Print ISSN: 1738-3110 / Online ISSN 2093-7717
JDS website: http:/accesson.kr/jds
http://doi.org/10.15722/jds.23.02.202502.63

Exploring Factors Influencing Chinese Consumers' Acceptance of Autonomous Delivery Vehicle Services

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Received: December 24, 2024. Revised: January 16, 2025. Accepted: February 05, 2025.

Abstract

Purpose: This study investigates the factors influencing the adoption of Autonomous Delivery Vehicles (ADVs) in China, focusing on consumer adoption intentions in last-mile delivery. By extending the Diffusion of Innovations (DOI) theory, the research explores traditional and novel constructs impacting the acceptance of this delivery technology. **Research Design, Data, and Methodology:** The study develops a model combining DOI theory constructs (relative advantage, complexity, compatibility) with factors like hedonic motivation, trust, social awkwardness, and public environment impact. A survey of Chinese consumers assessed their adoption intentions for ADVs, focusing on willingness to trial, preferences, and daily integration, analyzed through statistical methods. **Results:** Findings show relative advantage as the strongest adoption predictor, while complexity hinders adoption, emphasizing user-friendly designs. Compatibility with habits significantly impacts adoption. Social awkwardness suggests reducing social interactions can enhance ADVs' appeal, highlighting the importance of both traditional and novel factors in promoting ADV adoption. **Conclusion:** The study highlights the significance of both traditional and new factors in promoting ADV adoption. Service providers should focus on improving operational efficiency, simplifying usage, and ensuring compatibility with consumer behaviors. The findings also suggest that reducing social interactions could enhance the appeal of autonomous services, aligning with changing societal attitudes toward privacy.

Keywords: Autonomous Delivery Vehicle, Consumer Acceptance, Diffusion of Innovations Theory, Structural Equation Modeling

JEL Classification Code: M31, M21, D12

1. Introduction

The Chinese food delivery market reached approximately 650 billion RMB in 2023 and is projected to grow to 1.2 trillion RMB by 2029, with an average annual growth rate of 7.8%. The number of food delivery users in China reached 500 million in 2023 and was expected to grow to 540 million in 2024. With 2025 approaching, this number is anticipated to increase further. An increasing number of consumers are opting for and becoming accustomed to on-demand delivery services. The scope of instant delivery has expanded beyond meals to include pharmaceuticals, fresh produce, and documents (Lu et al., 2023). During the COVID-19 pandemic, government and corporate support for autonomous delivery accelerated the integration of unmanned vehicles and drones into food delivery services. This has catalyzed the gradual transformation of traditional food delivery services into human-machine collaborative autonomous delivery networks. Consequently, major food delivery companies have intensified their exploration of autonomous delivery services. Since March 2018, Meituan has piloted ADV in multiple Chinese cities, completing over 2.77 million deliveries by the end of 2022.

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ADV is increasingly gaining traction in the last-mile delivery industry, primarily due to its significant cost-saving benefits. By eliminating the need for human drivers, autonomous vehicles help companies reduce expenses related to wages and benefits. Additionally, these vehicles have been shown to substantially decrease the number of insurance claims associated with driving, further contributing to cost savings. From a customer's perspective, ADV offer reliable deliveries even under extreme weather conditions, overcoming the limitations of traditional delivery services that often struggle with timely and accurate deliveries during adverse weather and peak periods. From the government's perspective, since the last mile accounts for 53% of total transportation costs, ADV represents a crucial advancement toward low-carbon urban logistics and an integral part of the city's smart delivery system (Chhabra, 2021; Pani et al., 2020).

A public opinion poll conducted in Guangzhou, China, surveyed 800 randomly selected respondents, revealing acceptance rates of 61% for "delivery logistics within specific areas such as parks and communities" and 60% for "widespread use in delivery logistics." While many consumers are curious about and hold a positive attitude towards ADVs, significant issues persist. These issues include instances where ADVs overturn, causing damage to customers' items and delivery delays; collisions between ADVs and private cars, which, although occurring at low speeds and not resulting in injuries, diminish public acceptance and trust; and unclear road rights, which pose potential threats to all traffic participants. Consequently, some argue that the major barrier to the widespread adoption of ADVs is not technological capability but rather social acceptance (Kapser & Abdelrahman, 2020). Customers play a crucial role in the successful large-scale implementation of ADVs. Understanding the psychological factors influencing public acceptance is essential, as last-mile delivery is a consumer-oriented service with strong behavioral components (Choi & Ji, 2015; Collins, 2015). Identifying these factors will help design, develop, and promote ADVs as a viable alternative to traditional delivery methods. This paper aims to address this by expanding the DOI theoretical model to focus on the factors influencing public acceptance of unmanned delivery services.

The DOI model, introduced by Everett M. Rogers in his seminal work Diffusion of Innovations, offers a theoretical framework for understanding and predicting the adoption and spread of new technologies, products, or ideas within a social system (Rogers, 2003). This theory provides valuable insights into how innovations diffuse through various user groups, facilitating the analysis of their acceptance and dissemination. Unmanned vehicle food delivery, as both an emerging technology and an innovative service, plays a pivotal role in this context. Rather than being passive recipients of unmanned vehicle technology, users and the public are active participants in this novel service process. Consequently, this study utilizes the DOI theory to explore and elucidate these dynamics. In addition to the core constructs of the DOI theory, this study introduces supplementary constructs to enhance the framework's applicability to autonomous delivery services. In this context, users primarily engage with the service, making factors such as enjoyment and pleasure significant drivers for repeated usage. Thus, hedonic motivation is incorporated as an extended construct. Contemporary social dynamics, including the increasing complexity of interpersonal interactions and heightened aversion to contact, have elevated the appeal of contactless delivery methods (Zeng et al., 2020). Autonomous delivery is preferred by many as a means to avoid face-to-face social interactions. Traditional delivery services have encountered safety issues due to improper conduct by delivery personnel, including instances of meal tampering and unauthorized access to customers' homes, which pose serious safety concerns. Autonomous delivery systems have the potential to mitigate these risks by eliminating the need for human delivery personnel, thereby making trust in autonomous delivery a crucial factor. Additionally, this study will explore the impact of unmanned vehicles on the public environment during the delivery process.

