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Autonomous delivery vehicle acceptance: The moderating role of perceived risk of theft

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ABSTRACT

This paper assesses the public acceptance of Autonomous Delivery Vehicles (ADVs) by extending the Technology Acceptance Model (TAM), incorporating subjective norms, environmental concerns, and hedonic motivations alongside the original TAM constructs. The perceived security risk of theft is also defined and included in the model to explore its moderating role. Data was collected from an online survey of 1567 participants in different cities in Iran. The survey incorporated two open-ended questions as part of a qualitative approach to assessing control beliefs, exploring both the facilitators and barriers influencing people's intentions. Based on structural equation modeling, findings highlight the strong impact of subjective norms and perceived usefulness on intention, along with the significant effect of attitudes and environmental concern. The moderating effect of the perceived security risk of theft is significant in perceived ease of use and hedonic motivations' interactions with attitudes. Exploring the responses from open-ended questions showed that the majority of respondents perceived that using ADVs could help the environment, while the risk of stealing ADVs was identified as the main barrier to adopting them in urban settings.

1. Introduction

The final leg of the business-to-consumer delivery service is last-mile delivery, which entails delivering products to the ultimate consumer (Yuen et al., 2019). The need to handle an ever-increasing volume of shipments and deliver them through congested urban areas in a timely manner leaves last-mile delivery susceptible to disruptions (Joerss et al., 2016). As a result, last-mile delivery is known as the delivery industry's Achilles' heel (Hinzmann and Bogatzki, 2020). The significance of last-mile delivery has increased further in recent years, given the recent boom in e-commerce and online shopping (Alverhed et al., 2024). According to the Iran Center for E-commerce Development (ICeCD, 2021), e-commerce has grown almost six times in Iran since the COVID-19 outbreak. Nonetheless, it is believed that this market's capacity exceeds that, and further expansion is anticipated in the years to come. Also, Iran's business-to-consumer e-commerce values grew by almost 160% in 2021 compared to 2020 (ICeCD, 2021). It is expected that the rising value of business-to-consumer e-commerce will lead to a substantial rise in the number of packages delivered.

While home deliveries bring convenience to recipients and benefit logistics providers, their uncontrolled growth leads to social issues stemming from increased vehicle presence (Kapser et al., 2021). In Iran, motorcycles dominate package delivery for their maneuverability and low maintenance cost, yet they cause numerous urban problems. Motorcycles contribute significantly to air pollution, one of the biggest problems facing the Iranian people, causing over 30,000 annual deaths due to illnesses like cancer and heart attacks (Jolai et al., 2021). Their high carbon footprint results from outdated technology and lack of proper emission control systems. Moreover, motorcycles are responsible for around 50% of urban noise pollution (Safaei et al., 2021). In terms of road safety, motorcycles have the highest proportion of casualties in crashes, leading to social and economic challenges in Iran

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(Sadeghi-Bazargani et al., 2018).

Since these negative externalities not only lower the quality of life and the economic competitiveness of urban areas but also exacerbate overall traffic safety, it seems that current transportation practices (i.e., motorcycle delivery) lack the potential to cope with this fast-changing environment effectively. As a result, it becomes necessary to modify current last-mile transportation strategies.

In recent years, there has been significant interest in improving cities' operational efficiency through intelligent transportation systems and automation (Engesser et al., 2023). A recently developed transportation technology that is thought to have the capability to transform last-mile delivery by making it more efficient, sustainable, and customer-focused is the Autonomous Delivery Vehicle (ADV) (Hossain, 2023). This technology is a self-driving electric ground vehicle that travels on sidewalks and roadways (Joerss et al., 2016; Kapser and Abdelrahman, 2020; Marsden et al., 2018). Given the lingering challenges posed by conventional delivery techniques in Iran, ADVs could become a viable delivery option in its thriving e-commerce market.

The motivation for this study arises from the significant challenges associated with the widespread use of motorcycles in Iran, particularly their environmental and safety impacts. ADVs present a promising alternative, offering not only environmental benefits but also the added advantage of contactless delivery, which has proven crucial during pandemics like COVID-19. However, public acceptance remains a critical hurdle, as skepticism toward automation technologies (Lu et al., 2023), including ADVs, persists due to concerns about safety and fears of job loss. These concerns are likely to be even more pronounced in a developing country like Iran, where such technologies have not yet been deployed, and public awareness of them is limited.

Moreover, if ADVs are not widely approved by the public, introducing and investing in this technology will be a significant waste of resources for logistic service providers and technology developers (Kapser and Abdelrahman, 2020). Hence, there is a need to carefully explore public intentions of ADVs, particularly in a country like Iran with limited resources.

1.1. Objectives and aims

This study aims to explore the public's intention to adopt ADVs, examining their motivations and concerns to provide a comprehensive understanding of the factors influencing the acceptance of this technology in Iran by using an extended Technology Acceptance Model (TAM). By gaining insights into public opinion, the study seeks to identify the key drivers and potential barriers to the successful integration of ADVs into the Iranian delivery system. In summary, the following are the current study's contributions.

a) *ADV adoption in a developing country with a collectivist culture:* Nearly all previous studies have focused on the adoption of ADVs in developed and high-income countries. Limited resources, weak infrastructure, escalating environmental crises, a variety of traffic issues, and a high risk of vandalism and theft make developing countries' markets considerably different from developed countries. Consequently, the results of this study could serve as a benchmark for comparing countries with similar cultural, geographical and demographic features to Iran.

b) *TAM extension:* The literature indicates that the use of the TAM to evaluate intentions toward ADVs is scarce (Hinzmann and Bogatzki, 2020). The present study adds Subjective Norms (SN), Environmental Concern (EC), Hedonic motivation (HM), and Perceived Security Risk of Theft (PSRT) to the original TAM to explore additional factors that influence the intention of using ADVs. In the model development section, we introduce the constructs of the proposed TAM model and develop the hypotheses regarding their interactions. We then present the results of the model in Section 5.2 and discuss the findings in Section 6.1.

c) *Inclusion and moderation role of the perceived security risk of theft:* The perception of security risk, as defined in this study, specifically involving the apprehension of ADV or package theft, holds significant importance, particularly in developing nations grappling with high theft and vandalism rates. The notion of perceived security risk has been examined in earlier research regarding online shopping and e-banking, focusing on the risk of financial and personal data pilferage (Hartono et al., 2014; Roca et al., 2009). However, investigating the perceived security risk associated with physical asset theft within this framework remains unexplored, whether in the context of Autonomous Vehicles (AVs), ADVs, or any other domains, to the best of our knowledge. To bridge this gap, our study recalibrated this factor to address physical asset security instead of data security, specifically for the ADV context. This adjusted factor was employed as a moderator to identify its impact on construct dynamics and to evaluate its indirect influence on individuals' intentions. Section 3.6 offers a detailed description of this factor, while Section 6.2 discusses the moderating role of this variable.

