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Jianan Lyu

A Study on Chinese Users' Acceptance of Camera Monitor System Based on the Modified UTAUT2 Model

Jianan Lyu

School of Art and Design, Huizhou University, Huizhou 516007, China

coqw82@sina.com

Abstract: With the continuous development of automotive technology, the camera-monitor system (CMS) has gradually emerged as a new type of indirect vision device. However, even after more than 20 years of development, the market penetration rate of CMS in China is still less than 1%. This study aims to explore the key factors influencing the acceptance of CMS among Chinese passenger car users using the modified Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model to break the barriers to acceptance and use. The study collected 394 valid samples through a questionnaire survey and analyzed the data using the structural equation model (SEM). The results show that effort expectancy (EE), performance expectancy (PE), hedonic motivation (HM), and price value (PV) significantly affect behavioral intention (BI), among which EE has the most significant influence, followed by PE, PV, and HM. BI significantly influences drivers' usage behavior (UB). In addition, facilitating conditions (FC) and habit (HB) have a direct positive effect on UB. This study provides valuable insights for manufacturers to improve product design, optimize user experience, and formulate effective market strategies, helping to accelerate the popularization of CMS in China. At the same time, the research not only expands the application of the UTAUT2 model in the field of automotive technology acceptance but also provides practical significance for promoting the widespread acceptance of CMS.

Keywords: UTAUT2, User Technology Acceptance, CMS, User Acceptance Behavior

1. Introduction

With the rapid development of intelligent and connected vehicles as well as autonomous driving technologies, automotive electronic vision systems are gradually replacing traditional mechanical components, becoming key technologies for enhancing driving safety and user experience. The CMS, as a new type of indirect vision device, replaces traditional glass rearview mirrors with high-resolution cameras and in-vehicle displays, providing drivers with clearer, wider, and smarter visual support (see figure 1). Compared to traditional mirrors, CMS not only eliminates blind spots but also delivers stable imaging under low-visibility conditions such as nighttime, rain, or fog, significantly improving driving safety and comfort [1, 2].

Figure 1. Audi E-Tron CMS.

Since the 1990s, automotive manufacturers in Japan and Europe have begun developing CMS technologies. With advancements in image sensors, in-vehicle displays, and real-time image processing, CMS has evolved from proof-of-concept to commercial applications. In 2022, China officially released and implemented the new national standard GB 15084-2022, legally recognizing CMS as a compliant replacement for traditional rearview mirrors, marking a new stage of policy support and standardization for CMS in the Chinese market [3]. However, despite its technological maturity, the market penetration of CMS in China remains below 1% [3], significantly lower than in Europe, where high-end models such as the Audi e-tron and Honda e already feature CMS as standard equipment. This paradox of "technological readiness but market stagnation" highlights low user acceptance as a critical bottleneck hindering CMS adoption [4].

From a societal perspective, Chinese consumers are increasingly demanding vehicle intelligence, safety, and technological experience. According to iiMedia Research [5], the market size of intelligent and connected vehicles in China exceeded 1.2 trillion RMB in 2023 and is projected to surpass 2 trillion RMB by 2025. Intelligent features have become a key factor influencing consumer vehicle purchase decisions. Meanwhile, under the national "New Four Modernizations" strategy (electrification, intelligence, connectivity, and sharing), automakers are accelerating the deployment of intelligent sensing systems. As a core component of this ecosystem, CMS holds significant market potential. However, current user awareness of CMS remains limited, with widespread concerns about its functionality, reliability, and cost-effectiveness, resulting in a significant gap between technological potential and market acceptance [6].

Compared to traditional rearview mirrors, CMS offers the following advantages:

Wider field of view and reduced blind spots: CMS cameras provide broader lateral and longitudinal visibility, effectively reducing side and rear blind spots and improving safety during lane changes and reversing maneuvers [1];

Stronger environmental adaptability: CMS includes features such as night vision enhancement, anti-glare, and dynamic contrast adjustment, maintaining clear imaging in complex environments like nighttime, rain, or fog [7];

High integration potential with intelligent systems: CMS can be deeply integrated with Advanced Driver Assistance Systems (ADAS), blind-spot detection, and lane-keeping systems to enable information fusion and enhance overall vehicle intelligence [8];

Optimized vehicle design: Replacing traditional side mirrors reduces aerodynamic drag, improving vehicle airflow and contributing to extended driving range, especially for electric vehicles [4];

Personalized user settings: CMS allows users to adjust viewing angles, brightness, and display modes according to personal preferences, enhancing driving comfort and interactive experience [9].

Despite these advantages, CMS acceptance in China faces multiple challenges. On the one hand, users lack sufficient understanding and hands-on experience with CMS; on the other hand, high system costs and underdeveloped after-sales support further inhibit purchase intentions [3, 4]. Therefore, it is crucial to investigate the key factors influencing user acceptance of CMS and to uncover the psychological and behavioral mechanisms underlying the transition from user cognition to actual usage. Such insights are of great theoretical value and practical significance for promoting CMS acceptance and market popularization.

This study employs the modified UTAUT2 as the theoretical framework to construct a CMS acceptance model tailored to Chinese passenger car users. The model systematically analyzes how PE, EE, HM, and PV influence BI and actual UB. UTAUT2 has been widely validated across various technology acceptance contexts and demonstrates strong explanatory power [9, 10]. However, its application in CMS research remains scarce. This study fills a critical gap in the literature by extending UTAUT2 to the CMS domain and provides empirical evidence to support manufacturers and policymakers in optimizing product design, enhancing user experience, and formulating effective market strategies.

Through this research, we aim to break the deadlock of “advanced technology but low acceptance” for CMS in China, contribute to the intelligent transformation of the automotive industry, and support the transition of CMS from a “premium option” to a “standard feature.”

In response to the challenges faced by CMS acceptance, this study has identified three research objectives as follows:

RO1: Explore the key driving factors influencing Chinese passenger car users' willingness to adopt and use CMS to clarify the extent of users' acceptance of CMS technology and their psychological expectations.

RO2: Analyze how users' BI is transformed into actual UB under the influence of factors such as PE, EE, HM, and PV, to reveal the psychological and behavioral paths of users' acceptance of CMS.

RO3: Evaluate the direct promoting effects of FC and usage inertia on the actual UB of CMS, providing a basis for manufacturers to optimize product design, enhance user experience, and formulate market strategies, to accelerate the popularization and application of CMS in the Chinese market.

2. Literature Review, Hypotheses Development, and Research Framework

2.1. Literature Review

2.1.1. Current Research Status on CMS

Existing academic research on CMS primarily concentrates on three interrelated domains: (1) human-factor performance evaluation, (2) technical safety and image-quality enhancement, and (3) regulatory benchmarking and market outlook. First, simulator and on-road experiments consistently show that CMS can widen the horizontal field of view by 15–30 % and eliminate door-pillar blind spots, leading to shorter lane-change times and fewer glances away from the road compared with traditional mirrors [1, 11]. However, gaze-transition times initially increase when drivers switch from mirrors to monitors, stressing the need for interface consistency and adequate learning support [12].

Second, studies targeting image quality underline that high-dynamic-range (HDR) imaging, low-latency (< 60 ms) video pipelines, and glare-free LCD bonding are critical for maintaining situational awareness in night, rain, or tunnel ingress/egress scenarios [7, 13]. Objective metrics such as modulation transfer function (MTF) and veiling-glare index have been proposed to quantify CMS clarity under real-world stray-light conditions, forming the technical basis for the recent UN R46 and China GB 15084-2022 homologation tests [2].

