The Research on Influencing Factors of Autonomous Vehicle Usage Behavior: Root Analysis Based on UTAUT2 Model

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Abstract. As a new sustainable means of transportation, how to successfully make autonomous vehicles accepted and used by the public is a key challenge for research. Based on the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model, the research took the social media platform as the data source to conduct a grounded analysis, comprehensively considered the interaction of individual internal factors and external environmental factors, and combined the technology acceptance field, user behavior field, sociology, psychology, marketing and other disciplines to build an influencing factors of autonomous vehicle usage behavior model, which is suitable for Chinese market. The study found that performance expectation, effort expectation, social impact, facilitating conditions, price value, hedonic motivation, perceived risk and perceived trust influence individuals' intention to use autonomous vehicles. Facilitating conditions, perceived risk and intention affect individual’s usage behavior. The level of individual knowledge plays a regulatory role in the use behavior. The results provide a decision basis for the government and enterprises to effectively promote the use of autonomous vehicles.

Keywords. Marketing, Autonomous vehicle, Use behavior study, UTAUT2 model, Grounded theory.

1. Introduction
By minimizing human intervention and optimizing traffic control system, autonomous vehicles can bring less traffic flow and safer driving environment; therefore, promoting autonomous vehicles has a great significance for constructing a country with strong transportation [1]. The acceptability of autonomous vehicles in the consumer market has become the focus of increasing attention in the academic and business circles. Some domestic and foreign scholars study the various potential factors influencing individual use of autonomous vehicles, but most of the research focuses on the individual internal factors, such as user psychological factors, the research on the interaction between internal factors and external factors are still insufficient, and there is a lack of theoretical framework which is used to systematically analyze the interaction between various factors on the individual’s intention to use and use behavior of autonomous vehicles and the interaction between various factors. Therefore, this research chose the UTAUT2 model, which has the highest degree of explanation in technology acceptance field as theoretical basis, root analysis method is adopted to conduct the exploratory study, finally constructed an influencing factors of autonomous vehicle usage behavior model that is suitable for Chinese market. The research considers the individual psychological level, external environment level, technical level and other various influence factors, combined with the field of technology acceptance, user behavior research, sociology, psychology and marketing, from the perspective of innovation, reveals the influence mechanism on the user’s use intention and use behavior. It provides
directions for government and enterprises to conduct policy research and business development on autonomous vehicles.

2. Literature Review

2.1. Autonomous Vehicle

Autonomous driving refers to the realization of unmanned driving technology by sensing local environment, detecting targets, classifying targets, and using information from different sensors to identify navigation paths on the premise of obeying traffic rules [2]. In recent years, domestic and foreign research on the acceptability of autonomous driving technology has been on the rise. Merat et al. [3] believe that the reliability of autonomous vehicles may be a key factor affecting their use. Ward et al. [4] found that the perception of risks and benefits, knowledge and trust was related to the willingness to use autonomous vehicles. In Finland, Salonen [5] investigated and analyzed the significant differences in the subjective feelings of passengers of different ages, genders and education levels towards traffic safety, in-car safety and emergency management of autonomous buses. On the basis of TAM, ZHANG et al. [6] explored the influence of trust factors and perceived risks on the acceptability of autonomous driving technology. From the current research, the main limitation is that the research focuses more on individual psychological factors and demographic variables, and often ignores external factors, including technical factors and environmental factors.

2.2. UTAUT2 Model

Unified Theory of Acceptance and Use of Technology (UTAUT) was first proposed by Venkatesh, Morris and Davis in 2003 and improved in 2012, finally forming a more complete UTAUT2 theory. UTAUT2 theory comprehensively considers eight classic theories of technology acceptance, and its explanatory power in the field of individual acceptance and use behavior is the highest [7-8]. This theory shows that the seven factors including social influence, effort expectation, performance expectation, facilitating conditions, habit, hedonic motivation and price value directly influence behavioral intention, and behavioral intention, habit and facilitating conditions ultimately determine behavior. Gender, age and experience of use were used as moderating variables to regulate the relationship between antecedent variables and individual intention and use behavior.