d) *Investigating the effect of sociodemographic variables on ADV adoption:* The effect of age, gender, city of residence, education level, employment status, and pre-existing knowledge of ADVs, on individuals' intentions are also considered in the present study. This can help to provide insight into target communities by understanding their perceptions and help service providers to employ more effective marketing strategies by focusing on specific parts of society. The results and discussion related to this part are provided in sections 5.3 and 6.3, respectively.

e) *Identifying control beliefs through open-ended questions:* Along with extending the TAM model, this study explores indirect elements that can affect intentions to ADV usage by identifying control beliefs, encompassing respondents' perceived barriers and facilitators to use ADVs. This can show potential aspects that previous research has not investigated. Here, a particular focus is placed on contrasting and comparing beliefs which can subtly affect people's intentions to use ADVs. Table 1 contains the abbreviations employed in the current study. The results and discussion of the findings from the open-ended question analysis are presented in Sections 5.4 and 6.4, respectively.

Table 1
The abbreviations employed in the current study.

Abbreviation	Description
ADV	Autonomous Delivery Vehicle
ATT	Attitudes
AV	Autonomous Vehicle
AVE	Average Variance Extracted
BI	Behavioral Intention
CR	Composite Reliability
CFA	Confirmatory Factor Analysis
EC	Environmental Concern
HM	Hedonic Motivation
NFI	Normed Fit Index
PEOU	Perceived Ease of Use
PLS	Partial Least Squares
PSRT	Perceived Security Risk of Theft
PU	Perceived Usefulness
SAVE	Square root of Average Variance Extracted
SEM	Structural Equation Model
SN	Subjective Norms
SRMR	Standardized Root Mean square Residual
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology
VIF	Variance Inflation Factor
WTP	Willingness To Pay

2. Background

2.1. Perceptions of autonomous deliveries

Acceptance, adoption, and use of automation technologies have gained much attention in transportation research since they have the potential to enhance the operational efficiency of the urban setting while optimizing the time, cost, reliability, and safety of city transportation (Panagiotopoulos and Dimitrakopoulos, 2018). Hence, many studies have been conducted to assess public opinion toward autonomous vehicles, a groundbreaking technology in transportation. Nevertheless, in contrast to the wealth of literature exploring the public acceptance of autonomous technology as a personal car or shared transportation, there is much less research dedicated to understanding consumer approval of autonomous technology for delivery purposes (Kapser and Abdelrahman, 2020; Pani et al., 2020). One of the recent technologies for delivery purposes is the ADV, a pedestrian-sized ground robot that delivers goods to customers without the use of delivery persons (Jennings and Figliozzi, 2019). ADVs have already been deployed for package and food deliveries by companies such as Amazon, DHL, Hermes, and FedEx, although this is still in the pilot testing phase (Kaiser et al.; Pani et al., 2020; Schaudt, 2018). It is expected that, following the success of these pilot tests, the technology will be utilized in the last-mile market soon (Hinzmann and Bogatzki, 2020). Given the infancy of this technology, there is only a handful of studies that have investigated the psychological aspects of ADVs' public acceptance. Some of these studies are primarily descriptive in their approach (e.g., Gramatikov et al., 2019; Joerss et al., 2016; Rohleder, 2016), while some use frameworks such as UTAUT2 (Kapser and Abdelrahman, 2020; Kapser et al., 2021; AlKheder et al., 2023), TAM (Hinzmann and Bogatzki, 2020; Yuen et al., 2022; Lu et al., 2023), WTP (Pani et al., 2020), and other approaches (e.g., Mishra et al., 2023; Liang et al., 2024; Pröbster and Marsden, 2023) to investigate public intentions towards using ADVs. Table 2 represents summary of studies focused on public acceptance of ADVs.

For example, Kapser and Abdelrahman (2020) assessed the acceptance of ADVs in Germany adopting an expanded version of the Unified Theory of Acceptance and Use of the Technology model (UTAUT2) (Venkatesh et al., 2012). It was found that performance expectancy and price sensitivity have the strongest impact on users' acceptance. Based on their earlier study, Kapser et al. (2021) studied the moderating effect of gender and determined that the impact of social influence and hedonic incentive on the intention to use ADVs is only significant for females. The average intention to use ADR in both studies was neutral. Moreover, by using a clustering approach on a sample from Portland, Pani et al. (2020) identified the Willingness To Pay (WTP) for these clusters. Six distinct consumer segments were identified in their latent class analysis of attitudinal responses. They also found that customers are willing to pay additional costs for deliveries by ADVs. In another study, Koh et al. (2024) investigated consumer acceptance of ADVs in last-mile delivery by integrating resource-matching, perceived risk, and value theories. The study aimed to provide a comprehensive understanding of the factors influencing consumer acceptance. The authors used a mixed-methods approach, combining quantitative surveys and qualitative interviews to gather data on consumer perceptions. Their findings reveal that consumer acceptance is significantly influenced by the alignment of autonomous delivery services with their resource needs, the perceived risks associated with the technology, and the overall value proposition it offers. The study highlights the importance of minimizing perceived risks and maximizing perceived value to enhance consumer acceptance of ADVs.

2.2. Technology acceptance

Technology acceptance models have been widely adopted to investigate factors affecting people's intention to adopt a technology (Venkatesh et al., 2007). The first model to assess technology acceptance among people was the TAM (Davis, 1985), which initially developed from the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1977). The TRA is one of the most widely cited and recognized models for estimating human behavior. It includes the fundamental concepts of attitudes toward behavior and subjective norms (Dirsehan and Can, 2020). Davis (1985) adapted the TRA to measure attitudes toward technology and proposed the TAM by introducing two new factors of Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). According to the TAM, PU and PEOU constructs can affect the intention to use technology. Researchers have developed novel models based on different versions of the TAM. For instance, Venkatesh and Davis (2000) developed TAM2 by adding subjective norms as an external construct to TAM. UTAUT was another extended model based on TAM that included factors like hedonic motivation and facilitating conditions (Venkatesh et al., 2003). Venkatesh et al. (2012) later modified UTAUT and developed UTAUT2.

In the current study, the primary framework for the proposed model was based on the original TAM introduced by Davis (1985). The main constructs of the TAM model include ATT, PU, PEOU, and BI. PU shows the belief of an individual in improving overall job performance by using a particular technology or system, and PEOU refers to the belief of a

Table 2
Summary of studies focused on ADVs' acceptance.