Third, regulatory and market-oriented analyses reveal that while Japan and the EU allowed passenger-car CMS type-approval in 2016–2017, China only legalized CMS in July 2023; as a result, penetration remains < 1 % in China versus ≈ 10 % in Western Europe [3, 4]. Cost-benefit modeling further indicates that CMS unit costs must fall below 1,500 RMB and be bundled with after-sales calibration services to achieve positive price-value perception among mid-range Chinese buyers [3, 4]. Collectively, the literature confirms CMS safety and aerodynamic dividends, but also exposes research gaps in user-centered acceptance formation and economically viable business models within the Chinese context.

2.1.2. Current State of CMS User-Acceptance Research

Wei et al. [4] suggested that the development of CMS in China is mainly constrained by: (1) policy restrictions, as vehicles equipped only with virtual rearview mirrors cannot be sold or driven in China according to the provisions of the "GB15084-2013: Performance and Installation Requirements for indirect Vision Systems in Vehicles"; (2) ergonomics adaptation of the in-vehicle display interface; (3) overcoming the threshold of industrialization costs; and (4) verifying the reliability of multimodal environmental perception. Empirical research indicates that, although this study systematically identifies the objective limiting factors of technology acceptance, it has limitations in its perspective, as it fails to integrate subjective cognitive dimensions such as Perceived Usefulness (PU) and BI, and does not establish a theoretical mapping relationship between technological features and user experience. This could reduce the explanatory strength of current research findings.

Bernhard et al. [1] conducted an online study on CMS payment willingness and the price users are willing to pay. It should be noted that the methodology in Bernhard and Hecht's study has some limitations. In their experimental design, participants did not have direct contact with the core functions of CMS; instead, they evaluated CMS through static visual materials such as pictures or videos. This indirect experience might introduce biases in how participants perceive the benefits and limitations of CMS, consequently impacting the accuracy of the evaluation outcomes. Therefore, the study's conclusions require further validation to establish their reliability and generalizability. This can be achieved through additional empirical research that more accurately reflects real-world use scenarios.

Tan et al. [6] highlighted that several critical challenges can be found in human-machine interaction (HMI) for intelligent connected vehicles. These challenges include technology acceptance, the quality of HMI, and overall user experience. Notably, user acceptance and trust, which are key human factors, are critical in influencing autonomous driving technology's sustainable progress as well as user satisfaction.

2.1.3. The Research Status on the UTAUT2

A longitudinal study has been completed by Venkatesh et al. [14], and it aims to compare the UTAUT with eight alternative models: Social Cognitive Theory (SCT), Motivational Model (MM), Technology Acceptance Model (TAM), Combined TAM and TPB (C-TAM-TPB), Theory of Planned Behavior (TPB), Innovation Diffusion Theory (IDT), Model of PC Utilization (MPCU), and Theory of Reasoned Action (TRA). According to the findings of this research, the above-mentioned models' predictive ability toward behavioral motivation varied from 17% to 53%. Meanwhile, UTAUT achieved an efficiency of 70%, outperforming all other theoretical models. The UTAUT model provides a framework for understanding how individuals adopt and use technology, and it has been widely used in ADAS research [8, 15], demonstrating its considerable application potential in the area of automotive technology acceptance.

When consumer technologies diffused beyond organisational boundaries, scholars criticised UTAUT for ignoring price sensitivity, enjoyment, and habit—drivers decisive in voluntary, high-involvement purchase contexts [9]. The same authors therefore extended UTAUT into UTAUT2 by adding HM, PV, and HB and by modelling HB as a direct antecedent of UB as well as an indirect antecedent via BI. During the past decade, cross-cultural studies show that:

- HM and PV consistently influence BI for experiential or high-ticket innovations (mobile commerce, Cameroon [16]; autonomous vehicles, Korea [17]; battery-electric cars, Turkey [18];
- HB is the strongest longitudinal predictor of continued use once a product is acquired [10, 19].

CMS is a consumer-paid, durable automotive device that (i) delivers utilitarian safety gains (PE), (ii) requires low learning effort (EE), (iii) depends on dealer support and regulation (FC), (iv) offers novelty and visual enjoyment (HM), (v) competes on cost-effectiveness against mirrors plus sensors (PV), and (vi) becomes automated through repeated lane-change glances (HB). These six antecedents map exactly onto the UTAUT2 construct set that UTAUT omits. Consequently, adopting UTAUT2 provides three theoretical advantages over UTAUT:

1. Complete coverage of consumer decision triggers (HM, PV, HB) proven decisive in high-involvement technology acceptance;
2. Direct modelling of habit-formation paths critical for safety-related equipment that must be used automatically;
3. Continuity with prior automotive ADAS research that successfully employed the original UTAUT core (PE, EE, FC) [8], ensuring comparability while extending explanatory power to the consumer context.

2.1.4. Research Gap and Study Positioning

In summary, although the UTAUT2 model has been validated in ADAS acceptance research, its application to CMS—a novel and distinctive in-vehicle system—remains largely unexplored. Existing studies on CMS acceptance primarily focus on technical, regulatory, or isolated factor analyses, lacking a comprehensive theoretical framework that integrates users' subjective cognition, affective experiences, economic considerations, and habit formation processes. Given the significant differences between CMS and most previously studied ADAS in terms of functional nature (passive visual replacement), interaction patterns (high-frequency, continuous), and decision-making context (consumer-paid voluntary adoption), a systematic investigation into the mechanisms of user acceptance for CMS not only holds practical urgency for overcoming market diffusion barriers but also offers the potential to provide new empirical evidence and theoretical insights for the applicability and refinement of the UTAUT2 theory in the context of consumer-oriented, safety-critical, habit-forming automotive technologies. Therefore, this study aims to fill this gap.

2.2. Research Hypotheses and Research Model

In the UTAUT2 model, FC is the users' perceived level of organizational and technical infrastructure support for system use [9]. As a novel HMI device, CMS demands drivers to master specific skills like real-time perspective and brightness adjustment, and rapid display issue resolution. If users lack these capabilities, they may find it difficult to smoothly accept and continuously use the system. Moreover, the regular operation of CMS highly depends on vehicle bus matching, display system compatibility, and subsequent software maintenance. When users perceive that the manufacturers can provide comprehensive technical support—such as on-site demonstrations at 4S stores, one-click upgrades through official APPs, and free replacement of camera modules within the warranty period—the operational threshold and usage risks are significantly reduced. Therefore, the following hypothesis is proposed:

H1: Among Chinese passenger car users, the more fully perceived the "FC" is (i.e., the more complete the external resources such as pre-installation of vehicles, system compatibility, after-sales support, and regulatory compliance are), the more significantly their continuous UB of CMS is enhanced.

PE is described as the degree of belief that users have in the significant improvement of their task completion effectiveness through the use of a specific technology [9]. By expanding the field of vision, eliminating blind spots, and providing enhanced images at night or in bad weather, CMS directly improves driving safety and convenience. The more significant the benefits perceived by users, the stronger their willingness to accept. Based on the preceding considerations, the study establishes the following hypothesis:

H2: Among Chinese passenger car users, the higher the PE of CMS, the more significantly their BI to adopt it increases.

EE refers to the cognitive and operational costs that users expect to pay to master and continuously use the technology [9]. When the interface and interaction logic of the CMS are highly consistent with existing driving habits (such as seamless interaction with the central control screen or streaming media rearview mirror), the additional effort required by users is reduced, and their willingness to adopt it increases accordingly; conversely, complex menu hierarchies or additional eye movements will weaken the willingness. Numerous researches demonstrate that EE considerably impacts the willingness to adopt and use IT devices [20]. In the TAM, EE plays a crucial role, especially when a technology is first introduced; its influence reaches its peak [21]. The simplicity or complexity of the technology operation often becomes the key factor in determining whether users are willing to accept the technology [22]. Based on this, this study proposes the following hypotheses:

H3: Among Chinese passenger car users, the lower the "EE" for CMS (i.e., the easier and less effortful users perceive learning and using the system to be), the more significantly their acceptance intention increases.