The remainder of the study is organized as follows: Section 2 reviews the current research on autonomous delivery by unmanned vehicles and related studies utilizing the DOI theory. Section 3 presents the structure and hypotheses of the proposed theoretical model. Section 4 analyzes the collected data, provides descriptive statistics, and validates the expanded DOI model using SEM. Section 5 discusses the findings from the model evaluation. Finally, Section 6 summarizes the main contributions of the study, identifies its limitations, and suggests directions for future research.

2. Review of Related Literature

2.1. Traditional Food Delivery

Traditional food delivery typically involves couriers using electric bikes or motorcycles to deliver meals ordered through food delivery platforms, ensuring that the food is delivered to the consumer within the specified timeframe (Kapser & Abdelrahman, 2020). Research by Mengling Wu suggests that factors such as reliability, assurance, maintenance of food quality, system operation, traceability, and perceived service value can enhance customer satisfaction and optimize the intention to reuse food delivery services (Wu et al., 2024). Despite the rapid development of

traditional food delivery services, significant issues persist. Recent cases involving delivery riders posing safety threats to single female customers have garnered public concern. For instance, in 2021, an incident occurred in China where a delivery rider committed sexual harassment against a single female customer, which sparked widespread discussion about safety risks in the food delivery industry. Such incidents have a profound psychological impact on female customers, increasing their safety concerns regarding delivery services. Additionally, reports indicate that between July 1 and July 7, 2024, a single food delivery company in Shanghai recorded 6,090 traffic violations, with a rising number of traffic accidents attributed to delivery riders rushing to complete deliveries. These issues not only compromise the safety of the riders but also pose risks to other road users.

2.2. Autonomous Delivery

Autonomous delivery encompasses not only self-driving cars but also drones and automated robots. Li and Nie suggest that unmanned vehicles can operate 24/7, significantly enhancing delivery efficiency and reducing operational costs (Liu et al., 2020). Additionally, optimizing driving routes and maintaining stable driving behavior can reduce traffic accidents and minimize air pollution from delivery vehicles (Bansal & Kockelman, 2017). However, research by Litman and Goodall indicates that unmanned vehicle technology is not yet fully mature and presents safety risks, including sensor failures, software vulnerabilities, and inadequate capability to handle complex road conditions (Litman, 2020; Goodall, 2014). Therefore, promoting autonomous delivery vehicles requires a comprehensive evaluation of technological maturity, social acceptance, and regulatory policies to balance technological innovation with social benefits (Gkartzonikas & Gkritza, 2019). Existing literature primarily examines the acceptance of ADVs through the lenses of the TAM and the UTAUT. Kapser and Abdelrahman extended the UTAUT2 model, revealing that price sensitivity, perceived usefulness, and hedonic motivation are central to the acceptance of ADVs (Kapser & Abdelrahman, 2020). Notably, the significant impact of price sensitivity reflects consumers' economic rationality in evaluating new technologies, aligning with Rogers' concept of relative advantage within the DOI theory (Rogers, 2003). Variables such as "technology," "price sensitivity," "hedonic motivation," and "perceived risk" are commonly used to analyze the acceptance of autonomous vehicle delivery. In studies on autonomous drone delivery, additional variables such as "environmental impact" and "public space" are introduced to explore broader social acceptance beyond individual consumer perspectives.

2.3. Theoretical Background

In previous research on autonomous delivery, the TAM and the UTAUT have been the most commonly employed behavioral theories for investigating the adoption of new technologies (Davis, 1989). However, TAM and UTAUT primarily focus on individuals' perceptions of the usefulness and ease of use of technology. In contrast, unmanned vehicle food delivery involves a more complex array of factors, including regulatory policies, safety concerns, and public acceptance. During the food delivery process, users do not need to own a vehicle or understand its technology (Van & De, 2016); they merely request the vehicle when needed. Users do not operate the unmanned vehicle; instead, they experience the service it provides. Furthermore, the impact of unmanned vehicles extends beyond interactions with consumers during the delivery process. It also affects the road environment and public spaces. Therefore, the DOI theory is more appropriate for exploring the broad social impact of emerging technologies, extending beyond the individual-level technology acceptance focus of TAM and UTAUT(Lyytinen & Damsgaard, 2001).Additionally, while the TPB has been frequently applied in previous studies, focusing on the effects of attitudes, subjective norms, and perceived behavioral control on behavioral intentions, it does not fully address the complexity of unmanned vehicle delivery technology or the rapidly changing external environment, such as technological maturity and social acceptance (Ajzen, 1991; FishBein & Ajzen, 2010). The MCI, although useful in studying customer value and integration, has limitations in the context of unmanned vehicle food delivery research, as it does not adequately account for the interaction between technology and social systems (Grönroos & Voima, 2013).

The DOI theory, explains how innovations spread over time through specific channels within a social system. According to the DOI theory, the characteristics of an innovation impact its rate and extent of adoption. Rogers identified five key characteristics of innovations: relative advantage, complexity, compatibility, observability, and trialability (Rogers, 2003). However, previous research has shown that only the characteristics of relative advantage, complexity, and compatibility significantly influence the adoption of innovations. Consequently, this study concentrates on these three key variables.