Author(s)	Location of Study	Approach	Constructs Considered in Surveys
AlKheder et al. (2023)	Kuwait	Extended UTAUT2	Performance expectancy, Social influence, Hedonic motivation, Price sensitivity, Perceived risk, Trust, Innovation, Corona pandemic
Said et al. (2023)	USA	Choice experiment design	Affinity towards technology, Concerns regarding privacy and package handling, Environmental consciousness
Kapser and Abdelrahman (2020)	Germany	Extended UTAUT2	Effort expectancy, Social influence, Facilitating conditions, Perceived risk, Behavioral intention
Hinzman & Bogatzki, (2020)	Germany	Extended TAM	Perceived ease of use, Facilitating condition, Perceived usefulness, Price sensitivity, Privacy security, Hedonic motivation
Lu et al. (2023)	China	Survey based on Diffusion of innovation (DOI) Theory	Relative advantage, Compatibility, Complexity, Social influence, User Experience
Koh et al. (2024)	Singapore	Mixed-methods (resource-matching, perceived risk and value theories)	Perceived risk, Perceived value, Convenience, Reliability, Compatibility, Privacy
Yuen et al. (2022)	Singapore	Extended TAM	Perceived usefulness, Perceived ease of use, Attitude towards Use, Trust in technology
Liang et al. (2024)	China	Extended Behavioral Reasoning Framework	Technology readiness, Innovativeness, Optimism, Discomfort, Insecurity
Kapser et al. (2021)	Germany	Extended UTAUT2	Gender differences, Perceived safety, Risk perception, Behavioral intention
Pani et al. (2020)	USA	Willingness to Pay and Latent Class Cluster	Latent classes of attitude, locational and demographic factors

person whether a particular system or technology would be free of mental and physical effort. ATT encompasses an individual's comprehensive perception of technology, whereas BI is linked to an individual's intention to utilize technology. In the original TAM model, PU and ATT directly predict BI. Moreover, both PU and PEOU can indirectly influence BI through ATT. PEOU can also exert an indirect influence on BI through PU.

3. Model development

This study uses the TAM as the theoretical framework to explain the adoption of autonomous delivery vehicles. Subjective Norm (SN), Hedonic Motivation (HM) and Environmental Concern (EC) were added to the proposed model to evaluate the acceptance of using ADVs in Iran. Moreover, the moderating role of the perceived security risk of theft in this construct is also investigated. Fig. 1 shows the proposed model. The model's constructs and associated hypotheses are outlined as follows.

3.1. Attitudes (ATT)

ATT is defined as the overall view of using the technology and was usually considered one of the pivotal antecedents of BI, which was confirmed by various studies conducted in different contexts (Adu-Gyamfi et al., 2022; Rejali et al., 2024a, 2024b; Wang and Hao, 2020; Yadav and Pathak, 2017). In the context of last-mile logistic services, Wang et al. (2020) identified attitude as a critical focal point that effectively influences people's adoption behaviors toward logistic service innovations, which can be affected by external factors like perceived relative advantage and perceived compatibility. To explore the role of attitudes (ATT) in the acceptance of ADVs and the effect of attitude on BI, we hypothesize that.

H1. ATT positively affects BI to use ADVs.

3.2. Perceived usefulness (PU) and perceived ease of use (PEOU)

Numerous studies across diverse contexts have recognized the direct and indirect effects of PU and PEOU, the foundational constructs of the TAM model, on behavioral intentions. These two constructs have been confirmed as significant anticipators of users' intentions in numerous AV acceptance studies (e.g., Choi and Ji, 2015; Rejali et al., 2023; Xu et al., 2018). For ADVs, PU can be defined as the degree to which consumers will benefit from employing ADVs as a delivery alternative (Kapser and Abdelrahman, 2020). ADVs are thought to be more adaptable, convenient, and transparent for customers (Kapser and Abdelrahman, 2020; Marsden et al., 2018). Owing to these qualities, which are critical in last-mile delivery, ADVs are more customer-oriented and, as a result, may be perceived as more useful than their traditional alternatives, like motorcycles (Kapser and Abdelrahman, 2020). Additionally, ADVs are contactless delivery alternatives, which increases their utility during pandemics such as COVID-19 by reducing the likelihood of virus transmission (Kapser et al., 2021).

Furthermore, PEOU specifies how easily technology can be learned or used (Wu et al., 2019). Consumers generally lean toward products that are relatively simpler to operate (Davis, 1989). It has been found that compared to PU's impact on BI, which usually affects BI significantly, PEOU's influence on BI can sometimes be subtle at most (Chen, 2016; Wu et al., 2019). However, according to other studies, PEOU can substantially impact both ATT and BI (Kaplan et al., 2017; Park et al., 2015). It appears that using mobile apps to engage with ADVs may add another layer of complexity to the process (Kapser and Abdelrahman, 2020). Nevertheless, while some consumers may not mind using mobile apps, others may view this as an unnecessary hassle and create an unfavorable opinion of ADVs as a result.

Considering the significant role of PU and PEOU in user acceptance and following the hypotheses outlined in the original TAM model, it is hypothesized that.