In technology acceptance research, BI is the core indicator of users' willingness to adopt and continue using a specific technology. It captures their subjective readiness to engage in the behavior and is a key predictor of actual use (UB). In the research context of the CMS, BI reflects the psychological commitment formed by users to use or continue using the CMS after comprehensively considering its functionality, ease of use, economy, and pleasant experience. This concept helps us understand the critical transformation stage from cognition to behavior, providing an important basis for analyzing and predicting the market acceptance of CMS.

Accordingly, the study proposes the following hypothesis:

H4: Among Chinese passenger car users, the stronger BI toward CMS is positively associated with actual UB.

The HM typically describes the pleasure and satisfaction that users experience when using technology [9]. Research indicates that this sense of pleasure is a significant factor influencing the acceptance and use of technology, and it plays a significant role in predicting people's willingness to adopt different technologies [9, 16, 18]. This study posits that the "driving pleasure" and "novelty experience of technology" provided by the CMS, through features such as high-definition wide-angle images, night enhancement, and blind spot visualization, can stimulate users' intrinsic motivation beyond mere practical considerations. Therefore, this study proposes:

H5: Among Chinese passenger car users, the stronger HM toward CMS significantly increases BI.

PV mainly describes the process in which consumers perceive and balance the benefits they obtain and the costs they need to pay during the use of technology [9]. That is, the net utility evaluation formed by users after weighing the functional benefits brought by the CMS against its purchase/maintenance costs. When users believe that the safety gains, driving convenience, or brand premium brought by the CMS are sufficient to offset the additional expenses, the acceptance intention increases; otherwise, it decreases. Since the introduction of PV in UTAUT2, some studies [17, 18] have shown that there is a significant association between PV and BI. Therefore, this study proposes:

H6: Among Chinese passenger car users, the higher PV toward CMS significantly increases BI.

HB represents the degree to which consumers form habitual behaviors towards technology and systems [9]. Frequent and context-stable driving scenarios (such as the same route during morning and evening rush hours) prompt users to form an automatic script of "getting in the car → starting the engine → naturally looking at the CMS", reducing cognitive load and thereby strengthening continuous use. Raman and Don [19] confirmed in studies on social media learning tools and others that when users use technology frequently, over a long period, and in stable contexts, HB significantly and positively predicts continuous UB. Schmitz et al. [10] analyzed 66 UTAUT2 studies in the literature. Further, they pointed out that more than half of the empirical studies have examined the HB variable, among which 23 explicitly reported significant effects. These cross-domain and cross-cultural evidences provide a solid theoretical and empirical basis for introducing and testing "HB" in the adoption research of CMS in China. Building on the above analysis, this study formulates the subsequent hypothesis to guide the research exploration:

H7: Among Chinese passenger car users, stronger HB significantly increases continued UB.

Social Influence (SI) is omitted for both empirical and theoretical reasons. SI denotes “the extent to which an individual perceives that important others believe he or she should use the new system” [9]. However, a growing body of automotive-human-factors research shows that driving is a “private, enclosed and highly individual task setting” where peer pressure is markedly weaker than in organisational or social-media contexts. König & Neumayr [23] explicitly demonstrate that drivers tend to ignore social norms while inside the vehicle, supporting the view that the cockpit functions as a private space. In line with this, Bernhard et al. [1] found that only 5.8 % of respondents felt that friends or colleagues would influence their decision to adopt CMS, while safety and price were rated as decisive by over 60 %. Following the parsimony principle [24], this study therefore excludes SI to maintain model clarity and conserve statistical power for constructs with larger variance contributions.

Combining previous academic achievements with the unique features of CMS, this research adopts the UTAUT2 theoretical framework proposed by Venkatesh et al. [9], aiming to analyze the variable structure and formulate research hypotheses. The study retains the key elements of the original UTAUT2 framework, such as EE, PE, FC, HM, PV, and HB. As demonstrated in Figure 2.

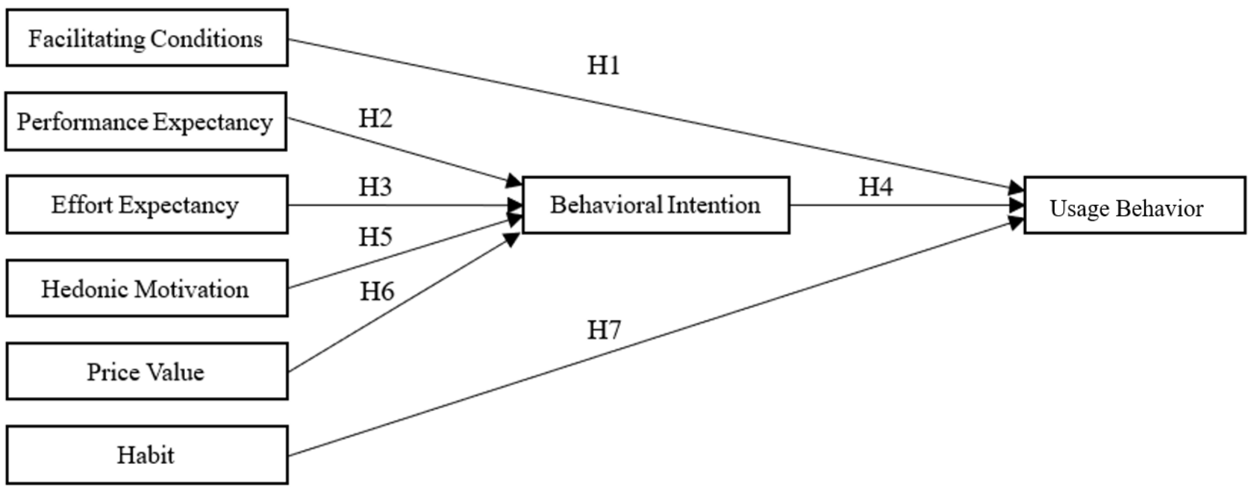


Figure 2. The Study's Hypotheses and the Modified UTAUT 2 Conceptual Framework.

3. Methodology

3.1. Sample Description

All procedures involving human participants were conducted in accordance with the Declaration of Helsinki and relevant national regulations. The study protocol, including the collection of identifiable images and the use of questionnaire data, was reviewed and approved by the Biomedical Ethics Committee of Huizhou University (Approval No. 2024IAC016). Written informed consent was obtained from every participant and/or their legal guardian prior to any data collection. Participants were informed of their right to withdraw at any time without penalty. All methods were carried out in compliance with the approved guidelines.

In June 2024, this study was conducted in three enterprises of comparable scale in Huizhou, with a wide range of employees. A stratified cluster sampling method was adopted, taking into account regional and job diversity. In the first stage, all current employee lists were retrieved, and functional departments stratified employees. Then, employee numbers were randomly selected from each stratum using a random number table, resulting in 603 candidates. In the second stage, electronically informed consent forms were sent to them, and those who had no intention or did not hold a valid driver's license were excluded. Ultimately, 407 people were included in the study. An independent data administrator ran the sampling script, and the researchers operated in a blinded manner throughout the process to prevent human intervention and ensure reproducibility. The sample covered 27 provincial administrative regions across the country, and the distribution of gender, age, education level, and job positions was less than 5% different from the overall enterprise population, demonstrating good generalizability.

A total of 407 usable questionnaires were gathered. Respondents who did not consent to data processing, did not possess a valid driver’s license, or did not finish the whole survey were left out based on a predefined standard. Finally, 394 valid responses were analyzed. It meets the sample size requirements of Boyd et al. [25] and Hair et al. [26], aligned with the research hypotheses.