UTAUT2 theory research focus on user acceptance and use of behavior in the collaborative teaching, mobile payment, Shared traffic, and other fields, some related research directly uses the original model, some factors affecting to add or remove, some concepts and factors of model for different scene scale redefine [9]. Wang Baoqian and Shao Zhiying [10] modified the UTAUT model based on SEM path analysis, established the user willingness model of Shared electric vehicles in China, and analyzed the factors influencing the user willingness of Shared electric vehicles. The results show that performance expectation, effort expectation, social impact, energy conservation, environmental protection and price value have positive and significant influence on users' willingness to use, while perceived risk has no influence on them.

However, at present, there are few researches on the application of UTAUT2 theory in the field of autonomous driving. Most researchers studied about the use of technology acceptance model or planned behavior model alone. This study chooses UTAUT2 model for the following two reasons: firstly, autonomous driving is a very cutting-edge new technology, which is unfamiliar to the public and belongs to the category of technology acceptance. Based on the previous review of theories in the field of technology acceptance, it is found that UTAUT2 theory integrates eight classical theories and has the highest degree of explanation in the field of technology acceptance. Therefore, it is most appropriate to study the acceptance willingness and use behavior of autonomous vehicles based on this theory. Secondly, UTAUT2 theory comprehensively considers the individual psychological level, external environmental level, technical level and other influencing factors, which can well solve the deficiencies in the field of automatic driving technology acceptance mentioned above.
3. Research Methods and Data Sources

3.1. Research Method
Holden [11] and Zhang Pei [12] believe that UTAUT2 theory is applicable to user research in most fields, but needs to be adjusted and corrected in different application scenarios. Compared with foreign countries, China's autonomous driving technology is less mature and unfamiliar to the public. In addition, due to differences in consumer culture and national personality, there have been some studies on the acceptability of autonomous driving in Europe, the United States and Australia [13-15], but they cannot be applied to the Chinese market. At present, there is still a blank in the domestic research on UTAUT2 model in the field of autonomous driving, so this study adopts the grounded theory method to conduct exploratory research. Grounded theory requires a systematic analysis and induction of the original data to extract concepts and categories, and then through continuous comparison and further refinement, the relationship between each category and concept is finally established to form a theoretical framework. The concrete steps of grounded theory mainly include open coding, spindle coding and selective coding.

As a data source, network text has been widely used in academic research due to its authenticity, freedom, anonymity and openness. Therefore, this study collected network text related to autonomous vehicles as a data source. In terms of platform selection, this study focused on Sina Weibo, Zhihu, Tieba and BBS four major social media platforms with huge user volume and open text information, and selected posts and comments about autonomous vehicles as data sources. After obtaining the data, this study analyzes the sample data in combination with qualitative analysis software NVivo (with the function of quantitative analysis of qualitative data as far as possible [16]). According to the process of grounded theory method, the data after theoretical sampling were coded with open coding, spindle coding and selective coding. After the theoretical degree saturation test, the intention and behavior model of autonomous vehicles based on UTAUT2 model applicable to the Chinese market was constructed.

3.2. Data Collection and Processing
Using octopus data collector (in a short period of time from various websites or web pages to get a lot of normalized data software) to collect Weibo, Zhihu, Tieba, BBS, four platforms on October 1, 2018 to October 1, 2019 times the official posts and "autonomous vehicle acceptance", "use of autonomous vehicles" and "use intention of autonomous vehicles" related posts and Posting a total of 5928, according to the content relevance and value of information filtering: 1) screen out advertisement; 2) screen out forwarding posts and duplicating posts without comments; 3) screen out too simple without substantive point of view. Finally, a total of 3332 posts were obtained for model construction and theoretical saturation. According to the classification of the data source platform, 1938 posts were selected through stratified sampling for modeling, and the remaining 1394 posts were used for theoretical saturation test.

