236	0.627	0.116	0.733
FC → BI**	0.535	0.464	0.008	0.930	0.009	0.926	0.227	0.634
HM → BI	1.233	0.267	0.000	0.996	0.246	0.620	0.300	0.584
PV → BI	0.117	0.732	1.177	0.278	0.931	0.335	0.060	0.897
HT → BI	0.346	0.556	0.860	0.354	1.898	0.168	0.933	0.334
PE → UB**	0.055	0.815	3.110	0.078	0.007	0.935	2.346	0.126
EE → UB	0.015	0.903	1.605	0.205	0.624	0.429	0.719	0.397
SI → UB	0.050	0.824	0.001	0.976	0.851	0.356	1.693	0.193
FC → UB**	0.012	0.911	6.839	0.009*	2.087	0.149	3.744	0.053
HM → UB**	0.078	0.781	0.112	0.738	3.518	0.061	4.662	0.031*
PV → UB**	0.077	0.782	2.703	0.100	0.523	0.470	0.016	0.900
HT → UB	0.022	0.883	2.193	0.139	0.389	0.533	4.114	0.043*
BI → UB	0.011	0.917	2.797	0.094	2.220	0.136	9.060	0.003*

*The level of significance is 0.05.
**Insignificant direct impact effect.

that facilitating conditions have negative influence on the use behaviour of male users and slightly positive influence on the use behaviour of female users. But neither of these two influence paths meets the criterion of significant. The test results regarding income were more intriguing. The user behaviour of the low-income group is significantly influenced by habit, a pathway that is not significant in the behaviour model of the high-income group. Moreover, regardless of whether it is the high-income group or the low-income group, their user behaviour is significantly influenced by behavioural intention, only that this effect is more pronounced in the high-income group.

Discussion

In this study, the UTAUT2 model was used to investigate users' intention to take robotaxis. Robotaxi is now entering the vision of users as a new solution to travel. Based on the driverless character, robotaxi is argued to free up more labour for society from the transportation system. Since the decision makers of the route planning have changed from human to machine, it can possibly reduce traffic congestion and improve safety, and indirectly promote energy saving and emission reduction. Therefore, it is important to investigate the factors that may affect users' intention and behaviour to improve users' intention to take robotaxi. Based on the results of the quantitative analysis, the important factors affecting behavioural intention and use behaviour are discussed as follows.

The first part is the strategies and suggestions for improving behavioural intention. This study finds that performance expectancy, hedonic motivation, price value, and habit can exert direct positive influence on behavioural intention, changes in effort expectancy, social influence, and facilitating conditions cannot. In a survey of rural users' behavioural intention using demand-responsive transport systems in Germany, performance expectancy is proved to be an important influencing factor, effort expectancy and social influence are not proved (König and Grippenkoven, 2020). A survey of users' intention to use shared e-scooters in Turkey affirmed the role of price value (Karlı et al., 2022). Research on public attitudes towards autonomous public transport systems shows that habit is an important factor to change users' decisions (Korkmaz et al., 2022). The findings of this study on robotaxis echo these previous studies.