This study enlisted 394 participants, as detailed in Table 1. Of these, 296 were male (75.1%), and 98 were female (24.9%). Participant ages varied widely, spanning from 18 to 54 years. Driving experience was distributed by years as follows: 0-3 (42.4%), 3-5 (24.6%), 5-8 (20.6%), and more than 8 (14.5%). Furthermore, 76.4% of the respondents owned a vehicle.

Table 1. Characteristics of CMS Users.

Variable	Level	Frequency	Percent %
Age	18-24	41	10.4
	25-39	249	63.2
	40-54	104	26.4

Variable	Level	Frequency	Percent %
Gender	female	98	24.9
	male	296	75.1
Driving experience	0-3	167	42.4
	3-5	97	24.6
	5-8	69	17.5
	>8	61	15.5
CMS experience	0-3	152	38.6
	3-5	104	26.4
	5-8	81	20.6
	>8	57	14.5
Car ownership	yes	301	76.4
	no	93	23.6
	Total	394	100.0

3.2. Research Instrument

This study's questionnaire, outlined in Table 2, comprises two primary sections. The first section aims to gather participants' demographic details, including age, gender, CMS usage history, driving experience, and vehicle ownership. This comprehensive approach ensures a robust contextual foundation for the research.

The second part of the questionnaire in this study centers on the core variables of the UTAUT2 model, employing a measurement tool adapted from the original UTAUT2 scale introduced by Venkatesh et al. [14]. However, these were accepted and refined to better accommodate the specific background of this study, ensuring that the scale accurately reflects the research objectives. This adjustment process followed the practices of prior relevant studies [27] to ensure the theoretical consistency of the scale and its adaptability to the actual study context.

The measurement items were subsequently systematically optimized and refined through multiple rounds of in-depth discussions and exchanges with senior experts in the automotive electronics field. To further enhance the professionalism and practicality of the questionnaire, the research team collected feedback via email from 15 industry experts and experienced drivers. Based on this feedback, the questionnaire items were rigorously revised and finalized to ensure their scientific accuracy and applicability.

In the latter section, a seven-point Likert scale was utilized to boost the precision and neutrality of data gathering, leading to more trustworthy outcomes in quantitative analysis.

Table 2. CMS Acceptance Survey Questionnaire.

Construct	Construct Definition	Item
Demographic	Age	What is your age?
	Gender	Please indicate your gender.
	Driving experiences	Please indicate how many years of driving experience you have.
	CMS experiences	Please specify the number of years you have been using CMS.
	Car ownership	Do you have a car?
PE	PE indicates the extent to which an individual perceives CMS acceptance as beneficial and how this perception drives their belief in CMS's ability to boost driving performance.	PE1 Using CMS can significantly enhance my driving safety in complex road conditions. PE2 The CMS helps me complete lane changing or reversing operations faster and more accurately. PE3 Compared with traditional rearview mirrors, CMS allows me to see more clearly at night or in bad weather. PE4 Overall, the CMS has significantly enhanced my driving efficiency and confidence.
EE	EE refers to the cognitive and operational costs that users expect to pay to master and continuously use the technology [9]. A higher EE score reflects easier learning and use of CMS.	EE1 Learning to operate the CMS poses no difficulty for me. EE2 I can master all the functions of the CMS without expending too much effort. EE3 The interface and operation logic of the CMS are clear and intuitive, allowing for quick mastery. EE4 It is effortless for me to adjust the perspective or brightness of the CMS.
FC	In the context of the use of CMS, FC refers to all the external support resources and institutional guarantees perceived by users.	FC1 The 4S store/manufacturer provided thorough on-site demonstrations and usage training, enabling me to understand how to operate it. FC2 When the CMS malfunctions, I can conveniently obtain maintenance or software upgrades through official channels. FC3 The current regulations and warranty policies provide sufficient support and guarantee for the use of CMS. FC4 The official APP or in-car system provides clear online help and one-click fault diagnosis, allowing me to solve problems at any time.

Construct	Construct Definition	Item
BI	BI refers to the subjective plan and willingness of Chinese passenger car users to "actively and continuously use CMS" in the short term.	BI1 If conditions permit, I will install or upgrade the CMS system for the existing vehicles as soon as possible. BI2 I am willing to recommend the use of CMS as a necessary safety feature to others. BI3 When I buy a car next time, I will take into consideration whether it is equipped with CMS as an important decision-making factor.
UB	UB refers to the patterns, habits, and actions of drivers when interacting with a CMS.	UB1 I will take the initiative to use CMS to assist in driving. UB2 I will encourage others to use CMS. UB3 I plan to keep using CMS.
HB	HB refers to the degree to which consumers have formed habitual behaviors towards CMS.	HB1 Every time I get into the car, I would check the image on the CMS without thinking twice. HB2 Using CMS has become a fixed HB in my daily driving. HB3 When I need to change lanes or reverse, I always automatically rely on the CMS rather than the traditional one. HB4 If a vehicle is not equipped with CMS, I would feel that the driving process is not smooth.
PV	PV refers to the subjective net utility assessment of "getting good value for money" formed by users after weighing the functional benefits brought by the CMS (such as driving safety, blind spot elimination, enhanced visibility at night or in bad weather, potential insurance discounts, etc.) against its total monetary cost (one-time purchase cost, long-term maintenance/upgrade cost, and potential depreciation risk).	PV1 I think that considering the security and convenience provided by CMS, its price is reasonable. PV2 The subsequent maintenance and upgrade costs of the CMS are within my acceptable range. PV3 Considering the possible reduction in insurance or accident costs, using CMS is worth the investment. PV4 Compared with installing traditional rearview mirrors or blind spot radars, CMS offers better cost performance.

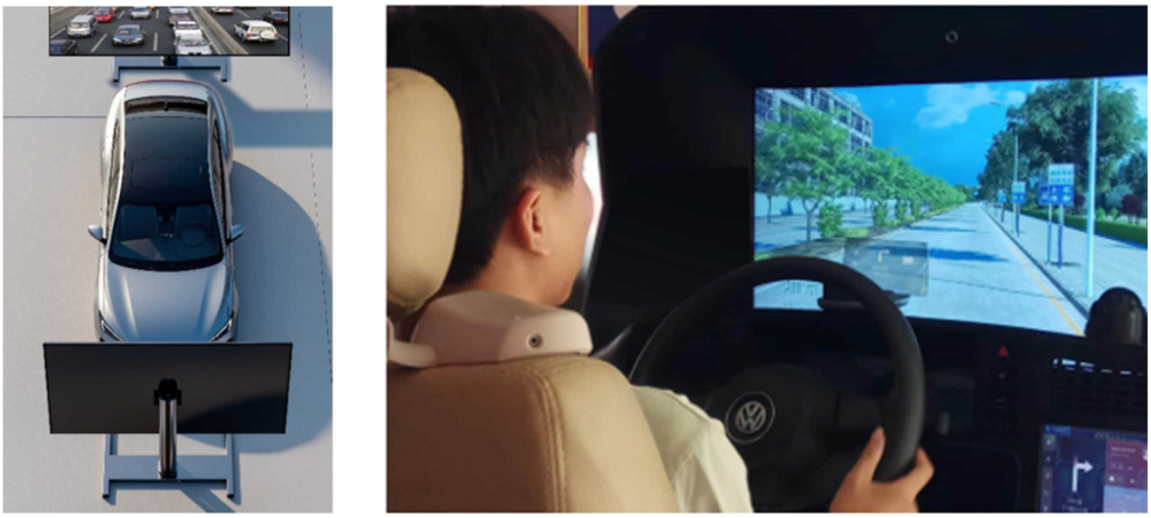
Construct	Construct Definition	Item
HM	HM refers to the immediate pleasure, technological novelty, and aesthetic enjoyment that users obtain from using the CMS itself, rather than the intrinsic motivation driven by functional or performance considerations.	HM1 Using CMS makes me feel happy when driving. HM2 The high-definition wide-angle view of the CMS brings me visual enjoyment. HM3 I think using CMS is an enjoyable technological experience. HM4 Operating the various functions of the CMS itself brings me great pleasure.
Total		3**5**