Hedonic Motivation is an essential construct in the UTAUT2 model, referring to the enjoyment and pleasure users derive from engaging with a particular technology or service (Venkatesh et al., 2012). This construct plays a pivotal role in users' acceptance and continued use of technology or services. Similarly, service design emphasizes the enjoyment and pleasure of the user experience, creating delight and satisfaction through

carefully designed details and touchpoints (Stickdorn et al., 2018). The sense of pleasure and enjoyment not only enhances the overall user experience but also encourages repeated service use. Therefore, it can be argued that hedonic motivation aligns with the core principles of service design, which aim to optimize user experience to increase satisfaction and loyalty. Existing literature predominantly explores technological aspects; however, for consumers, the experience of the delivery service process directly impacts their choices more than the technology of ADV itself. Thus, incorporating "hedonic motivation" from the UTAUT2 model into the extended model can provide insights into consumers' perceptions from the perspective of user experience in service design. In studies on autonomous drone delivery, factors such as "public space" and "aerial environment" have been identified as influencing variables. With respect to autonomous vehicle delivery, several studies have indicated that traffic accidents involving unmanned vehicles raise public concerns (Kellermann et al., 2023). The public may require time to adapt to and learn how to safely coexist with and interact effectively with unmanned vehicles. Consequently, this study includes "public space impact" in the model to explore the acceptance factors concerning unmanned vehicle delivery, extending beyond mere consumer perspectives. Additionally, we incorporate new constructs that may influence end customers' willingness to adopt ADVs, such as social awkwardness and perceived trust (Tencent, 2021). ADVs can reduce direct contact between customers and delivery personnel, making this delivery method potentially more suitable for users with social anxiety. Moreover, it can mitigate conflicts between customers and delivery personnel, thereby enhancing customers' personal safety and potentially increasing their trust in ADVs.

2.4. Research Gap

Despite the rapid advancement of autonomous delivery technology, research on consumer acceptance of ADVs remains limited. Existing literature primarily focuses on technological implementation and operational efficiency, with insufficient in-depth exploration of end-user acceptance. While current ADV research mainly employs the TAM or the UTAUT, this study extends the DOI theory to examine ADV acceptance, offering a novel theoretical perspective on the adoption of emerging delivery technologies. Moreover, existing studies on ADV acceptance predominantly focus on Western countries, lacking validation in diverse cultural contexts. This research provides valuable insights into ADV acceptance across different cultural settings. Additionally, by incorporating factors such as safety and privacy, hedonic motivation, social awkwardness, and public space impact into the DOI model—elements not previously addressed in earlier research—this study contributes a more comprehensive ADV acceptance model. Compared to existing studies, this research not only considers technological factors but also integrates socio-psychological and environmental factors, offering a broader perspective on ADV acceptance.

3. Methodology

In this section, the constructs employed in the customer adoption intention model for this study are identified and described. Customer adoption intention encompasses the willingness to trial and use ADVs, the preference to select ADVs when conditions permit, and the readiness to accept and integrate ADVs into their living environment. First, a conceptual research model incorporating the DOI theory and four additional constructs is proposed, along with associated hypotheses. The proposed "Customer Adoption Intention of ADV " model is illustrated in Figure 1. Second, the survey design is detailed, covering aspects such as the timing, location, scale, and content of the survey questionnaire.

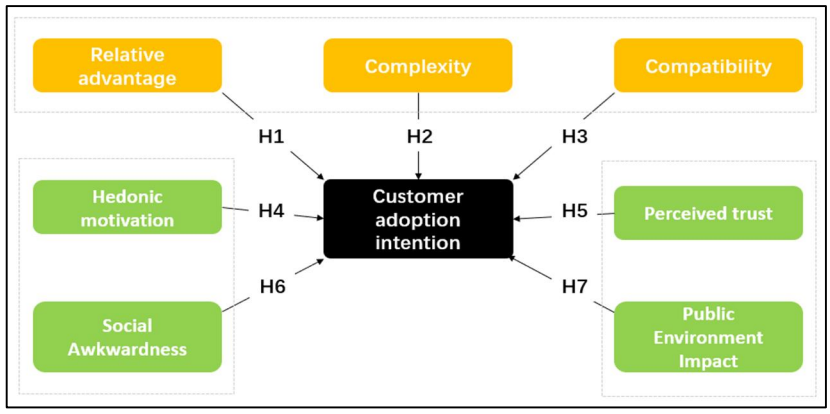

Figure 1: Customer Adoption Intention toward Autonomous Delivery Vehicle Model

3.1. Constructs in the Conceptual Research Model and Proposed Hypotheses

The constructs are categorized into two groups: the original constructs from the DOI theory and the additional constructs introduced in this study. The original constructs include relative advantage, complexity, and compatibility. The additional constructs comprise hedonic motivation, perceived trust, social awkwardness, and public environment impact. Definitions, relevant studies, and hypotheses for each construct are detailed as follows:

Relative Advantage (H1): Relative advantage is defined as "the degree to which an innovation is perceived as being better than the idea it supersedes"(Rogers, 2003). In the context of ADVs, relative advantage refers to the subjective evaluation of the benefits that ADVs provide compared to traditional delivery services. ADVs can offer 24/7 service, reduce the rate of order rejections, shorten waiting times during adverse weather conditions, and potentially enhance food safety (Pani et al., 2020). According to the TAM and DOI theory, perceived usefulness and relative advantage significantly impact adoption intention (Rogers, 2003). This influence is likely achieved by increasing users' expected performance and reducing anticipated effort. Thus, we hypothesize:

H1: Relative advantage is positively related to customer intentions to use ADV services.