4. Category Refinement and Model Reconstruction

4.1. Open Coding
The open coding stage is to discover the concepts implicit in the text from the original data and categorize them [17]. In this study, sentence by sentence coding is adopted, and the specific coding method is as follows: source platform - tool type - post serial number - sentence serial number. After the coding was completed, Cohen's Kappa value was used for reliability tests, and the reliability coefficient was found to be 0.86, which proved that the coding result had a high reliability and could be used. The group function of NVivo was repeatedly summarized and refined, and 33 initial concepts were formed through preliminary coding (table 1). Then, the categories were further condensed from the initial concepts, and the initial concepts that were repeated for more than 3 times were selected in the study. Finally, 18 categories were obtained, and an original statement was selected to represent
Table 1. Initial concepts and categories in the open coding phase.

| Category                        | Concept           | Sample Original Statement                                                                 |
|---------------------------------|-------------------|------------------------------------------------------------------------------------------|
| Comparative advantage           | Efficiency        | Autonomous cars can improve the efficiency of traffic flow and reduce traffic congestion. (4-1-12-17) |
|                                 | Environmental    | It can be shared and powered by electricity, which is the real green travel (2-3-13-19)   |
| Extrinsic motivation            | Gain time         | With the autonomous car, I got more time to work. (1-1-33-1)                            |
|                                 | Enjoy scenery     | The best way to travel is autonomous cars, and I will not miss the scenery outside the window. (3-1-22-8) |
| Accessibility                   | Convenience       | Because of the convenience provided by autonomous vehicle bus, it has won the public's love (1-2-21-4) |
|                                 | Sharing           | It's sure that autonomous car-sharing improves the social efficiency (4-3-10-5)          |
| Simplicity                      | No intervention  | It can sense the environment without human intervention (3-1-37-2)                       |
|                                 | One click travel  | If there is automatic driverless driving, just press a key to send me to the company. (1-1-18-2) |
| Status symbol                   | Vanity            | Nothing’s more decent than autonomous cars (1-1-34-1)                                    |
|                                 | Personal tag      | The first people to use autonomous driving are more eager to show off their technology enthusiasts’ labels (2-1-13-1) |
| Group psychology                | Influence of friends | There are friends around me who want to buy autonomous vehicles. I also learned about the brand of autonomous vehicles (2-1-19-5) |
|                                 | Social atmosphere | Many people regard autonomous vehicles as a fashion, and it will become a fashion (4-1-14-9) |
| Supporting facilities           | Infrastructure   | According to the current road infrastructure in China, automatic driving is still far away from commercial use (3-1-15-4) |
|                                 | Supporting services | The intercity fast charging network has been fully connected, and autonomous vehicle owners have no worry about charging (1-1-57-2) |
| Traffic policies and regulations | Policy orientation | The Ministry of transport of the people's Republic of China printed and distributed the code for road test management of intelligent Internet connected vehicles (2-1-42-27) |
|                                 | Reward and punishment | We should implement incentive policies to encourage citizens to drive less and take public transport (1-2-31-5) |
| Appearance novelty              | Sense of Technology | Tesla's autopilot is cool and full of technology. It's really fun (2-1-62-3)              |