3.3. User Experience CMS Experiment Simulation and Data Collection Procedure

a b c

Figure 3. Beijing Auto Magic Cube and Its CMS

The research adopted a method combining real vehicle static experience with scenario simulation, which was carried out in the cabin of a 2022 Beijing Magic Cube car (Figure 3a). The vehicle was originally equipped with dual-side CMS (Figure 3b) and a 10.25-inch high-brightness LCD interior screen (Figure 3c). To create a high-fidelity driving scenario, two LED screens were set up 2.5 meters in front of and behind the vehicle (Figure 4a), used to dynamically render complex driving scenarios including urban congestion, low-light at night, rainy and foggy weather, and lane changing on highways.



a b

Figure 4. Driving Situation Simulation (Photos Taken by the Author)

The experimental procedure follows a standardized three-stage protocol. Stage one: Preparation and guidance. Before entering the experimental environment, participants receive standardized guidance from the experimenter, covering the functions of the CMS system, the operation interface, and the task objectives. The duration is controlled within 5 minutes to ensure that all participants have a consistent initial cognitive baseline. Stage two: Contextualized experience. Participants enter the driver's seat and have a 5-minute autonomous experience (Figure 4b). During this period, participants can freely operate the vehicle and observe the external dynamic simulation scenes through the CMS system, focusing on perceiving its performance in terms of field of view, image clarity, and adaptability to special environments. The experimenter does not intervene but only provides necessary scene-switching prompts. Stage three: Data collection. After the experience session, participants immediately fill out a standardized evaluation questionnaire based on the TAM and PU theory.

The study strictly adhered to ethical research standards. After being fully informed of the study’s objectives, participants voluntarily signed the consent form. The research design emphasized voluntary participation and anonymity, and participants were clearly informed of their right to withdraw at any time. All data were encrypted and stored on a secure server, accessible only for academic analysis, to ensure participants’ privacy and data security.

The entire CMS simulation session took place at the company simulation driving test field and lasted approximately 25 minutes: ① sign informed consent at reception (2 min); ② a 5-min standardized briefing on CMS functions and operation; ③ participant entered the driver’s seat of a Beijing Magic Cube, viewed four 30-s traffic clips on LED screens ahead and behind, and freely explored CMS for 5 min; ④ immediately completed a 7-point Likert questionnaire (35 items, 5 min); ⑤ provided demographic data, received a souvenir compensation and left. The procedure was run in a closed site with a fixed script to ensure uniformity.

3.4. Data Analysis

The primary aim of this study is to analyze the factors influencing drivers' acceptance of CMS. To achieve these research goals, both descriptive and inferential statistical analyses were performed. Before entering the quantitative data analysis phase, the research team performed several data preprocessing procedures, including data cleaning and screening [28]. The sample data underwent processing and encoding via SPSS version 26 for quantitative statistical analysis.

Hypotheses were examined with AMOS 26.0 following Anderson & Gerbing's [29] two-step procedure. A confirmatory factor analysis was first conducted to verify the measurement model's reliability and validity. Subsequently, structural equation modeling was performed to estimate the directional paths among the six exogenous constructs (FC, PE, EE, HM, PV, HB) and the two endogenous constructs (BI, UB). Model fit was assessed using χ^2/df, CFI, TLI, and RMSEA; all indices met or exceeded conventional thresholds ($\chi^2/df < 3$, CFI & TLI > .95, RMSEA < .08), supporting the hypothesized relationships.

3.4.1. Common-Method Variance Test

To address common-method bias, this research employed a single-factor test. As per Harman [30] and Podsakoff and Organ [31], if the first factor's variance contribution is below 50%, common method bias isn't a major concern. Some studies set this threshold at 40% or 30%. Here, the first factor explained only 29.647% of the variance, suggesting minimal common-method bias impact. Table 3 presents the test results.

Table 3. Common-Method Variance Test Result

	Initial Eigenvalues			Extraction Sums of Squared Loadings	
Component	Total	% of Variance	Cumulative %	Total	% of Variance
1	8.894	29.647	29.647	8.894	29.647

Extraction Method: Principal Component Analysis.

3.4.2. Reliability and Validity Tests

This study employed a multi-stage validation system to ensure the scientific rigor of the measurement tools. This research rigorously validated the questionnaire's content validity through a cross-institutional expert panel comprising five renowned professors and three industry specialists in automotive electronics, utilizing the Delphi method. Subsequently, the scale's reliability was quantitatively assessed using Cronbach's alpha coefficient, with the results presented in Table 4. The empirical data show that the average α coefficients of all subscales exceed the 0.70 threshold for psychometric reliability [32], confirming the stable internal consistency of the scale. Notably, the whole scale’s Cronbach's alpha coefficient reached 0.913, significantly higher than the 0.70 benchmark proposed by Nunnally [33], indicating an excellent level of reliability for the measurement tool.

Table 4. The Reliability Assessment Results of the Questionnaire.

Factor	Number of Items	Cronbach's alpha coefficient	The Overall Reliability
PE	4	.849	.913
EE	4	.862	
FC	4	.813	
BI	3	.815	
UB	3	.824	
HM	4	.848	
PV	4	.848	
HB	4	.846	

3.4.3. Multicollinearity Analysis

The research utilized a series of multicollinearity diagnostic criteria for evaluation. As per Table 5, all predictor variables for BI and UB have a tolerance above 0.5, and VIF ranges from 1.071 to 1.695. These values are well below Hair et al. [26] suggested threshold (Tolerance < 0.1 or VIF > 10) and meet stricter criteria (VIF < 3). Hence, the model has no multicollinearity, and each construct's influence on the dependent variable is independent. The SEM's estimation results are robust and credible.

Table 5. Multicollinearity Analysis Result.

Construct	BI		UB	
	Tolerance	VIF	Tolerance	VIF
PE	.629	1.589		
EE	.765	1.307		
HM	.590	1.695		
PV	.812	1.231		
BI			.878	1.139
FC			.933	1.071
HB			.926	1.080

3.4.4. Convergence Validity Test

This study's empirical results, presented in Table 6, reveal that each latent variable's standardized factor loadings span from 0.717 to 0.834 ($p < 0.001$), with squared multiple correlations (SMC) between 0.514 and 0.696. The composite reliability (CR) values lie in the range of 0.816 to 0.862, and the average variance extracted (AVE) values are from 0.525 to 0.611. These metrics satisfy the validity criteria set by Hair et al. [26] and the Fornell-Larcker criterion [34], which are: (1) factor loadings exceeding 0.5; (2) CR above 0.7;

(3) AVE over 0.5; and (4) SMC greater than 0.5. The measurement models for these eight constructs all display strong convergent validity.

Table 6. Convergent Validity Test Results.