This study finds that to promote the wide adoption of robotaxi and improve users' goodwill, robotaxi operators should pay attention to performance expectancy, hedonic motivation, price value, and habit when developing strategies. These four factors correspond to four very specific strategies in market behaviour. 1. Robotaxi operators should help users figure out what practical help robotaxis can bring, such as its usefulness in reducing congestion times, optimizing traffic routes, and providing combined travel solutions. Nikolopoulou et al. (2021) argued that performance expectancy is closely related to users' perception of the actual efficacy of products. Therefore, this study suggests that manufacturers should add publicity and interpretation of productivity improvement brought by robotaxi in their marketing activities to help users understand the actual favour robotaxis can do. We recommend initiating promotional efforts from specific quantitative perspectives such as time and cost, to allow users to more clearly perceive the role that robotaxis play within the transportation system. 2. More entertainment fantasy and sensory stimulation should be added to the experience of robotaxi. Tyrväinen et al. (2020) stated that hedonic motivation is a kind of perception that integrates pleasure, exploration and even adventure. Unlike utilitarian, hedonic emphasizes the importance of the user experience during the ride. Therefore, robotaxi operators should optimize the ride experience. For example, add some additional audio-visual equipment to turn the ride into a mystery or adventure story, or bring a sense of fun and novelty to the user from the sense of smell or touch inside the carriage. In addition, the characteristics of robotaxi can be highlighted in the promotional video or test-riding activities to introduce the different experiences it can bring. This study suggests that the process of taking robotaxi can be defined as a pleasure-seeking process different from other travel modes through extended human-computer interaction design combined with marketing and publicity means. 3. Robotaxi operators should establish reasonable pricing and assess the price that users are willing to pay for robotaxi service. In order to make robotaxis a regular travel option, operators should pay attention to the nature of robotaxis as transportation tools, rather than just a novel experience project. The importance of the price factor is self-evident, just as the 4 C theory is an important way of thinking in marketing (Huijing et al., 2021). The price users are willing to pay is one of the key considerations for marketers. A reasonable price can not only make users feel the value of the services provided by robotaxi, but also make it cost-effective, and help robotaxi differentiate from other transportation modes. 4. Robotaxi operators should cultivate users' habit of using robotaxis, which means that operators need to encourage users to take robotaxis and convert them into a continuous behaviour (S. W. Lee et al., 2019). In order to make robotaxi a long-term choice for users, operators need to consider the substitutability of robotaxi for existing modes of transportation. For different users, robotaxi may replace different transportation tools, including walking sections that do not need to take transportation tools previously. Therefore, operators must conduct a comprehensive analysis of robotaxi's benefits compared to other modes of transportation, and further enhance these advantages in both service and experience design. Moreover, strategic embellishment and emphasis in advertising can be employed to position robotaxis as a more preferred option within users' travel selections.

The second part is the strategies and suggestions to improve use behaviour. This study finds that effort expectancy, social influence, and habit are helpful to motivate users' use behaviour. In contrast, performance expectancy, facilitating conditions, hedonic motivation, and price value are ineffective in enhancing use behaviour. This study provides new insights into the relationship between constructs in the UTAUT2 model. When the theory was first proposed, and in many subsequent studies, only facilitating conditions and habit among the antecedent variables were considered to have a direct and significant effect on use behaviour (Tamilmani et al., 2021). Thus, the contribution of this study is the finding that to promote robotaxi more effectively, effort expectancy and social influence are influential factors to which robotaxi operators need to pay attention. The conclusion of this study is consistent with the research result of Taneja and Bharti (2021). Facilitating conditions have no influence on users' behavioural intention or use behaviour. As Nordhoff et al. (2020) reported that users are not concerned about the facilitating conditions brought about by the vehicles. This study again validates that convenience is not the primary concern of robotaxi users when considering autonomous vehicles. In addition, behavioural intention is confirmed can be translated into users' actual ride behaviour, rather than just remaining in intention and planning. This finding echoes the research of Gansser and Reich (2021) which suggests a close relationship between behavioural intention and use behaviour. Although behavioural intention was shown to act as an effective mediating variable providing a significant indirect effect of the antecedent variable on use behaviour, these weak boosts from indirect effects do not transform any variable that would otherwise have a non-significant direct effect into providing a significant total effect. These modest boosts

from indirect effects do not bring any of the otherwise insignificant direct impact paths to have a significant total impact. Therefore, the significance of finding a relationship between intention and actual behaviour is limited.