| Entertainment                   | Interactive       | Autonomous cars unveil a new era of travel, voice                                         |
| Category                  | Concept       | Sample Original Statement                                                                 |
|---------------------------|---------------|------------------------------------------------------------------------------------------|
| operation                 | operation     | manipulation creates new ways of interaction (2-1-48-5)                                    |
| Implementation cost       | Money cost    | Try to save money to buy a Tesla's autonomous car. It's not affordable in a short time (1-1-53-2) |
|                           | Time cost     | Choose autonomous bus in a short distance, and the time is similar to that of cars (3-2-16-4) |
| Perception of behavior    | Reduce traffic| Autonomous cars can improve the efficiency of traffic flow and reduce traffic congestion (4-1-12-17). |
| effect                    | Improve air   | New energy vehicles, reduce the pollution of vehicle exhaust emissions (1-1-73-1)          |
|                           | quality       |                                                                                          |
| Technical risk            | Perception    | Artificial intelligence lacks the ability of emotion perception of social environment, it is difficult to perceive society. (4-1-37-10) |
|                           | defect        |                                                                                          |
|                           | Signal delay  | The car "brain" receives signals with a fatal delay (3-1-22-6)                            |
| Privacy risk              | Hacker attack | Once hackers invade the system, there will be unimaginable and terrible consequences (1-1-69-7) |
|                           | Travel leakage| Tesla has the travel data of all users, which is a terrible privacy risk (2-1-45-3)         |
| Technology maturity       | Readiness     | Holland is the most well-prepared country for autopilot, and Dutch are more likely to accept it (1-1-72-1). |
| Brand image               | High-end      | Tesla takes the lead in the electric vehicle market with high-end technology products (4-1-25-3) |
|                           | technology    |                                                                                          |
|                           | Safety and    | Safety is the most concerned issue of Didi. Didi takes safety first as the code of conduct (2-3-14-5) |
|                           | environmental |                                                                                          |
|                           | protection    |                                                                                          |
| Prior knowledge           | Driving       | In real cities, there must be many places where you can't drive without prior knowledge (2-1-68-3) |
|                           | knowledge     |                                                                                          |
|                           | Autopilot     | I chatted with 20 relatives and friends about autonomous vehicles in the new year, but no one knew (2-1-54-1) |
|                           | knowledge     |                                                                                          |
| Education level           | High level of | A university student says this is unfortunate, but the autonomous vehicle is still the future (1-1-89-33). |
|                           | Education     |                                                                                          |
|                           | Low level of  | When I told my relatives that autonomous cars would run all over the street in 20 years, they mostly don't believe it (2-1-84-25) |
|                           | education     |                                                                                          |