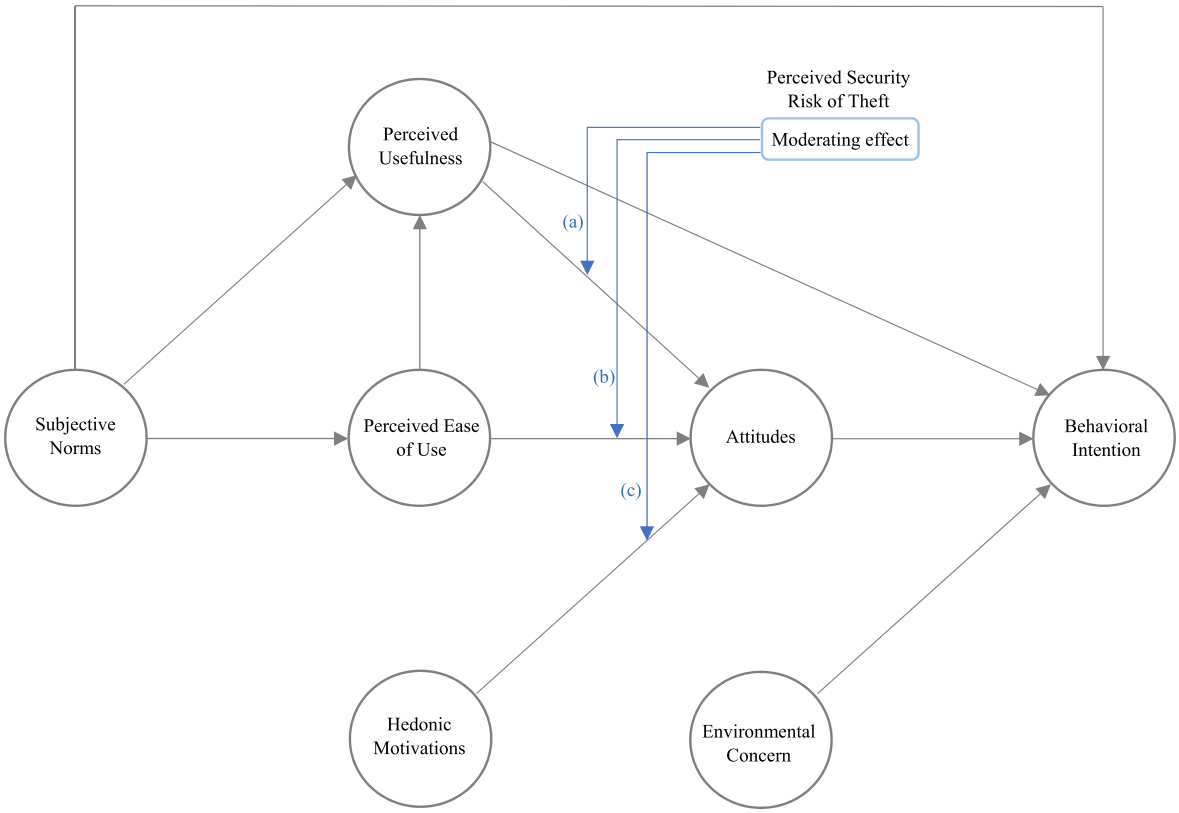

Fig. 1. Conceptual framework.

H2. PU positively affects ATT.

H3. PEOU positively affects ATT.

H4. PU positively affects BI to use ADVs.

H5. PEOU positively affects PU,

3.3. Subjective norms (SN)

SN denotes instances in which a person's thoughts and beliefs, and subsequently, their behaviors, are impacted by others (Giang et al., 2017). These important 'others' are typically influential in decision-making, including family members, friends, and also the media. With establishing the TRA, Fishbein and Ajzen (1977) first considered the significance of SN in forming behaviors. Venkatesh and Davis (2000) later verified that SN is one of the most influential BI indicators of technology acceptance. Multiple Studies on the topic of AV acceptance have shown that social influence is a robust predictor of adoption (Panagiotopoulos and Dimitrakopoulos, 2018). Subjective Norms have also been investigated in the context of ADVs acceptance in recent studies. Using the UTAUT2 model, Kapser and Abdelrahman (2020) found the significance of social influence on the intention of the German population, revealing the importance of considering peer pressure in marketing purposes of ADVs. Likewise, by utilizing the UTAUT2 model, the significant impact of SN on the US population's intentions to use autonomous vehicles in last-mile delivery was validated by Saravanos et al. (2022). Due to the collectivist culture in Iran, the effect of significant others' opinions could be pronounced (Wong and Cheng, 2020). Thus, it is expected that SN has a considerable impact on the adoption of ADVs in Iran. Furthermore, as ADVs are not publicly available and the majority of people may not have past knowledge of ADVs, their perceptions about the usefulness and ease of use of ADVs could be highly affected based on public opinion (Rejali et al., 2021).

Based on the insights from previous studies, we hypothesize that.

H6. SN positively affects BI to use ADVs.

H7. SN positively affects PEOU.

H8. SN positively affects PU.

3.4. Environmental concern (EC)

EC is correlated with public awareness of environmental problems, manifesting in people's attitudes, knowledge and responsiveness to environmental issues (Weigel and Weigel, 1978). Studies have demonstrated that EC is significantly associated with intentions to acquire green products like electric vehicles (Ozaki and Sevastyanova, 2011; Wu et al., 2019). Autonomous electric vehicles are expected to contribute to the sustainability of transportation by enhancing traffic efficiency, reducing private car ownership and improving air quality (Anderson et al., 2014). Therefore, it stands to reason that those with deeper environmental concerns will be more inclined to employ delivery practices with minimum environmental impact, such as ADVs. Despite its significance, EC and its interaction with BI are understudied in the ADV acceptance literature. Thus, to evaluate the role of EC on BI, it is hypothesized that.

H9. EC positively affects BI to use ADVs.

3.5. Hedonic motivation (HM)

Venkatesh and Davis (2000) posited that the extent to which individuals find a technology entertaining and enjoyable is another factor that can influence their intent to use it. HM refers to conceptualized perceived pleasure (Rejali et al., 2021). Keszey (2020) revealed a strong impact of HM on individuals' intentions to adopt AVs. HM was also found to be highly influential on public acceptance of autonomous road transport systems (Madigan et al., 2017). In the context of ADVs, Kapser and Abdelrahman (2020) showed that HM is positively associated with BI to use ADVs and indicated that most individuals find ADVs to be a fun product. As individuals' enjoyment of technology can contribute to a positive attitude towards its utilization, this study explores the impact of HM on shaping people's intention to use ADVs and hypothesizes the indirect effect of HM on BI through ATT.

H10. HM positively affects ATT.

3.6. Perceived security risk of theft (PSRT)

In general, risk is defined as an unexpected outcome when using a service, leading to consumer dissatisfaction (Adu-Gyamfi et al., 2022). Risk perception is defined as an individual's subjective evaluation of objective risk (Pennings and Smidts, 2003). Perceived risk can be financial, social, performance, psychological, and physical (Adu-Gyamfi et al., 2022). However, other aspects of risk have also been defined and used in studies. For instance, in online shopping, security, privacy, and source risk are considered as an extension of perceived risk (Bhatti et al., 2018).

3.6.1. Perceived risk in an e-commerce context

Research on consumer behavior in the areas of e-commerce, m-commerce, and related offshoots, like online banking and mobile payment, has considered the perceived risk as a significant barrier to customers' adoption decisions (Martins et al., 2014; Thakur and Srivastava, 2014; Wang et al., 2019). Acquisition, storage, and transfer of sensitive information required for customer acceptance in an online context may expose customers to security breaches and potential privacy violations. Furthermore, lack of face-to-face engagement can create significant information asymmetry and ambiguity for customers (Wang et al., 2019). These factors cause internet-based services, such as online shopping, to be considered riskier than the conventional offline purchasing option. As a result, consumers are more reluctant to utilize and embrace internet-based services (Thakur and Srivastava, 2014).

3.6.2. Perceived risk in the context of autonomous vehicles (AVs)

Multiple research studies have indicated that the acceptance of AVs can be influenced by individuals' perceptions of the associated risks. For instance, it has been consistently observed that the negative impact of perceived risk is a significant factor influencing consumers' willingness to use AVs (Schoettle and Sivak, 2014; Zhang et al., 2019; Guo et al., 2021). Potential safety risks in AVs, including functional failure leading to possible crashes, are the top concern in this context (Gopinath and Narayanamurthy, 2022; Zhang et al., 2019). Another risk associated with AVs acceptance is the privacy risk, including software hacking and data misuse (Zhu et al., 2020). Hence, risk perception is regarded as an antecedent of AV adoption (Gopinath and Narayanamurthy, 2022).