Complexity (H2): Complexity is defined as "the degree to which an innovation is perceived as difficult to understand and use"(Rogers, 2003). In ADV services, complexity may be reflected in the difficulty of operating the order system, interacting with automated devices, and resolving delivery issues. According to Cognitive Load Theory (Sweller, 1988), higher complexity increases cognitive load, thereby reducing willingness to use. Davis' Technology Acceptance Model also emphasizes the direct impact of perceived ease of use on usage intention (Davis, 1989). Specifically, if ADV systems are designed to be straightforward, user-friendly, and easy to maintain, with a quick learning curve, their complexity is perceived as lower, thereby facilitating acceptance and adoption. It is worth noting that complexity may interact with perceived trust, where high complexity may reduce users' trust in the system. Therefore, we hypothesize:

H2: Complexity is negatively related to customer intentions to use ADV services.

Compatibility (H3): Compatibility is defined as "the degree to which a service is perceived as consistent with users' existing values, beliefs, habits, and past and present experiences" (Rogers, 2003). In the context of ADVs, compatibility involves how well the service aligns with consumers' daily lifestyles, shopping habits, and values. If consumers perceive that ADVs seamlessly integrate into their lives without causing additional inconvenience or burden, they are more likely to accept and use the technology. The effect of compatibility may be realized by reducing users' adaptation costs and psychological resistance. Thus, we hypothesize:

H3: Compatibility is positively related to customer intentions to use ADV services.

Hedonic Motivation (H4): In UTAUT2, hedonic motivation is defined as the pleasure and enjoyment experienced when using technology (Venkatesh et al., 2012). In ADV services, hedonic motivation may arise from the excitement of using new technology, the novelty of interacting with automated devices, and the satisfaction of reduced waiting times. For customers, receiving orders via ADVs may be perceived as more enjoyable and offer a better service experience; for the public, the presence of ADVs might be perceived as a fun and innovative element within the city. Hedonic motivation may promote adoption intention by enhancing users' positive emotional experiences. Therefore, we hypothesize:

H4: Hedonic motivation positively influences the behavioral intention to use ADVs.

Perceived Trust (H5): Perceived trust in this study is defined as the overall level of trust that users have in ADV technology, including beliefs about its reliability, safety, and efficacy. This trust reflects users' confidence that ADVs will reliably and safely perform delivery tasks, protect personal information and property, and operate responsibly in public spaces. High levels of perceived trust are likely to increase users' willingness to accept and use ADVs, potentially by reducing perceived risks and enhancing usage intentions. It is important to note that perceived trust may interact with complexity, where high trust may mitigate the negative effects of complexity. Thus, we hypothesize:

H5: Perceived trust positively influences the behavioral intention to use ADVs.

Social Awkwardness (H6): Social awkwardness in the context ADVs can be defined as the discomfort, anxiety, or stress that customers experience when engaging in traditional interpersonal delivery interactions. This feeling drives them to prefer delivery methods that reduce or eliminate direct social contact. It reflects the psychological burden that some individuals may experience when facing unfamiliar couriers, engaging in face-to-face communication, or dealing with unexpected social situations (Kellermann, 2023). This social awkwardness encompasses not only the discomfort experienced during actual

interactions but also anticipatory anxiety about potential social scenarios, such as worrying about missing a delivery, navigating unfamiliar social norms, or needing to communicate when it is inconvenient to receive a package. In the ADV context, technology serves as a "social buffer," making essential services more accessible to individuals who are less comfortable with social interactions. Social awkwardness may influence adoption intentions by reducing users' psychological stress and increasing their preference for non-interpersonal interaction services. Thus, we hypothesize:

H6: Social awkwardness is positively related to customer intentions to use ADV services.

Public Space (H7): Public environment impact refers to the cumulative effects of ADV operations in urban public spaces and the public's perceptions and evaluations of these effects. This concept encompasses both the direct and indirect impacts of ADVs on urban physical environments, social interaction patterns, and public space usage. Specific concerns may include the occupation of pedestrian spaces, impacts on traffic flow, visual effects on urban landscapes, and potential changes to community interaction patterns (Tencent, 2021). When ADV services disrupt the balance between technological innovation and urban quality of life, concerns about the future shape of cities may arise, leading to resistance to adoption. This impact may influence adoption intention by increasing users' environmental concerns and sense of social responsibility. Thus, we hypothesize:

H7: Public space is negatively related to customer intentions to use ADV services.

3.2. Survey Design

Our analysis incorporates two methodologies: demographic analysis and Structural Equation Modeling (SEM). The demographic analysis covers the basic profiles of respondents and their frequency of using delivery services. Following this, SEM is employed to explore the relationships between observed and latent variables (Zhang et al., 2020). The SEM process includes two stages: evaluating the measurement model and assessing the structural model.

At the beginning of the questionnaire, an overview of the key technologies, delivery processes, and major advantages and disadvantages of ADV services was provided, accompanied by images of operational ADV. This ensured that respondents had a comprehensive understanding of ADV services when completing the questionnaire. The questionnaire is divided into two sections: the first section gathers demographic information, including gender, age, education level, occupation, and frequency of using delivery services; the second section assesses each model variable. To operationalize the latent constructs in the study, measurement scales for the model constructs were adapted from existing literature and modified to suit the study context, the related observational variables and corresponding references are presented in Table 1. All items were rated on a 5-point Likert scale, ranging from "1 strongly disagree" to "5 strongly agree," following the internationally recognized Likert scale. Respondents rated each item using the levels "strongly disagree," "disagree," "neutral," "agree," and "strongly agree," corresponding to scores from 1 to 5.

This study employs a non-discriminatory sampling method, distributing and collecting questionnaires through the online platform "Wenjuanxing" in the Shunyi District of Beijing. Shunyi is the pilot area for Meituan's autonomous delivery vehicle service, which has already served over 100 communities, covering 300,000 residents. Therefore, Shunyi was selected for distributing the electronic questionnaires to obtain valid and reliable data. The data collection took place from January 2 to March 30, 2024, with a total of 576 questionnaires collected. After removing 31 invalid responses, 545 valid questionnaires remained. Statistical tools SPSS 26.0 and AMOS 24.0 were primarily used in this study to test the hypotheses.