4.2. Spindle Coding

Spindle coding is to mine and construct the potential logical relationship between categories from the categories formed by open coding through cluster analysis. Through spindle analysis, according to the relationship between variables of utat2 theory, the categories that affect the use behavior of autonomous vehicles are classified according to causal analysis and logical thinking, forming two major types of relationships, as shown in table 2.
Table 2. Relationship based on spindle code.

| Number | Relationship category                                      | Category of influence relationship                                                                 |
|--------|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| 1      | Formation of willingness to use autonomous vehicles        | Performance expectation, effort expectation, social influence, facilitating conditions, hedonic motivation, price value, perceived risk, perceived trust |
| 2      | Formation of behavior of using autonomous vehicles         | Use intention, facilitating conditions, perceived risk, knowledge level                              |

The main category analysis is based on the main axis code, and 18 categories are analyzed by the model. According to the correlation, causal conditions and logical relations of each category at the conceptual level, 9 main categories are finally formed, including performance expectation, effort expectation, social impact, facilitating condition, hedonic motivation, price value, perceived risk, perceived trust and knowledge level, as shown in Table 3.

Table 3. Main category based on spindle coding.

| Main category        | Subcategory                  | Category connotation                                                                 |
|----------------------|------------------------------|-------------------------------------------------------------------------------------|
| Performance expectations | Comparative advantage | Autonomous vehicles will improve the quality of life and travel efficiency          |
| Effort expectation   | Simplicity                  | The convenience of using autonomous vehicles                                        |
| Social influence     | Status symbol               | Personal image embodied by using autonomous vehicles                                |
|                      | Group psychology            | Individual behavior tends to be consistent with most people                           |
| Facilitating conditions | Supporting facilities     | Insufficient construction of autonomous vehicles supporting facilities will affect individual willingness to use and behavior |
|                      | Traffic policies and regulations | Government regulations, policies and incentive mechanisms will affect individual willingness to use and behavior |
| Hedonic motivation  | Appearance novelty          | Novelty look will interest users                                                     |
|                      | Entertainment operation     | Automatic operation mode can enhance user experience                                  |
| Price value          | Implementation cost         | The cost of money and time for using autonomous vehicles                             |
|                      | Perception of behavior effect | The effect of the income of using behavior on value perception                       |
Main category | Subcategory | Category connotation
--- | --- | ---
Perceived risk | Technical risk | Perceived risks of autonomous vehicle technology
Privacy risk | | Perceived risk of privacy by using autonomous vehicles
Perceived trust | Technology maturity | The maturity of technology has impact on individual trust
Brand image | | The image of autopilot brand affects the trust of individuals.
Knowledge level | Prior knowledge | Individual's prior knowledge of autonomous driving will affect their use behavior
Education level | | Individual's educational level will affect their use behavior

4.3. Selective Coding
By building a "story line" that can command all categories, selective coding can summarize the categories and main categories of open coding and spindle coding into a complete theoretical framework, and describe the phenomena involved in data [18]. Through the comparative analysis of various categories in the original data and open coding, it can be found that the core category of "autonomous vehicles use behavior" can be compared with other categories of the same age and explain the core issues of this study, as shown in figure 1.

4.4. Theoretical Saturation Test
The coding analysis of the remaining 1394 posts was applied to the theoretical saturation test according to the above method, and the results showed that no new category was found, and no new constituent factors were found in the 9 main categories that affect the autonomous vehicles behavior, and the remaining posts can still be summarized in the model. It can be concluded that the core category of the model has reached saturation.

5. Model Analysis and Research Findings
The study is based on UTAUT2 model and grounded analysis method to construct the influencing factor model of autonomous vehicles use behavior (figure 1). In this model, performance expectation, effort expectation, social influence, facilitating conditions, hedonic motivation, price value, perceived risk and perceived trust affect use behavior by influencing potential users' use intention, and knowledge level is used as a regulating variable to regulate use intention. The influence of using behavior, including facilitating conditions and perceived risk, will also directly affect using behavior.

5.1. Formation of Intention to Use Autonomous Vehicles
Performance expectation has a positive impact on the autonomous vehicle behavior of individuals, which is reflected in the benefits brought by comparative advantage and extrinsic motivation. The safety and environmental protection in comparative advantage, and the more time gained in extrinsic motivation have a greater impact on the performance expectation of individuals. 2) Effort expectation refers to the degree of difficulty and convenience for individuals to use autonomous vehicles. This study found that the stronger the individual's effort expectation for autonomous vehicles, the stronger their willingness to choose autonomous vehicles. 3) Social impact can also positively affect the willingness to use autonomous vehicles. Social impact mainly affects individual willingness through personal image symbols, subjective norms and herd psychology. 4) Facilitating conditions have a positive impact on the willingness to use autonomous vehicles. Through the improvement of infrastructure, traffic policies and regulations, and traffic management level, it can provide users with
the facilitating conditions to use autonomous vehicles. 5) Hedonic motivation has a positive impact on the willingness of individuals to use autonomous driving. Hedonic motivation mainly attracts users' interest through innovative space, novel appearance and entertaining operation. 6) Price value has a positive impact on users' behavior intention, which means that users pay more attention to the price when choosing whether to drive automatically or not. 7) Perceived risk has a negative impact on the individual's willingness to use, among which the individual's perception of technical risk and psychological risk is the strongest. 8) Perceived trust has a positive impact on individual willingness to use. Technology maturity and brand image are important factors that affect individual perceived trust.

Figure 1. Model of factors influencing the use behavior of autonomous vehicle.