In order to effectively improve users' use behaviour in actual management, robotaxi operators should pay attention to the cultivation of user habit, which is the same as the above-mentioned method to improve behaviour intention. In addition, this study gives the following two recommendations based on the findings, including: 1. Robotaxi operators should lower the technical threshold for taking robotaxi. Because some technically inadequate, and older users often show vulnerability when faced with technology products (Embarak et al., 2021). As a new type of transportation, robotaxi's operation mechanism and use process are not yet familiar to most users. Therefore, users may be ready to take it, but they may also be discouraged by the unknown and difficult operation procedure before actual taking. It is considered that robotaxi operators should try to simplify the process of hailing a taxi and enhance the guidance function of using taxi hailing software from the perspective of interactive interface design. In addition, the necessary threshold for using robotaxi should be lowered. For example, minimizing jargon in the act of human-machine interaction between the hailing software and the ride, and communicating with the user in a more straightforward way. The future fully autonomous driving robotaxi may completely eliminate the need for human drivers (Lim and Hwangbo, 2021b), but this may lead to confusion in the operation of the user who does not have access to direct communication. This study argues that customer service calls and reducing waiting time for inquiries can be considered as alternative answers to this problem. 2. Robotaxis operators are suggested to consider using community marketing or finding key opinion consumers to enhance the possibility of users choosing robotaxi from social opinion. Social influence is when a person trusts the recommendations of others, especially acquaintances, and then gets the idea that he or she should use a new system (Kamal et al., 2020). Therefore, this study suggests that encouraging mutual recommendation among users is one of the effective strategies for robotaxi to gain wider use. Especially in recent years, with the popularity of digital marketing, more information is disseminated to users through experts or key opinion consumers (S. H. Lee and Chow, 2020). These key opinion consumers even participate in the development of product evaluation criteria, which positively influence users' decisions(C. Ng and Law, 2020). Given the correlation between social influence and use behaviour, this study suggests that robotaxi operators should pay attention to community communication and recommendation by friends and family, which are effective means to help robotaxi enter the market.

Notably, although experience, gender and age have been identified as valid moderating variables in many previous studies on UTAUT2 (Bernhard et al., 2020; M. Zhou et al., 2021). There was no significant moderating effect of these three variables in all other path relationships in this study except for gender moderating the relationship path of facilitating conditions on use behaviour. As the only significant moderating effect in this study, the path coefficients for males and females differed but neither met the criteria for significance, which makes the moderating effect much less important. This is probably because robotaxi has just entered the market and various groups of users are generally unfamiliar with this new mode of transportation. As the robotaxi industry continues to develop, different groups may slowly show differences in their perceptions and preferences. Therefore, the survey results reflect the general public's attitude toward robotaxi without preconceived notions and with little actual knowledge. Additionally, it is particularly interesting that we discovered a significant moderating effect of income on the three influence paths of hedonic motivation, habit, and behaviour intention on use behaviour. This finding coincides with the general perception of the high-income group, which seems very willing to engage in behaviours motivated by hedonism. Possibly because the cost of using robotaxis is within their acceptable range, which allows them to indulge in their consumption behaviour purely for pleasure. On the other hand, the low-income group appears to be more driven by habit in their use of robotaxis. This may be due to a sense of familiarity and security provided by long-term living habits and, from a cost perspective, a preference for a fixed lifestyle pattern that minimizes unnecessary additional expenses. When it comes to transforming intention into actual user behaviour, both high and low-income groups show a clear significant path relationship, although the path coefficient is higher in the high-income group. We think this reveals the high-income group's more proactive nature in consumer behaviour, as they do not need to overconsider the potential costs or expenses of an activity. Conversely, while the low-income group also ends up engaging in the behaviour, income factors require them to thoroughly consider their use of robotaxis.

Conclusions

Practical contribution. The results of this study can be a practical reference for robotaxi operators in terms of operation as well as design of robotaxi. First, in order to enhance the behavioural intention of robotaxi users and the conversion of actual use behaviour, robotaxi operators should strengthen the publicity of the practical value of robotaxi for improving traffic efficiency and reducing traffic congestion, and enter the users' vision with the image of efficient travel, so as to improve the users' adoption of robotaxi. Secondly, robotaxi operators may also consider catering to consumers' hedonic motivation by adding visual, auditory, tactile, or other devices or items that can bring novel and interesting ride experiences to robotaxi to expand the human-vehicle interaction dimension, further strengthen the image of robotaxi as an emerging transport tool, create a differentiated ride experience, and enhance the users' ride experience and strengthen the intention of continuous use. In addition, robotaxi operators need to price robotaxi services precisely. A price that is acceptable to consumers determines whether robotaxi services can be widely used, and the price range set should also take the competition and substitution relationship with other transportation modes into account. A service that is sufficiently cost-effective will be able to gain the long-term popularity of users.