		Parameter Significance Estimation				Convergent Validity			
Constructs	Indicator	Unstd.	S. E.	T-Value	P	Std.	SMC	CR	AVE
BI	BI1	1.000				.742	.551	.816	.598
	BI2	1.099	.084	13.090	***	.830	.689		
	BI3	1.006	.078	12.911	***	.744	.554		
EE	EE1	1.000				.759	.576	.862	.611
	EE2	.989	.071	13.984	***	.730	.533		
	EE3	1.184	.075	15.817	***	.834	.696		
	EE4	1.181	.077	15.309	***	.800	.640		
FC	FC1	1.000				.717	.514	.816	.525
	FC2	.827	.068	12.100	***	.721	.520		
	FC3	.922	.076	12.202	***	.730	.533		
	FC4	.964	.079	12.200	***	.730	.533		
HM	HM1	1.000				.721	.520	.849	.585
	HM2	1.156	.080	14.361	***	.816	.666		
	HM3	1.163	.083	14.033	***	.798	.637		
	HM4	.957	.075	12.714	***	.720	.518		
HB	HB1	1.000				.750	.563	.846	.580
	HB2	1.095	.075	14.510	***	.800	.640		
	HB3	.995	.071	13.954	***	.761	.579		
	HB4	.952	.071	13.481	***	.732	.536		
PE	PE1	1.000				.718	.516	.851	.590
	PE2	1.200	.083	14.513	***	.830	.689		
	PE3	1.096	.078	14.079	***	.793	.629		
	PE4	1.114	.086	13.016	***	.724	.524		
PV	PV1	1.000				.772	.596	.853	.592
	PV2	1.073	.074	14.534	***	.777	.604		
	PV3	1.072	.074	14.400	***	.792	.627		
	PV4	1.086	.084	12.881	***	.735	.540		
UB	UB1	1.000				.780	.608	.824	.610
	UB2	1.014	.074	13.662	***	.778	.605		
	UB3	1.016	.074	13.697	***	.785	.616		

3.4.5. Discriminant Validity Analysis

In this research, discriminant validity is assessed using Fornell and Larcker [34] criteria and Hair et al. [26] procedures. As shown in Table 7, the square roots of AVE for each latent variable exceed their inter-construct correlations. For instance, the AVE square roots for HB, PV, UB, BI, HM, EE, FC, and PE are

0.762, 0.769, 0.781, 0.773, 0.765, 0.782, 0.725, and 0.768 respectively, all surpassing their corresponding correlation values. This confirms discriminant validity, indicating the eight constructs are distinct and suitable for the SEM analysis.

Table 7. Discriminant Validity Test Result.

	AVE	HB	PV	UB	BI	HM	EE	FC	PE
HB	.580	**.762**							
PV	.592	.312	**.769**						
UB	.610	.410	.507	**.781**					
BI	.598	.317	.499	.557	**.773**				
HM	.585	.346	.478	.389	.644	**.765**			
EE	.611	.251	.265	.350	.600	.503	**.782**		
FC	.525	.136	.266	.396	.312	.318	.275	**.725**	
PE	.590	.256	.415	.317	.631	.659	.474	.271	**.768**

4. Results

4.1. Structural Model and Hypotheses Testing

This study utilized multiple fit indices, such as the Chi-square statistic, GFI, AGFI, CFI, TLI, RMSEA, and SRMR, to assess the model's overall fit and verify its alignment with specific data. The evaluation results are presented in Figure 5, illustrating the standardized coefficients of the conceptual model.

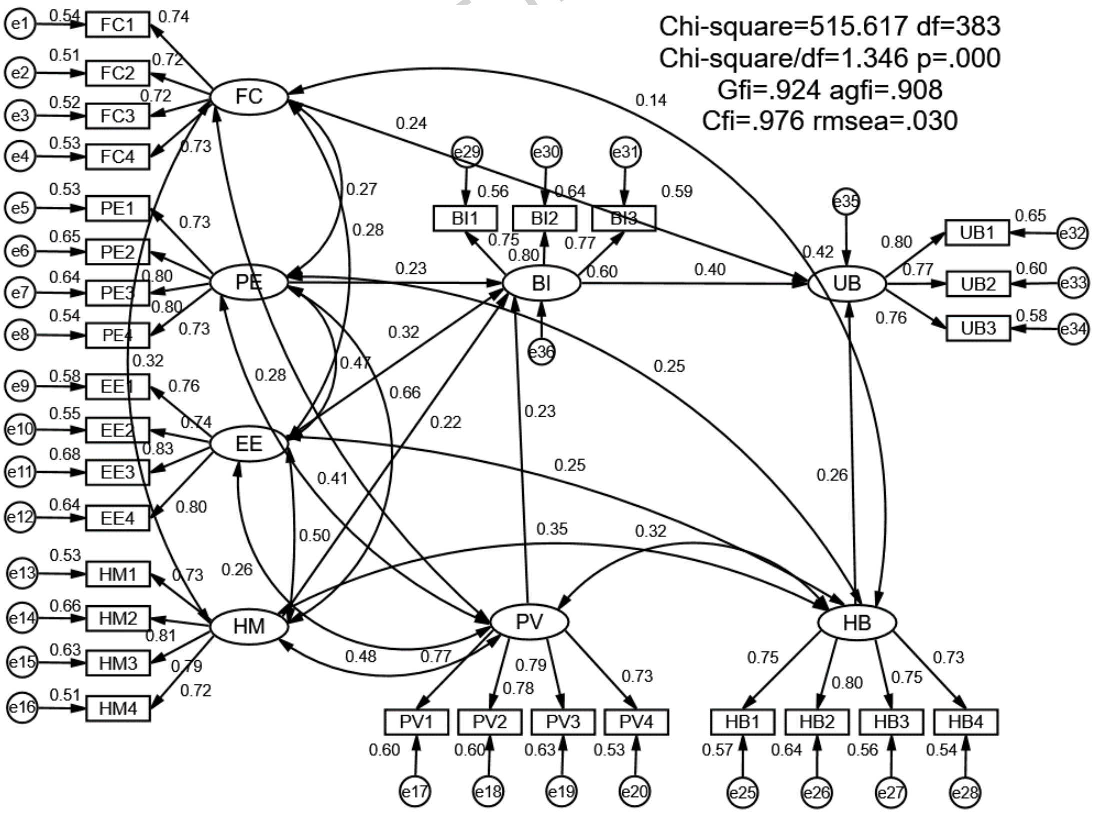


Figure 5. The Standardized Coefficients of the Conceptual Model.

As indicated in Table 8, the overall model demonstrates exceptional fit. The χ^2 value is 515.617 (p <.001); while statistically significant, the χ^2/df ratio of 1.346 is well below 3, suggesting acceptable sample differences. Additional fit indices include GFI of 0.924 and AGFI of 0.908, both exceeding 0.9. RMSEA is 0.03 (below 0.08), SRMR is 0.04 (below 0.05), and TLI, IFI, and CFI are 0.973, 0.976, and 0.976 respectively, all surpassing 0.95. These results confirm that the model structure aligns closely with the data on Chinese users' acceptance of CMS and is suitable for subsequent path and hypothesis testing.

Table 8. The Model Fitness Index.

Model Fitness Index	Ideal Standard Indicators	Mode Fitness Index
X2	the smaller, the better	515.617(p=.000)
X2/df	<3	1.346(DF=383)
GFI	>.9	.924
AGFI	>.9	.908
RMSEA	<.08	.030
SRMR	<.5	.040
TLI (NNFI) rho2	>.9	.973
IFI Delta2	>.9	.976
CFI	>.9	.976

The outcomes of the SEM's path analysis (n=394) are detailed in Table 9. All seven hypotheses were supported (p<0.01). Among them, FC (FC→UB: β =0.243, t=4.232) and HB (HB→UB: β=0.257, t=4.549) had significant positive effects on actual UB; PE (PE→BI: β=0.235, t=3.403), EE(EE→BI: β=0.317, t=5.529), HM (HM→BI: β=0.217, t=2.956), and PV (PV→BI: β=0.233, t=4.264) all significantly promoted BI; and BI further significantly drove actual usage (BI →UB: β=0.405, t=6.527). In conclusion, the model effectively revealed the key psychological and situational mechanisms for Chinese users' acceptance of CMS.

Table 9. Results of Path Regression Coefficients and Significance Testing.