3.6.3. Conceptualizing perceived security risk of theft in the context of autonomous delivery vehicles (ADVs)

Regarding ADVs, Marsden et al. (2018) found that they are seen as a risky delivery alternative. Moreover, in a study conducted by Io and Lee (2019), people asserted the risk of stealing ADVs or the package inside it to be concerning. The risk of theft was also identified by Gramatikov et al. (2019). However, these studies were descriptive and did not investigate perceived risk as a construct in the acceptance of ADVs. Accordingly, perceived risk was included as an additional construct in Kapser and Abdelrahman's (2020) study to understand the effect of risk on people's intention toward ADVs. They found that perceived risk has a significant negative impact on people's intention to use ADVs. However, this study investigated people's perception of overall risk without a specific dimension.

The impact of perceived risk dimensions varies depending on the research subjects and contexts (Wang et al., 2019). Perceived risk

dimensions can be specified by purchasing behavior, trading environment, and cultural variations, as stated by Stone and Grønhaug (1993) and Veloutsou and Bian (2008). For instance, in online shopping, concerns about security risks regarding money transfers stand out (Wang et al., 2019). Likewise, in the context of AVs, perceived safety risks due to the potential system or equipment malfunction are the top concern (Zhang et al., 2019). Perceived safety risk becomes more relevant in this context because AVs carry the user, and any malfunction leading to crashes could directly endanger the user.

Subsequently, the perception of risk regarding ADVs could be different since, unlike AVs that carry users, ADVs carry their parcels. As mentioned, some studies acknowledged public concern about potential theft from ADVs (Gramatikov et al., 2019; Io and Lee, 2019). Moreover, theft has increased drastically in Iran in recent years, damaging the society's financial security and causing distress and anxiety for individuals (Yosefi et al., 2021). High rates of vandalism and theft were recognized as significant barriers to utilizing emerging transportation technologies such as electric bikes (Jahanshahi et al., 2019). The high rate of vandalism and theft in Iran could also become a substantial hindrance to ADVs' adoption. ADVs may also appear more vulnerable to theft compared to traditional motorcycle deliveries in Iran due to several factors. A significant distinction is the absence of a driver, which removes a natural deterrent against theft. Furthermore, while ADVs are equipped with security technologies, their compact size makes them more susceptible to being physically stolen or tampered with.

While the risk of theft could be a critical factor concerning the acceptance of new technologies in transportation, especially in developing countries, its effect has not been investigated in any studies in this field before. To address this gap, and by considering the situation of Iran coupled with attributes of ADVs, the perceived security risk was adjusted for the ADV context in this study. Based on the definitions of security risk by Roca et al. (2009) and Hartono et al. (2014), the Perceived Security Risk of Theft (PSRT) is described as the potential for ADVs to cause loss of property, time or other resources due to either stealing the parcel inside the ADV or hijacking/stealing the ADV.

3.6.4. Moderating effect of perceived security risk of theft (PSRT)

Although in the context of e-commerce, it has been confirmed that risk perception directly influences users' attitudes and intentions (Martins et al., 2014), the direct effect of perceived risk on attitude or BI was not hypothesized in this study for the following reasons. First, as it was found in a recent meta-analysis examining the interactions between trust, risk, and acceptance, removing the link from perceived risk to BI improved the model's fitness (Kim and Peterson, 2017; Zhang et al., 2019). Furthermore, in AV acceptance models developed by Choi and Ji (2015) and Xu et al. (2018), no statistically significant relationship was found between risk perception and BI. In these studies, the key variable of trust was incorporated into the model, likely capturing the direct influence of perceived risk through its effect on trust. However, other studies have examined perceived risk independently, without trust variable in their models, and still treated perceived risk as a moderating variable.

Moreover, Im et al. (2008) also showed that perceived risk could be modeled as a moderating variable, where users' acceptance behavior was better explained. Similarly, risk has an important moderating effect in predicting consumer willingness to use e-services, according to Featherman and Fuller (2003). The moderating role of risk transforms the simple and direct relationship between behavioral constructs and intention into a more intricate, conditional, and in-depth association (Wang et al., 2019).

In consideration of the above, the moderating role of PSRT on ATT toward ADVs is investigated, based on the following hypothesis.

H11. PSRT moderates the relationship between ATT toward ADVs and (a) PU (b) PEOU (c) HM.

4. Method

4.1. Data collection

Data collection for this study was based on a questionnaire consisting of three main parts. The first part included demographic questions about gender, age, education level, city of residence, employment condition, and prior knowledge of ADVs. The next part of the survey included measurement items to investigate the factors included in the extended TAM model (Table A1, see Appendix). A seven-point Likert scale (1 = strongly disagree to 7 = strongly agree) was used for the measurement items. The final section of the survey included two open-ended questions designed to explore control beliefs, specifically facilitators and barriers, related to ADVs. These control beliefs could indirectly shape public intentions regarding their usage (Kaye et al., 2020). These questions were: (1) "In your opinion, what would be the most important facilitators that can affect your intention to use autonomous delivery vehicles?" (2) "In your opinion, what would be the most important barriers that can affect your intention to use autonomous delivery vehicles?"

Furthermore, expecting that a considerable number of respondents might not possess prior knowledge about ADVs, a 2-min video was provided to give respondents basic information about the technology. Respondents were asked to watch the video before filling in the survey questions. This provided a brief introduction to ADVs, outlining their overall advantages and disadvantages, as well as the procedure for using them. Snapshots from this video are shown in Fig. 2. A pilot test showed that participants spent around 15 min watching the introduction video and completing the survey. The survey was converted into Farsi through the back-translation approach, involving an initial translation into Farsi followed by a subsequent translation back into English to ensure a comparable meaning to the original text.

4.2. Sample profile

The survey was conducted online and distributed via Porsall, a highly trusted platform that generates online surveys for research purposes in Iran. The questionnaire and the introduction video link were sent randomly to more than 10,000 people in different cities to reach a representative sample size. The snowball sampling technique was employed to extend the sample size, involving participants being requested to share the questionnaire with their family members and friends. Responses were regularly evaluated to ensure validity in the data collection process. Duplication of responses was also not permitted. The survey was distributed over 35 days, from January 20, 2022, to February 25, 2022. After removing invalid and incomplete responses, a total of 1567 respondents formed the final sample.