Theoretical verification results. This study employed the UTAUT2 model to evaluate the relationship between perceptions and behaviours regarding the use of robotaxis by consumers. The results partially corroborated the relationship paths of the model found in previous research, and we also discovered that some of the classic relationship paths are not significant in the study of robotaxi user behaviour. In other words, we have proposed a targeted development of the UTAUT2 model in robotaxi research. It must be objectively stated that this finding is not a theoretical breakthrough, but it does point out the specific changes in the UTAUT2 model in certain domains with concrete evidence. Moreover, this study also represents a successful and effective application of the classic model. It should be emphasized that the theoretical results of this study are only based on the current stage when this robotaxi market is just starting in China, and the results of the model may change accordingly as the robotaxi industry develops and matures. This study confirms that performance expectancy, hedonic motivation, price value, and habit have significant influence on the behavioural intention of

robotaxi users. And effort expectancy, social influence, and habit have significant influence on consumers' use behaviour. In addition, this study found that users' behavioural intention of using robotaxi did lead to actual use behaviour but the effect was rather limited. Finally, there was a significant moderating effect of gender only on the effect of facilitating conditions on use behaviour in this study. This study speculates that this result stems from the fact that users do not know much about robotaxi as a travel mode today, and that the differences in perceptions and preferences between different groups are not significant.

Research limitations. For more than a decade, China's Internet market has experienced the scene of many industries such as e-commerce, bike-sharing, and takeaway. From nothing to a hundred groups, and the users of these different types of services are about to become the users of the robotaxi industry now and in the future. In other words, the reactions and preferences that users might develop during the process of adapting to lifestyle changes brought about by new technologies could be influenced simultaneously by the interplay of multiple evolving complex applications. However, this study focuses solely on the discussion of robotaxis as a single mode of transportation. It is foreseeable that at this preliminary stage of robotaxi development in China, users' behaviour towards robotaxi is mainly influenced by effort expectancy, social influence, and habit that is in line with expectations and reflects the reality. That is, users' habit of using robotaxi is still in the process of cultivation, and essentially the decisive factors of the consumers' use behaviour are still novelty and cost effectiveness. The development stage of robotaxi industry is one of the limitations of our study. As time progresses and new technologies become more integrated into the social environment, conducting further preference comparisons on an annual basis to solidify the robustness of the theory and develop its soundness would be beneficial. Additionally, due to time and financial constraints, this study only covers users in several provinces in China, which is also one of the limitations. Our conclusions are specific to particular regions and have regional specificity. Conducting surveys and analyses in more regions in the future would benefit the generalizability of the research findings. Moreover, our research was conducted within the framework of the established structural equation modelling theory, which was possibly not comprehensive enough to fully explore the factors affecting Chinese users' acceptance and usage of robotaxis. Future studies could adopt a more comprehensive perspective, such as an open questionnaire, to explore other additional influencing factors.

Data availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Conceptualization: Wei Wei and Chao Gu; methodology: Jie Sun, Wei Miao, and Chao Gu; Formal Analysis, Wei Wei, Tong Chen, and Chao Gu; Investigation: Hanchu Sun, Shuyuan Lin, and Chao Gu; Data Curation: Chao Gu; Writing – Original Draft Preparation: All authors; Writing – Review & Editing: All authors; Visualization: Chao Gu; Project Administration: Chao Gu; Funding Acquisition, Wei Wei.

Competing interests

The authors declare no competing interests.

Ethical approval

This study was conducted according to the guidelines of the Declaration of Helsinki and received academic ethics review and approval (No. CIT MSS-E-2022-001) from the review committee of the Ministry of Social Science, Changshu Institute of Technology.

Informed consent

The authors confirmed that all participants involved in the study were informed of its purposes, potential outcomes, and their rights, including the right to withdraw at any point. They gave their consent to participate voluntarily.

Additional information

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