Table 1: Measurement Model Evaluation

Construct	Item	Sources
Relative advantage (RA)	I believe that using ADVs would help me receive orders more quickly. I believe that ADVs can operate in inclement weather. I believe that ADVs can deliver at any time I want. I believe that using ADVs would be cool.	Mathew et al., 2021
Complexity (COL)	I believe that learning how to use ADVs would be easy. I believe that the use of ADVs would be clear and easy to understand. I believe that it is easy for me to become skillful at using ADVs. I believe that interacting with ADVs would not require much of my mental effort.	Manis & Choi, 2019; Yuen et al., 2021
Compatibility (COA)	I would have the resources necessary to use ADVs. I would have the knowledge necessary to use ADVs. ADVs would be compatible with my current lifestyle and habits. I have the ability to learn how to use ADVs easily.	Venkatesh et al., 2012; Li et al., 2021

Construct	Item	Sources
Hedonic Motivation(HM)	Using autonomous delivery vehicles would be fun. Using autonomous delivery vehicles would be enjoyable. Using autonomous delivery vehicles would be very entertaining.	Venkatesh et al., 2012
Perceived Trust(PT)	I would feel secure to use autonomous delivery vehicles. I feel that using autonomous delivery vehicles would not increase the chances that my personal information will be used for other purposes. I feel that using autonomous delivery vehicles would not lead to a loss of privacy for me because my personal information would be treated confidentially.	Yuen et al., 2019
Social Awkwardness(SA)	When communicating with strangers, I tend to feel uncomfortable. Using ADVs can reduce my social anxiety. Using an autonomous delivery vehicle can remove the need for communication with couriers. I feel less nervous about potential misunderstandings when interacting with an autonomous delivery vehicle compared to human couriers. Using an autonomous delivery vehicle makes me feel more confident in managing delivery processes without worrying about social judgments.	Lu et al., 2023 This sdudy
Public Space (PS)	I think ADVs take up too much public space. I think ADVs reduce the beauty of our city. I am concerned that ADVs will affect pedestrian safety in public spaces.	Kellermann et al., 2023
Adoption tention(AI)	I intend to use autonomous delivery vehicles as a delivery option in the future. I would always try to use autonomous delivery vehicles as a delivery option in my daily life when available in the future. I plan to use autonomous delivery vehicles frequently when available in the future.	Kapser & Abdelrahman, 2020

4. Results

4.1. Sample Population Distribution

The sample distribution of this study is detailed in Table 2, encompassing demographic variables such as gender, age, education level, occupation, and frequency of ordering takeout per week. The gender distribution shows that 51.19% of respondents are male, while 48.81% are female. The majority of respondents are under 39 years of age, with 26.97% being under 20 years old, 44.22% between 20 and 29 years old, and 21.47% between 30 and 39 years old. Although there are fewer respondents over the age of 50, younger individuals are more likely to use smartphones and mobile applications, which are the primary channels for food delivery services. This younger demographic typically has a relatively stable income and higher consumption capacity, and they often lead busier lifestyles, which results in more frequent use of food delivery services. Thus, focusing on this core user group can provide valuable insights for enhancing service quality and user experience. Most respondents hold a bachelor's degree or higher, and a significant majority are employees, constituting 63.30% of the sample. Furthermore, 71.19% of respondents report ordering food more than twice a week, indicating a high frequency of food orders.

Table 2: Demographic Details of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Female	279	51.19%
	Male	266	48.81%
Age	Below 20	147	26.97%
	20-29	241	44.22%
	30-39	117	21.47%
	40-49	29	5.32%
	50-59	9	1.65%
	Over 60	2	0.37%
Education	High school degree or below	81	15.23%
	Bachelor’s degree	385	70.64%
	Master’s degree	54	9.91%
	Doctorate	25	4.59%
Occupation	Student	83	15.23%
	Office worker	345	63.30%
	Freelance	98	17.98%
	Other	19	3.49%
Frequency of ordering takeout per week	No more than once a week	157	28.81%
	2-4 times a week	272	49.91%
	5 times a week or more	116	21.28%

4.2. Measurement Model Assessment

As illustrated in the table 3, the Kaiser-Meyer-Olkin (KMO) values for all variables exceed 0.70, and Bartlett’s test of sphericity is significant ($p < 0.01$), confirming that the data are suitable for factor analysis. Subsequently, a confirmatory factor analysis (CFA) was performed to

comprehensively evaluate the quality of the measurement model, assessing structural validity, convergent validity, and discriminant validity. This analysis not only tests the theoretical factor structure but also examines the relationships between measurement indicators and latent constructs, as well as the uniqueness of each construct. The results, as shown in Table 4, indicate that the Cronbach's α coefficients for all variables exceed 0.8, reflecting high internal consistency. The factor loadings (FL) for all items are greater than 0.7, demonstrating good convergent validity. The composite reliabilities (CR) of all constructs exceed 0.7, further supporting convergent validity. Additionally, the average variance extracted (AVE) for all constructs surpasses 0.5, indicating robust convergent validity. These findings suggest that the scales exhibit high reliability and validity, fulfilling the study's requirements. In Table 5, the factor loadings for all items ranged from 0.75 to 0.84, meeting the threshold for acceptable item reliability (≥0.7). Composite reliability (CR) values for all constructs exceeded 0.8, indicating high internal consistency. The average variance extracted (AVE) values were above 0.5 for most constructs, supporting convergent validity. However, two constructs, HM (AVE = 0.591) and AI (AVE = 0.576), fell slightly below the recommended threshold, suggesting potential refinement of these constructs. Overall, the results validate the reliability and convergent validity of the measurement model.