The data included 50.5% males and 49.5% females, reflecting a gender distribution similar to that of Iran, and the sample's age distribution also closely follows the age distribution pattern of Iran (SCo, 2017). Among the four age groups, individuals aged 25–39 years accounted for the largest percentage of respondents (33.4%). Additionally, the study incorporated the participants' city of residence, considering that larger cities exhibit distinct traffic issues and patterns compared to smaller ones, potentially influencing individuals' attitudes and perceptions toward ADVs. Consequently, data collection encompassed respondents residing in metropolitan areas with a population exceeding 1 million as well as those in smaller towns with a population below 1 million, ensuring a representative sample of the general population. Regarding the city of residence, 54% of the respondents lived in cities with a population exceeding 1 million, commonly referred to as metropolitan areas in Iran, while the remaining 46% resided in smaller cities (See Table 3).

4.3. Data analysis

Confirmatory Factor Analysis (CFA) was applied to assess the

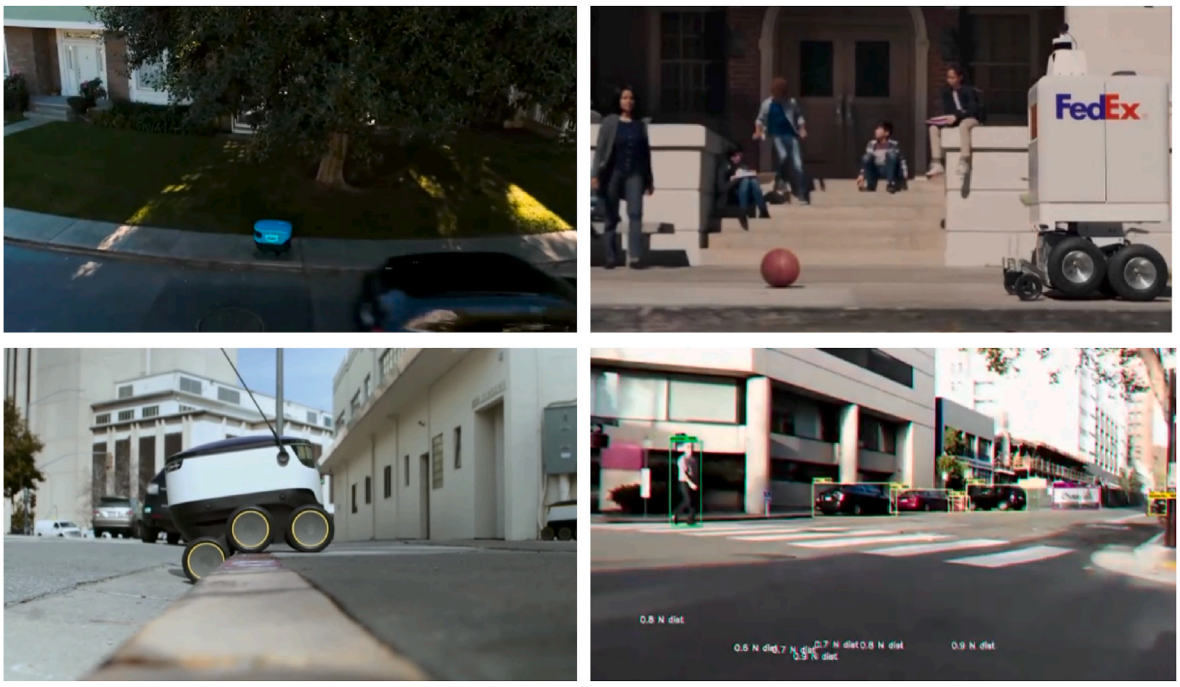

Fig. 2. Snapshots from the introduction video.

Table 3
Demographics of the sample.

	Frequency	Percentage
Gender		
Male	792	50.5
Female	775	49.5
Age		
18-24	417	26.6
25-39	523	33.4
40-60	385	24.6
>60	242	15.4
City of Residence		
Metropolises	846	54.0
Other cities	721	46.0
Education		
Doctorate	59	3.8
Master's degree	160	10.2
Bachelor's degree	495	31.6
University diploma	149	9.5
High school degree	504	32.2
No degree	200	12.8
Employment Status		
Full-time employment	379	24.2
Part-time employment	297	19.0
University student	385	24.6
Seeking work	323	20.6
Retired	159	10.1
Unable to work	24	1.5
Pre-existing knowledge		
Yes	473	30.2
No	1094	49.8

measurement model. Normed Fit Index (NFI), Standardized Root Mean Square Residual (SRMR), and Root Mean Squared Residual Covariance Matrix (RMS_Theta) were estimated to evaluate data fit on the proposed model. Moreover, Cronbach alpha and Composite Reliability (CR) were derived to assess the reliability and validity of the model. Values higher than 0.7 for these two indicators demonstrate a good internal consistency for the constructs (Fornell and Larcker, 1981). The convergent validity was tested based on factor loadings and the Average Variance Extracted (AVE). Significant factor loadings above 0.7 and AVE higher than 0.5 are recommended (Adu-Gyamfi et al., 2022; Choi and Ji, 2015).

The Square root of AVE (SAVE) for each factor was compared with its correlations with other factors to assess discriminant validity. To have good discriminant validity, SAVE for each factor should be greater than its correlations with other factors (Choi and Ji, 2015; Fornell and Larcker, 1981). To avoid multicollinearity, the common-method variance was estimated. The inner Variance Inflation Factors (VIFs) less than 5 show acceptable multicollinearity in the model (Hair et al., 2009; Kock and Lynn, 2012). The present study used SPSS software for the evaluation of questionnaire data and descriptive analysis. SmartPLS3 software was utilized to conduct the Partial Least Squares (PLS) method of the Structural Equation Model (SEM). This method was used to verify the validity of the constructs and the direct and indirect relationships between the proposed constructs and behavioral intention. The PLS-SEM analysis with a bootstrap procedure of 1000 subsamples was employed to estimate the significance level of the model's constructs.

The moderating effect of PSRT on the interactions between ATT, PEOU, PU, and HM was estimated using SmartPLS software (Ramayah et al., 2018). A moderator variable influences the relationship between two variables, altering the impact of the predictor on the criterion based on the moderator's level or value (Holmbeck, 1997). In essence, a moderator interacts with the predictor to affect the dependent variable's level, thereby specifying the conditions under which a particular effect occurs, and how the direction or strength of that effect may vary (Ramayah et al., 2018).

To evaluate these moderation effects, the product-indicator method was employed, in line with previous research (Chin et al., 2003; Wang et al., 2019). This method, which involves cross-multiplying measures of latent variables, provides more accurate estimates of moderator effects by identifying errors that can weaken estimated relationships, thus enhancing the validity of the hypotheses (Chin et al., 2003).