Path and Hypothesis		STD. Estimate	UNSTD. Estimate	S.E.	C.R. T-value	P value	Result
H1	FC → UB	.243	.227	.054	4.232	***	Accepted
H2	PE → BI	.235	.221	.065	3.403	***	Accepted
H3	EE → BI	.317	.250	.045	5.529	***	Accepted
H4	BI → UB	.405	.350	.054	6.527	***	Accepted
H5	HM → BI	.217	.210	.071	2.956	**	Accepted
H6	PV →BI	.233	.214	.050	4.264	***	Accepted
H7	HB → UB	.257	.212	.047	4.549	***	Accepted

***p < .001, **p < .01, **p < .05*

The structural-model results show that, among all antecedents, EE (β = 0.317) is the strongest predictor of BI, followed by PE and PV; for actual UB, BI itself (β = 0.405) exerts the largest impact, with HB and FC ranking next.

4.2. Coefficient of Determination (R^2) of the Endogenous Variables

This study performed model assessment using Chin's effect size evaluation framework. Per this framework, effect sizes are categorized as low (R^2 = 0.19 - 0.33), medium (R^2 = 0.34 - 0.66), and high ($R^2 \geq$ 0.67). As per the SMC test results in Table 10, BI's SMC is 0.596, meaning the model explains about 59.6% of BI's variance. UB's SMC is 0.422, indicating the model accounts for 42.2% of UB's variance. Both exceed the 0.20 threshold typical in social sciences. Thus, the model's predictive accuracy reaches a medium effect level, showing strong explanatory power for the key outcome variables and reinforcing the SEM's validity.

Table 10. SMC Test Results.

Dependents Variable	SMC
BI	.596
UB	.422

4.3. Mediation Analysis of BI

To further examine the mediating role of BI between its antecedents (PE, EE, HM, PV) and UB, a bootstrapping analysis with 5000 resamples was conducted to estimate the indirect effects. As shown in Table 11, all indirect effects were statistically significant, as their 95% bias-corrected confidence intervals did not include zero. Specifically, EE had the strongest indirect effect on UB via BI, followed by PE and PV, while HM showed the weakest yet significant indirect effect.

Table 11 Bootstrap analysis results of the mediation effect (n=394)

Indirect Path	Point Estimate	Bootstrap S.E.	Bias-Corrected 95% CI		Significance
			Lower	Upper	
PE → BI → UB	.095	.036	.025	.141	*
EE → BI → UB	.128	.036	.046	.147	*
HM → BI → UB	.088	.040	.013	.151	*
PV → BI → UB	.094	.034	.032	.144	*

***p < .001, **p < .01, *$p < .05$

5. Discussion

5.1. Analysis of Factors Affecting User Willingness to Accept CMS

This section interprets the antecedents of BI in the context of CMS adoption, moving beyond statistical confirmation to elucidate their theoretical implications for understanding technology acceptance in the automotive safety domain.

5.1.1 EE: Safety-Critical Operational Fluency

The finding that EE exerted the strongest influence on BI (β = 0.317) is theoretically significant. It extends the classic TAM postulate that perceived ease of use is crucial during initial technology introduction [21]. In the high-stakes context of driving, where cognitive resources are limited and distraction costs are high, any perceived operational complexity is not merely an inconvenience but a potential safety threat. This amplifies EE's role from a general facilitator to a fundamental adoption prerequisite. Our result empirically validates the argument by Venkatesh et al. [22] that operational complexity can be a decisive rejection factor, and it aligns with findings in automotive HMI research where low learning effort predicts positive initial attitudes [8]. Consequently, for CMS to gain acceptance, its design must transcend basic functionality to achieve seamless, intuitive interactivity that minimizes glance time and mental effort.

5.1.2 PE & HM: Utilitarian-Affective Dual Pathway

The significant effects of both PE (β = 0.235) and HM (β = 0.217) reveal a dual-pathway motivation model for CMS, which enriches the UTAUT2 framework. PE's strong influence reaffirms the core utilitarian calculus of technology adoption—users are driven by tangible gains in safety and task efficiency [9]. This aligns with prior automotive studies where perceived functional benefits are primary drivers for ADAS acceptance [8].

Simultaneously, the significant role of HM underscores a critical affective pathway. This finding corroborates UTAUT2's expansion beyond organizational settings, where Venkatesh et al. [9] identified intrinsic enjoyment as a key driver for consumer technologies. In the automotive domain, where the vehicle is an extension of personal identity, HM captures the "experience value" of CMS—the novelty, visual pleasure, and sense of technological sophistication [9, 16, 18]. This suggests that CMS marketing and design must not only communicate safety (PE) but also evoke the positive affective experience associated with smart driving, thereby engaging both rational and emotional decision-making systems.

5.1.3 PV: Economic Gateway to Mass Market

The significant impact of PV (β = 0.233) highlights that CMS adoption is ultimately a consumer economic decision. This construct, introduced in UTAUT2 to account for voluntary consumer contexts [9], proves decisive. Users perform a mental trade-off between the CMS premium and its perceived benefits—not just against traditional mirrors, but also against competing ADAS features. This extends beyond upfront cost to include total cost of ownership, such as maintenance, insurance implications, and residual value [3, 4]. The strong effect of PV empirically supports findings in similar high-involvement consumer technologies, where cost-benefit perception is a stronger predictor of intention than in mandatory organizational use [9, 16, 18]. Therefore, market strategies must articulate and validate the long-term value proposition of CMS to justify its price point and accelerate diffusion.

5.1.4 Toward a Contextualized Hierarchy of UTAUT2 Constructs

Collectively, these findings propose a contextualized hierarchy for UTAUT2 constructs in the automotive safety periphery market:

1. Foundation Layer (EE): Operational fluency is non-negotiable in safety-critical, high-cognitive-load environments.
2. Core Evaluation Layer (PE & PV): Rational assessments of functional superiority and economic viability form the central decision matrix.
3. Enhancement Layer (HM): Affective and experiential benefits provide additional persuasive leverage, especially for early adopters.

This model refines UTAUT2 by specifying conditionality and salience: the weight of each construct varies based on the technology's context (safety-critical, consumer-paid, experiential). It suggests that for technologies like CMS, success requires a staged strategy: first guaranteeing effortless use, then convincingly demonstrating superior utility and cost-effectiveness, and finally amplifying its experiential appeal.

5.2. The Dynamics of UB: Habit, Facilitation, and Intention

Our tripartite framework extends recent UTAUT2 evidence from ADAS research, where Khattak et al. [8] similarly report that facilitating conditions and habit exert significant direct effects on actual use behaviour, reinforcing the contextual salience of these constructs for safety-critical automotive technologies.

5.2.1 Overview: From Intention to Habitual Use

Building on the confirmed paths, this section dissects how BI, HB and FC jointly shape real-world CMS uptake and, in doing so, refines UTAUT2's framework for durable, safety-critical automotive technologies.

5.2.2 HB: Automation Script for Safety-Critical Glances

The significant direct effect of HB on UB ($\beta = 0.257$) is a cornerstone finding that underscores the behavioral internalization required for CMS to become truly effective. Recent on-road eye-tracking evidence shows that drivers with >3 months CMS experience perform 32% fewer mirror glances and 18 % shorter glance duration during lane changes, indicating automated script formation [35]. In UTAUT2, habit represents the extent to which behavior becomes automatic due to repeated performance in stable contexts [9]. For CMS, this translates to the transformation of deliberate visual checks into automatic, glance-based routines. The driving environment, characterized by repetitive scenarios (e.g., lane changes, roundabouts), provides the ideal "stable context" for such habit formation [19]. Once established, this habit reduces the cognitive load associated with mirror-use decisions, potentially enhancing safety by freeing attentional resources for primary driving tasks. This finding empirically validates Schmitz et al.'s [10] assertion that HB is a critical longitudinal predictor of continued use for acquired technologies. It extends this notion to the automotive safety domain, suggesting that for peripheral vision systems, habit formation is not merely a marker of acceptance but a prerequisite for their intended safety benefit—the technology must be used automatically and reliably to be effective.