Table 3: KMO and Bartlett's Sphericity Test Results

Construct	KMO	Bartlett Spherical Test		
		Approx. Chi-Square	df	Sig.
RA	0.729	671.593	3	0.000
COL	0.832	1098.421	6	0.000
COA	0.830	1069.651	6	0.000
HM	0.715	547.321	3	0.000
PT	0.731	699.418	3	0.000
SA	0.892	1600.688	10	0.000
PS	0.724	645.033	3	0.000
AI	0.712	515.025	3	0.000

Table 4: Construct Measurement Validation Summary

Construct	Item	Mean	Cronbach's α （≥0.7）	S.D.	FL (≥0.7)	CR （≥0.7）	AVE（≥0.5）
RA	RA1	3.499	0.844	1.128	0.785	0.844	0.644
	RA2	3.464		1.161	0.818		
	RA3	3.461		1.129	0.804		
COL	COL1	3.356	0.874	1.151	0.755	0.874	0.635
	COL2	3.308		1.136	0.827		
	COL3	3.327		1.128	0.791		
	COL4	3.341		1.130	0.812		
COA	COA1	3.536	0.877	1.108	0.769	0.878	0.642
	COA2	3.569		1.079	0.805		
	COA3	3.596		1.097	0.806		
	COA4	3.512		1.125	0.824		
HM	HM1	3.549	0.812	1.117	0.872	0.812	0.727
	HM2	3.572		1.081	0.842		
	HM3	3.494		1.100	0.843		
PT	PT1	3.499	0.850	1.122	0.799	0.850	0.654
	PT2	3.512		1.133	0.806		
	PT3	3.418		1.122	0.821		
SA	SA1	3.517	0.903	1.121	0.797	0.903	0.651
	SA2	3.462		1.139	0.841		
	SA3	3.464		1.144	0.823		
	SA4	3.466		1.126	0.805		
	SA5	3.481		1.105	0.766		
PS	PS1	2.552	0.838	1.099	0.773	0.838	0.633
	PS2	2.571		1.121	0.792		
	PS3	2.578		1.130	0.821		
AI	AI1	3.229	0.803	1.100	0.764	0.803	0.576
	AI2	3.257		1.083	0.75		
	AI3	3.253		1.051	0.763		

Notes. RA= relative advantage; COL=complexity; COA=compatibility; HM=Hedonic Motivation PT=Perceived Trust; SA =Social Awkwardness; PS=Public Space; AI=adoption tention.

Table 5: Summary of Factor Loadings, CR, and AVE for Constructs

Construct	Item	FL	CR	AVE
RA	RA1	0.786	0.844	0.644
	RA2	0.817		
	RA3	0.804		
COL	COL1	0.755	0.874	0.635
	COL2	0.827		
	COL3	0.791		
	COL4	0.812		
COA	COA1	0.769	0.878	0.642
	COA2	0.805		
	COA3	0.807		
	COA4	0.823		
HM	HM1	0.8	0.812	0.591
	HM2	0.753		
	HM3	0.752		
PT	PT1	0.799	0.850	0.655
	PT2	0.807		
	PT3	0.821		
SA	SA1	0.797	0.903	0.651
	SA2	0.84		
	SA3	0.823		
	SA4	0.805		
	SA5	0.766		
PS	PS1	0.773	0.838	0.633
	PS2	0.793		
	PS3	0.821		
AI	AI1	0.767	0.803	0.576
	AI2	0.75		
	AI3	0.759		

Notes. RA= relative advantage; COL=complexity; COA= compat ibility ; HM= Hedonic Motivation PT=Perceived Trust; SA =Soci al Awkwardness; PS=Public Space; AI=adoption tention.

The measurement model fit indices are reported in Table 6, showing an excellent fit. Specifically, the chi-square value (x^2) is 470.670 with 322 degrees of freedom (df), yielding a x^2/df ratio of 1.462, which is well below the critical value of 3, indicating a good fit. The Root Mean Square Error of Approximation (RMSEA) is 0.029, which is below the threshold of 0.08. The Normed Fit Index (NFI) is 0.941, exceeding the standard value of 0.7. The Goodness of Fit Index (GFI) and the Adjusted Goodness of Fit Index (AGFI) are 0.98 and 0.929, respectively, both surpassing their critical values of 0.9 and 0.7. These indices confirm that the measurement model fits the data well, validating its appropriateness and applicability.

Table 7 evaluates the discriminant validity of constructs using the Fornell-Larcker criterion. The square root of AVE for each construct (diagonal values) exceeds the inter-construct correlations (off-diagonal values), confirming sufficient discriminant validity in most cases. For example, PS (0.80) and SA (0.807) demonstrate strong discriminant validity, as their diagonal values are greater than all corresponding correlations. However, moderate correlations were observed between AI (0.759) and RA (0.394), as well as COA (0.801) and RA (0.211), suggesting some conceptual overlap. These results validate the model's discriminant validity while highlighting areas for potential refinement.

4.3. Structural Model Assessment

Table 8 summarizes the results of the path analysis. Six out of seven hypothesized relationships were supported, with significant effects observed for constructs such as relative advantage (H1: β = 0.271, p < 0.001) and compatibility (H3: β = 0.202, p < 0.001), confirming their positive influence on adoption intention (AI). Conversely, complexity (H2: β = -0.225, p < 0.001) and public space (H7: β = -0.207, p < 0.001) negatively impacted AI, suggesting these factors act as barriers to user adoption. Notably, hedonic motivation (H4: β = -0.023, p < 0.001) did not exhibit a significant effect, implying a secondary role in influencing adoption behavior. These findings emphasize the importance of functional and contextual factors over hedonic elements in driving adoption intention.