In the last step, responses to the open-ended questions were analyzed. Adapting from the literature and using the experience of previous studies (Kaye et al., 2020; Rejali et al., 2021), the responses were scrutinized and categorized by extracting keywords, aiming to identify participants' control beliefs, which encompassed both facilitators and barriers. These control beliefs were considered to have an indirect influence on participants' intentions to use ADVs. Upon reviewing the categorized responses and their frequency, several recurring themes

emerged, providing insights into the control beliefs held by the respondents.

5. Results

5.1. Confirmatory Factor Analysis (CFA) results

Based on the results of CFA, one item in the original measurement (PU1) had a factor loading less than 0.7 (0.622), so this was excluded from further analysis. After eliminating PU1, all factor loadings exceeded 0.7, and all AVEs were larger than 0.5, indicating good convergent validity of the model. Furthermore, since Cronbach's alpha and CR values were greater than 0.7, the proposed model has good internal consistency (Table 4). In addition, as the VIFs were less than 4, multicollinearity is not considered to be of any major concern (Table A2, See Appendix). As shown in Table A3 (See Appendix), SAVE values for each factor are higher than their bivariate correlations with other factors. This result shows good discriminant validity of the model construct (Fornell and Larcker, 1981).

5.2. Structural equation modelling and hypothesis testing

A structural equation model was employed to test the proposed hypotheses in Section 3. The overall fit of the model was analyzed, and it was found that the model fits the data well (Chi-Square = 4816.203; SRMR = 0.059; NFI = 0.802). A lower SRMR value indicates a better model fit, with a threshold of 0.08 or less being generally accepted (Hu and Bentler, 1999). For NFI, values closer to 1 indicate a better fit, with the traditionally accepted threshold being 0.9, although a threshold of 0.8 is also considered acceptable (e.g., Akinyode, 2016; Singh and Kathuria, 2023; Khairi et al., 2021). The structural equation model results confirm that the theoretical pathways hypothesized in this study are acceptable. Furthermore, all the coefficients are significant at $p < 0.001$. The results of the model are presented in Fig. 3.

According to the results, SN is positively associated with both PU ($\beta = 0.471$; $t = 15.542$; $p < 0.001$) and PEOU ($\beta = 0.730$; $t = 43.541$; $p < 0.001$), confirming hypotheses H3 and H4. Likewise, the effect of SN on BI is significantly positive ($\beta = 0.273$; $t = 8.510$; $p < 0.001$), showing that hypothesis H2 is supported. Moreover, PEOU positively affects PU ($\beta = 0.422$; $t = 13.599$; $p < 0.001$), and ATT ($\beta = 0.293$; $t = 10.069$; $p < 0.001$), which confirms hypotheses H6 and H8. PU has a significant positive effect on ATT ($\beta = 0.356$; $t = 11.914$; $p < 0.001$) and BI ($\beta = 0.312$; $t = 8.984$; $p < 0.001$), which indicates that hypotheses H5 and H7 are supported. The positive impact of ATT on BI is significant ($\beta = 0.244$; $t = 7.476$; $p < 0.001$), which has confirmed hypothesis H1. It was also found that HM has a positive effect on ATT ($\beta = 0.261$; $t = 8.404$; $p < 0.001$), confirming hypothesis H9. Finally, EC is positively associated with BI ($\beta = 0.118$; $t = 4.682$; $p < 0.001$); thus, hypothesis H10 is also confirmed. Table 6 shows the coefficients and the results of hypothesis testing.

The explanatory power of the model can be investigated with the R^2 values of endogenous constructs (Choi and Ji, 2015; Dirsehan and Can, 2020), where R^2 represents the percentage of a construct's variance in the model. As shown in Fig. 3, R^2 values for ATT, PEOU, PU and BI are 0.752, 0.533, 0.690 and 0.735 respectively. R^2 values greater than 0.10 are suggested for a latent construct to be considered adequate (Falk and Miller, 1992). Therefore, the R^2 values indicate that the proposed model provides a good explanation of behavioral intention to use ADVs. PU and SN were found to have the strongest effect on BI, with $\beta = 0.312$ and $\beta = 0.273$, followed by ATT and EC, with $\beta = 0.244$ and $\beta = 0.118$. SN was also found to have a strong indirect effect on BI ($\beta = 0.363$), as was PEOU ($\beta = 0.240$) (see Tables 5 and 6).

The moderating effect of PSRT on the interactions of ATT between PEOU, PU and HM was also estimated. In keeping with prior research efforts, the product-indicator method (measures of latent variables are cross-multiplied) was employed to assess moderation effects (Chin et al., 2003; Wang et al., 2019). This method offers more accurate estimates of moderator effects by identifying an error that weakens estimated links and enhances the validity of hypotheses (Chin et al., 2003). The results of the moderating analysis are presented in Table 7 and Fig. 4. This shows that PSRT can significantly moderate the effects of PEOU ($\beta = -0.096$, $p = 0.007$) and HM on ATT ($\beta = 0.097$, $p = 0.007$), confirming hypotheses H11(b) and H11(c), respectively. However, no significant moderating effect on the relationship between ATT and PU was found, disproving hypothesis H11(a).

5.3. Relationship between background variables and behavioral intention (BI)

The descriptive analysis indicated that respondents exhibited a high level of intention to use ADVs ($X = 5.385$; $SD = 1.162$) (see Table A3). A significant difference in BI was found among age groups ($F(3,1563) = 15.260$, $p < 0.001$). The Bonferroni post hoc test indicates that individuals aged over 60 have a significantly lower intention to use ADVs compared to other age groups ($p < 0.001$). ANOVA results also indicate a significant difference between education levels ($F(5,1561) = 4.270$, $p < 0.01$). The Bonferroni post hoc test revealed that people with a bachelor ($p = 0.012$) or master's ($p = 0.046$) degree expressed significantly higher intentions to use ADVs than those with no degree. In terms of employment status, a significant difference between groups was found ($F(5,1561) = 11.624$, $p < 0.001$). The Bonferroni post hoc test showed that either full-time or part-time employees showed a higher intention to use ADVs than unemployed people ($p < 0.001$). The results also reveal that those who reported pre-existing knowledge of ADVs showed a higher intention to use ADVs compared to those without prior knowledge ($t(1565) = 4.028$, $p < 0.001$).

5.4. Open-ended questions

Key themes were identified based on responses to the open-ended questions. These are summarized in Table 8. Almost three-quarters (72%) of respondents replied to the first open-ended question which focused on the facilitators of ADVs. The results showed that 387 respondents believed that ADVs are more environmentally friendly for

Table 4
Confirmatory Factor Analysis (CFA) results, convergent validity and internal consistency.