5.2.3 FC: From Technical Support to Ecosystem Trust

FC's robust direct effect on UB ($\beta = 0.243$) reveals that CMS acceptance is deeply embedded within a broader technological and institutional ecosystem. While UTAUT2 defines FC as the perceived support for system use [9], in the CMS context, this construct encapsulates more than just ease of access. It encompasses perceived reliability of the supply chain (availability at 4S stores), confidence in after-sales support (software updates, module repairs), and trust in regulatory and insurance frameworks [3, 4]. A 2024 industry-wide survey indicates that users who receive bundled insurance premium reductions (avg. €68/yr) and 4S-store lifetime calibration vouchers report 27 % higher trust in CMS after-sales support, confirming that ecosystem incentives amplify FC effects on continued use [36].The significant path FC → UB indicates that users' willingness to consistently rely on CMS is contingent upon their belief that the entire supporting infrastructure is robust and low-risk. This finding aligns with and extends prior ADAS research, where perceived support structures significantly influence long-term usage patterns [37, 38]. It suggests that for novel vehicle architectures like CMS, manufacturers and policymakers must co-create a visible and trustworthy ecosystem; technology excellence alone is insufficient without the perceived safety net of seamless support and regulatory endorsement.

5.2.4 BI: The Motivated Yet Mediated Precursor

As hypothesized and consistent with core technology acceptance theories, BI demonstrated the strongest direct effect on UB ($\beta = 0.405$). This reaffirms the theory of planned behavior's central tenet that intention is a proximal determinant of behavior [9]. In the CMS context, a strong BI reflects a user's consolidated psychological commitment, forged from the evaluation of EE, PE, HM, and PV as discussed in Section 5.1. However, the presence of equally strong direct effects from HB and FC provides a crucial nuance: BI is necessary but not always sufficient for sustained UB in complex, real-world settings. While BI may drive the initial trial or purchase decision, the transition to routinized, long-term use is co-determined by the automaticity developed through HB and the reassurance provided by FC. This triangulation of influences offers a more complete picture than models considering intention alone, highlighting the multi-stage nature of technology assimilation—from motivated trial to habitual, ecosystem-supported use.

5.2.5 Synthesis: A Tripartite Model for Durable Technology Assimilation

The concurrent significance of BI, HB, and FC in driving UB presents a tripartite framework for understanding the acceptance of durable, safety-enhancing automotive technologies like CMS. This framework refines UTAUT2 by specifying the interdependent roles of its constructs:

1. BI acts as the key ignitor, capturing the motivational thrust derived from initial evaluations.
2. HB serves as the behavioral sustainer, automating usage and embedding the technology into daily practice, which is especially critical for safety equipment that must operate subconsciously.
3. FC functions as the contextual enabler, reducing perceived external barriers and risks, thereby providing the stability required for habit formation and intention realization.

This integrated view suggests that promoting CMS requires parallel strategies: marketing and UX to foster strong initial intentions (BI); design and repetitive exposure to encourage habit formation (HB); and ecosystem development to ensure robust FC. The absence of any one element may stall the progression from interest to ingrained use.

5.3. The Mediating Role of BI

The bootstrapping analysis confirmed that Behavioral Intention (BI) plays a significant mediating role in the acceptance of CMS. Among the factors influencing UB through BI, Effort Expectancy (EE) demonstrated the most substantial indirect effect (as reported in Table 11). This underscores that the primary pathway through which ease of use influences actual usage is by first fostering a strong intention to adopt the technology. Performance Expectancy (PE) and Price Value (PV) also exhibited strong and significant indirect effects, nearly equal in magnitude. This suggests that users' rational assessments of the system's functional benefits and its cost-effectiveness are equally potent in driving actual use behavior through the formation of behavioral intention. While significant, the indirect effect of Hedonic Motivation (HM) was comparatively weaker. This implies that the enjoyment derived from using CMS, though important, is a less dominant driver of sustained usage compared to utilitarian and economic considerations when channeled through behavioral intention. In summary, BI acts as a crucial psychological mechanism that translates key cognitive and affective evaluations into tangible usage behavior.

6. Conclusions, Limitations, and Future Directions

(1) Theoretical contribution

This study is the first to apply the full UTAUT2 model to passenger-car CMS adoption. It demonstrates that HM, PV and HB have distinctive explanatory power for automotive-safety peripherals. The path coefficient of EE → BI (β = 0.317) is the largest, showing that "ease of use" is a prerequisite for consumers to adopt high-involvement vehicular electronics; the significant path HB → UB (β = 0.257) confirms the role of habitual scripts in driving automation. These findings extend Venkatesh et al. (2012) to the road-traffic context and respond to Schmitz et al.'s (2022) call to test HB under frequent, stable usage situations, offering new evidence for contextualising UTAUT2.

(2) Practical implications

The findings indicate that EE is the most critical factor influencing user intention, meaning that CMS interface design must prioritize extreme usability. Split-screen or picture-in-picture layouts should be adopted to intuitively replicate the spatial positioning of traditional rearview mirrors, while core functions should be adjustable via steering-wheel buttons or single-command voice control. This significantly reduces cognitive load and glance-away risk during driving, directly addressing user concerns regarding operational latency and driving safety.

The significant influence of PV calls for a reframing of the cost-value narrative. The industry should collaborate with insurance institutions to develop premium discount schemes based on safety performance data, directly linking CMS usage to reduced accident risk. At the same time, it is essential to publicly disclose standardized performance data under complex conditions such as strong light, rain, and fog (e.g., latency <60 ms), repositioning CMS from an "additional cost" to a verifiable long-term safety investment.

The direct impact of HB on sustained usage indicates the need to actively cultivate user reliance through immersive scenario-based test drives and flexible subscription or upgrade plans. Furthermore, it is imperative to enhance FC by establishing industry-wide after-sales service standards and clarifying liability determination and certification processes to build a trustworthy ecosystem. By following the promotional logic of "first ease of use, then exceptional value, and finally habitual integration," CMS can truly evolve from a "premium feature" into a "mass-market standard."(3) Limitations

The study has four main constraints. First, although the two-stage random sample covers 27 provinces, it over-represents 25 to 39-year-old male subjects who already own a car, limiting generalisability to older drivers or prospective car-less buyers. Second, the cross-sectional design cannot capture how BI and HB evolve as test-drive exposure or policy campaigns unfold. Third, SI and technology readiness (TR) were omitted, risking omitted-variable bias. Finally, the sample was analysed as a single population; no multi-group invariance test was conducted to determine whether the structural relationships differ across age cohorts, gender, or prior CMS experience.

(4) Future research

Future work should:

① Run 6- to 12-month longitudinal panels to observe the “momentum switch” where hedonic motivation decays and habit strengthens with repeated usage.

② Collect data in CMS-legal regions (EU, Japan) for cross-cultural comparison of how price value and regulatory trust moderate acceptance.

③ Introduce SI and TR as antecedents in a higher-order model to identify early-adopter segments.

④ Employ measurement-invariance testing and multi-group SEM to verify whether the proposed model holds equivalently across distinct user segments.

⑤ Combine driving-simulator and eye-tracking metrics with self-reported usage behaviour to reduce common-method bias and examine the causal impact of long-term CMS use on visual behaviour, crash rates, and insurance claims, providing cost-benefit evidence for policymakers.

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Data Availability Statement

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

Statement on Research Ethics

The questionnaire and methods of this study have been approved by the Biomedical Ethics Committee of Huizhou University (Ethics Approval Number: 2025IAC016). At the same time, the researchers confirmed that informed consent had been obtained from all subjects and/or their legal guardians.

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