Table 6: SEM Fit Indices and Evaluation Standards

Indices	χ2	df	CMIN/DF	RMSEA	NFI	GFI	AGFI
Standards	—	—	<3	<0.08	>0.7	>0.9	>0.7
	470.670	322	1.462	0.029	0.941	0.98	0.929

Table 7: Discriminant Validity Analysis of Constructs

	AVE	PS	SA	HM	PT	COL	COA	RA	AI
PS	0.644	**0.80**							
SA	0.651	-0.219	**0.807**						
HM	0.591	-0.005	-0.033	**0.769**					
PT	0.655	-0.183	0.152	0.020	**0.809**				
COL	0.635	0.190	-0.143	0.026	-0.142	**0.797**			
COA	0.642	-0.153	0.184	-0.038	0.162	-0.144	**0.801**		
RA	0.644	-0.204	0.130	0.014	0.196	-0.116	0.211	**0.802**	
AI	0.576	-0.365	0.357	-0.031	0.361	-0.332	0.343	0.394	**0.759**

Table 8: Results of Path Analysis

Hypothesis	Path	Proposed effect	β	Signifcance	Result
H1	RA→AI	+	0.271	<0.001	Supported
H2	COL→AI	−	-0.225	<0.001	Supported
H3	COA→AI	+	0.202	<0.001	Supported
H4	HM→AI	+	-0.023	<0.001	Rejected
H5	PT→AI	+	0.216	<0.001	Supported
H6	SA→AI	+	0.217	<0.001	Supported
H7	PS→AI	−	-0.207	<0.001	Supported

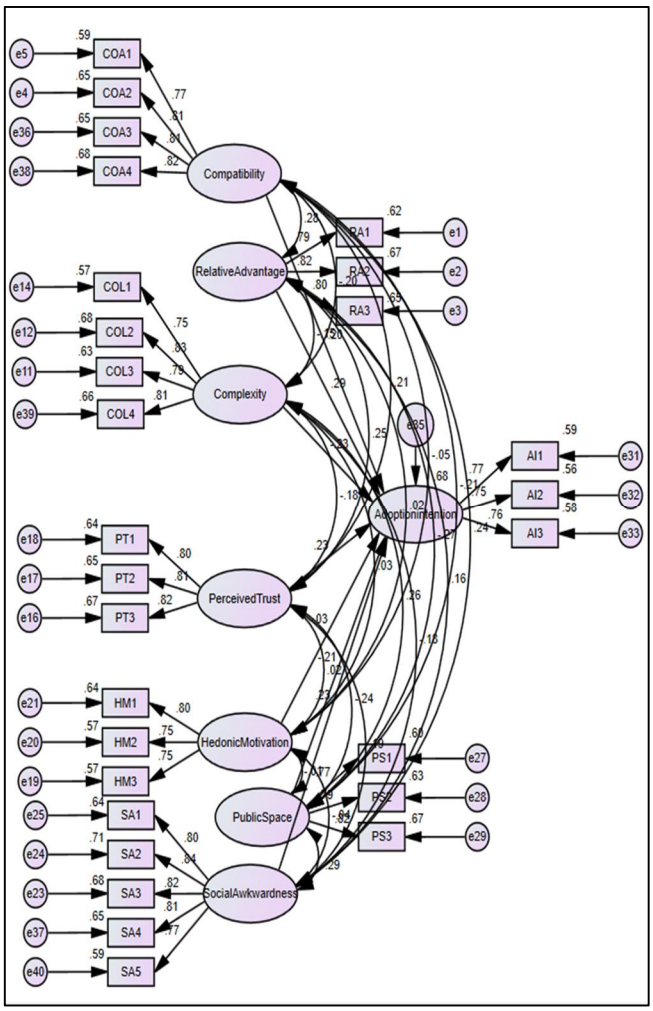

Figure 2: Structural Model and its Parameter Approximations

5. Discussion

This study investigates the factors influencing Chinese consumers' adoption of ADV services by extending the DOI theory. The findings not only validate the significance of traditional DOI factors but also highlight the considerable impact of newly introduced variables, offering a comprehensive perspective on the adoption of this innovative technology.

Relative Advantage, a core concept of the DOI theory, is confirmed in this study as the strongest positive predictor. This result aligns with Rogers'[10] assertion that a higher perceived relative advantage increases the likelihood of innovation adoption. In the context of ADVs, relative advantage is evident through enhancements in delivery efficiency, cost savings, and service quality. For instance, ADVs can maintain delivery operations during extreme weather conditions and alleviate the pressure on delivery staff during peak periods. Service providers should leverage these advantages by focusing on efficiency optimization and developing advanced route planning algorithms to fully exploit ADVs' continuous operation capabilities, thereby significantly enhancing delivery efficiency. Additionally, as technology advances and economies of scale are realized, reducing operational costs can lead to more competitive pricing strategies to attract price-sensitive consumers. Furthermore, incorporating distinctive ADV service features, such as precise delivery time predictions or temperature-controlled delivery for specialized items, can further emphasize their relative advantage and bolster market competitiveness.

Complexity, another crucial factor in the DOI theory, underscores the importance of simplifying the use process for ADVs. This concept is consistent with the ease of use in Davis' TAM. To mitigate perceived complexity, ADV services should be designed with a focus on intuitiveness and user-friendliness. This may involve integrating intelligent assistance features and contextual designs to lower the usage threshold for users.

The positive impact of compatibility highlights the importance of aligning ADV services with existing values, past experiences, and the needs of potential adopters. This finding resonates with Moore and Benbasat's research, which established that innovations more closely aligned with personal lifestyles and work habits are more likely to be adopted[40]. For ADV service providers, this implies the need to design service processes that integrate seamlessly with users' existing food ordering and receiving habits, while also considering how ADVs can be incorporated into users' daily routines. For instance, in residential areas, it is crucial to consider users' initial motivations for ordering food delivery and to minimize the distance they need to travel to collect their orders. This could involve implementing a hybrid delivery model that combines automated delivery vehicles with human couriers for the final delivery segment. Additionally, allowing automated delivery vehicles to enter buildings for interior deliveries could address current limitations in unmanned delivery

solutions.