5.2. Formation of Autonomous Vehicles Use Behavior
Adjustment of knowledge level. This study found that knowledge level as a moderating variable affects the use behavior. The richer the prior knowledge about autonomous vehicles and the higher the education level of potential users, the more likely they are to use automatic driving products. 2) Impact of facilitating conditions and perceived risk. This study found that facilitating conditions and perceived risks can directly affect individual's behavior of using autonomous vehicles, that is to say, when the infrastructure, traffic policies and regulations and traffic management level meet certain standards, individual experience will directly generate the behavior of choosing autonomous vehicles, and the same way, when individual perceived technical risk, ethical risk and privacy risk are too high, they will not form Use behavior. 3) Intention and behavior of using autonomous vehicles. The core idea of UTAUT2 is that the individual's behavior intention determines its actual behavior, and the technology acceptance model also confirms the intention decision behavior. It can be seen that the individual's use behavior is a rational behavior, which has a strong correlation with behavior will. The formation of use behavior is closely related to the formation of behavior intention.

6. Conclusions and Suggestions
6.1. Conclusion and Contribution
1) Based on UTATU2 model, the study creatively constructs a technology acceptance and use integration model applicable to the consumer market of China's autonomous vehicles, it reveals the influence mechanism of performance expectation, effort expectation, social influence, facilitating conditions, hedonic motivation, price value, perceived trust, perceived risk and knowledge level to control user's use intention and use behavior, and expands the theoretical scope of UTAUT2 model.

2) Existing researches mostly study the use intention and behavior of autonomous vehicles through questionnaire survey, experimental interview and other methods. In this study, the qualitative research
method based on the grounded theory was used for exploratory research. By collecting the online texts on four large social media platforms, Weibo, Zhihu, Tieba and Forum, which is more authentic, objective and comprehensive. Grounded theory has been paid more and more attention in management, sociology and other fields. However, it is rarely used in the research field of autonomous driving user behavior. This study provides a new method reference for the research in technology acceptance field.

3) Most of the existing researches only focus on individual influencing factors. This study combines technology acceptance field, user behavior field, sociology, psychology, marketing and other disciplines to build a model of influencing factors of autonomous vehicles use behavior, forming a multi-disciplinary intersection, and more comprehensively analyzing the factors on internal psychology level, external environment level, technology system level, and public policy level. It reveals the influence of various factors on user's intention and behavior, as well as the relationship between these factors, which has improved the research on the acceptance and use behavior of autonomous vehicles.

6.2. Management Suggestions
In order to promote the commercial development of autonomous vehicles and promote the use behavior of the public, the following suggestions are put forward according to the research conclusion of this study:

1) For the government, first of all, it should increase the public publicity of autonomous vehicles, actively guide the public to accept and trust the automatic driving technology, issue public service advertisements, and publicize the environmental and social benefits brought by automatic vehicles; secondly, the government should establish complete and effective laws and policies, and clarify the allocation of responsibilities, solve ethical risks, and protect the legitimate rights and interests of users; thirdly, the government should improve the supporting facilities implementation and service, increase the construction of intelligent transportation infrastructure, ensure good road conditions, provide strong support for the landing of autopilot cars. Finally, it is necessary to provide support such as subsidize for autonomous vehicle company to ensure the rapid development of technology, and pave the way for the realization of a country with transportation power.

2) For autonomous vehicle companies, first of all, it is necessary to constantly improve the level of technological innovation, the performance and configuration of autonomous cars, the novelty and entertainment of the products and enhance the user experience; secondly, the companies need to increase advertising input, publicize the values of enterprises, and create a brand image of safety, green and high-tech so as to enhance public trust; Thirdly, simplify the operating system, make the product simpler and easier to use, reduce the user's learning time cost; Besides, ensure the reliability and stability of technology to resist hacker attacks, to ensure the security of user travel data to reduce privacy risks; finally, enterprises should spread the knowledge of autonomous vehicles through major new media platforms, supplement the prior knowledge of the public, and promote the formation of their use behavior. In the early stage of the market, targeted marketing can be carried out for individuals with higher education level, so as to promote them to choose autonomous vehicles. In the later stage, individuals with lower education level will have follow-up behavior due to social impact.

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