The introduction of social awkwardness as a positive predictor in this study represents a significant advancement in extending the DOI theory. These finding challenges traditional perspectives that view social interaction as an essential component of the service experience [5]. Our study suggests that, in certain contexts, reducing social interaction can enhance the appeal of a service, particularly for consumers who experience discomfort during social interactions. This may reflect contemporary societal values emphasizing privacy and personal space[13]. This insight provides a novel perspective on how technology can transform service experiences. Based on these findings, developing "contactless" delivery options that enable consumers to interact with ADVs via mobile apps or voice commands can enhance privacy. Moreover, creating customizable ADV interaction interfaces that allow users to select their preferred level and mode of interaction can cater to varying levels of social comfort. In marketing strategies, emphasizing the "low social pressure" feature of ADVs and targeting consumers who value privacy or prefer minimal social interaction may yield positive outcomes.

The negative impact of public environment factors underscores the social dimension of innovation adoption, enhancing the DOI theory's understanding of how social systems influence the innovation-decision process. To address this challenge, the design and deployment of ADVs must account for broader social and environmental considerations, including urban planning, public safety, and visual aesthetics. It is essential for ADVs to be capable of adjusting their behavior according to varying urban contexts, such as reducing speed or selecting alternative routes in densely populated areas[39]. Furthermore, collaborating with local governments to implement public education campaigns that increase awareness of ADV operational principles and safety features can mitigate public concerns. Engaging with urban designers to optimize the visual integration of ADVs into cityscapes can also minimize visual disruption and improve public acceptance.

The significant positive impact of perceived trust highlights the crucial role of trust in the adoption of ADVs, extending the DOI theory's explanatory scope for technology adoption behavior. Users' confidence in ADVs to perform delivery tasks reliably and safely, protect personal information and property, and operate responsibly in public spaces is a key determinant of adoption intentions. This finding underscores the importance for ADV service providers to build and sustain user trust. Strategies to enhance perceived trust levels include providing transparent technical explanations, displaying real-time operational data, implementing stringent data protection measures, and collaborating with city management to demonstrate the safe operational capabilities of ADVs. Future research should investigate how different dimensions of perceived trust independently influence adoption intentions and how these trust dimensions evolve throughout the ADV usage process. Such insights will offer detailed guidance for the ongoing optimization and promotion of ADV services.

6. Conclusion

This study extends the DOI theory to examine the acceptance of ADV services among Chinese consumers. The findings not only validate the effectiveness of the model but also identify key factors influencing consumer adoption intentions. Relative advantage emerges as the strongest positive predictor of adoption intention, suggesting that consumers are more likely to embrace ADV services when they perceive clear benefits compared to traditional delivery methods. Notably, social awkwardness also shows a significant positive impact, becoming the second strongest predictor. Perceived trust further exhibit significant positive impacts, underscoring the importance of consumer trust in the technology during the service process in driving adoption intentions. The positive effect of compatibility highlights that the alignment of the service with consumers' existing lifestyles is a crucial factor in the adoption decision. The hypothesis regarding hedonic motivation influencing adoption intention was not supported, indicating that enjoyment or entertainment associated with the use of autonomous delivery vehicles does not significantly impact customers' adoption intentions. This suggests that functional and practical considerations may outweigh hedonic factors in shaping user preferences. Future studies could further explore this aspect to determine if specific contexts or populations exhibit differing sensitivities to hedonic motivations.

These findings offer new insights into the adoption of ADV services, demonstrating not only the functional advantages of autonomous delivery but also its potential to enhance user experience and accommodate diverse social preferences. Public environment factors reveal a significant negative impact, reflecting consumer and public concerns regarding the use of ADVs in urban spaces, which may involve issues related to privacy, safety, or social norms. Additionally, the negative impact of complexity emphasizes the necessity to simplify the user experience and mitigate perceived operational difficulties.

For service providers, these results have considerable practical implications. Businesses should focus on highlighting the relative advantages of their services, ensuring compatibility with users' existing lifestyles, and promoting how ADV delivery offers increased privacy and controllable service options in their marketing strategies. Continuously building user trust in the technology, and

simplifying operational processes to reduce perceived complexity are essential strategies for increasing adoption rates.

This study also provides valuable insights for smart cities and future urban development. Autonomous vehicle delivery, as an integral component of smart city infrastructure, is anticipated to enhance urban logistics efficiency, reduce environmental impacts, bolster urban resilience, advance intelligent transportation systems, create new job opportunities, and improve overall urban quality of life while fostering urban innovation. However, the negative impact of public environment factors underscores the challenges associated with implementing autonomous vehicle services in urban public spaces. This finding highlights the necessity of reconsidering and redesigning public spaces within smart city planning to better accommodate and integrate emerging technologies, while preserving the livability and social functionality of urban environments.

This study has certain limitations. Notably, the sample primarily consists of young individuals from the Shunyi District of Beijing. Future research should expand the sample to include a broader range of demographic characteristics and cultural backgrounds, to explore how these factors influence adoption across different populations. Additionally, longitudinal studies tracking how user attitudes and behaviors evolve with the increasing prevalence of autonomous delivery services could provide deeper insights.

Overall, this research extends existing theoretical frameworks and provides crucial empirical evidence and strategic recommendations for the development and promotion of autonomous vehicle delivery services. The findings illustrate how technology can transform social interaction patterns while addressing both functional and emotional needs of consumers. As technology advances and societal demands evolve, autonomous delivery services are expected to play a progressively significant role in urban life, offering more convenient, personalized, and comfortable service experiences.

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