Constructs	Items	Factor loadings	α	CR	rho_A	AVE
Attitude (ATT)	ATT1	0.821	0.780	0.872	0.782	0.694
	ATT2	0.853				
	ATT3	0.826				
Perceived Usefulness (PU)	PU2	0.819	0.803	0.884	0.806	0.718
	PU3	0.863				
	PU4	0.859				
Perceived Ease of Use (PEOU)	PEOU1	0.819	0.843	0.895	0.844	0.681
	PEOU2	0.826				
	PEOU3	0.845				
	PEOU4	0.810				
Subjective Norm (SN)	SN1	0.860	0.781	0.873	0.781	0.696
	SN2	0.828				
	SN3	0.814				
Hedonic Motivation (HM)	HM1	0.864	0.805	0.885	0.809	0.719
	HM2	0.863				
	HM3	0.817				
Environmental Concern (EC)	EC1	0.795	0.748	0.855	0.761	0.663
	EC2	0.806				
	EC3	0.841				
Perceived Security Risk of Theft (PSRT)	PSRT1	0.744	0.712	0.808	0.736	0.585
	PSRT2	0.850				
	PSRT3	0.703				
Behavioral Intention (BI)	BI1	0.868	0.832	0.899	0.833	0.749
	BI2	0.858				
	BI3	0.869				

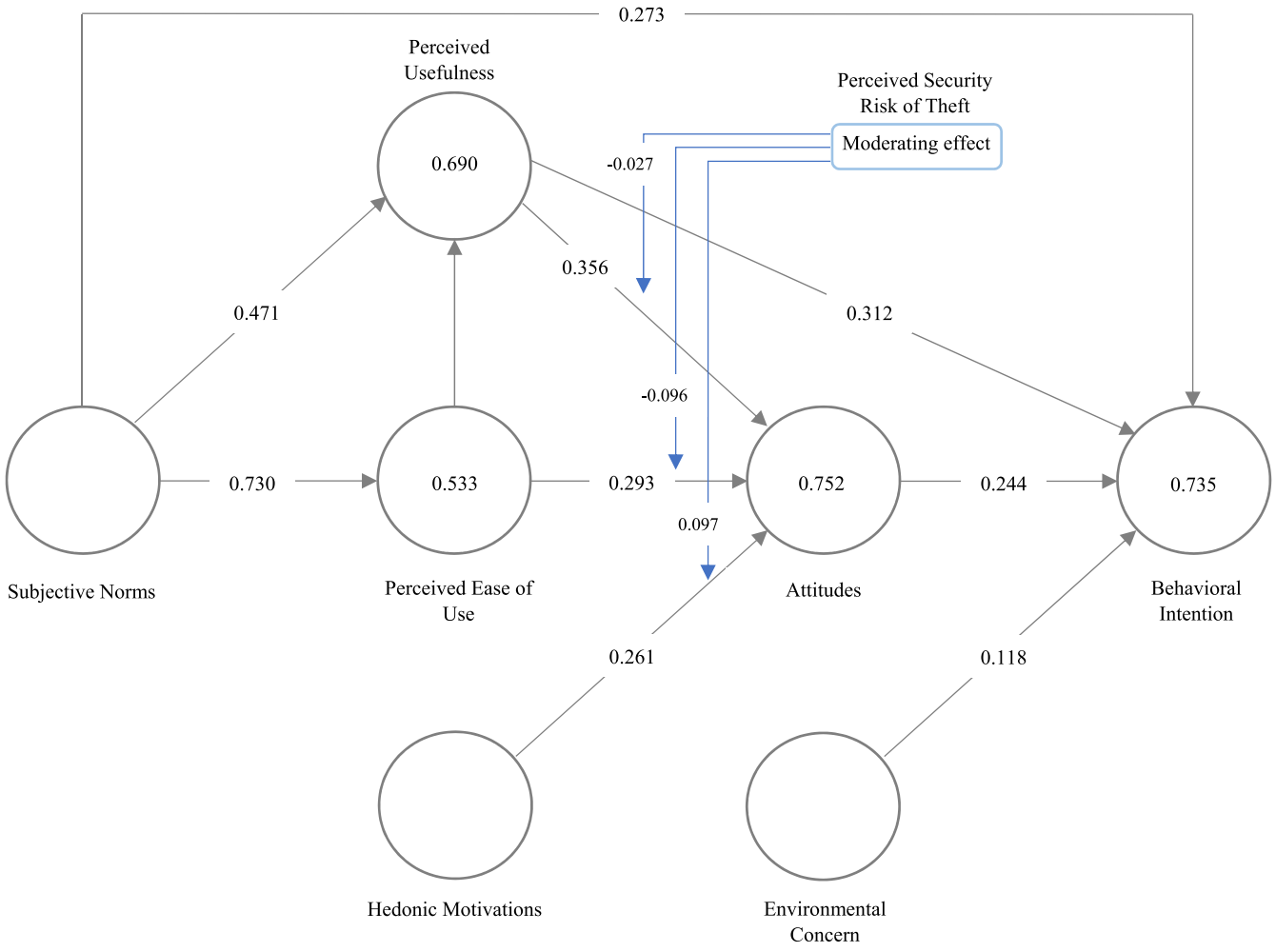

Fig. 3. Extended Technology Acceptance Model (TAM) results.

Table 5
Effects of factors on Behavioral Intention (BI).

Effects of factors on Behavioral Intention (BI).

Hypotheses	Direct effects	Indirect effects	Total effects	
	β	β	β	t-value
ATT → BI	0.244***		0.244***	7.249
PU → BI	0.312***	0.087***	0.399***	13.369
PEOU → BI		0.240***	0.240***	11.087
EC → BI	0.118***		0.118***	4.489
SN → BI	0.273***	0.363***	0.636***	26.78
HM → BI		0.064***	0.064***	5.354

***p < 0.001.

Table 6
Results of hypothesis testing.

Hypotheses	Direct effects		Indirect effects		Total effects	
	β	T-value	β	T-value	β	t-value
ATT → BI	0.244***	7.249			0.244***	7.249
EC → BI	0.118***	4.489			0.118***	4.489
PEOU → ATT	0.293***	9.805	0.150***	9.877	0.443***	14.782
PEOU → BI			0.240***	11.087	0.24***	11.087
PEOU → PU	0.422***	14.196			0.422***	14.196
PU → ATT	0.356***	11.591			0.356***	11.591
PU → BI	0.312***	9.572	0.087***	6.316	0.399***	13.369
SN → ATT			0.491***	19.664	0.491***	19.664
SN → BI	0.273***	8.233	0.363***	14.251	0.636***	26.780
SN → PEOU	0.730***	41.658			0.730***	41.658
SN → PU	0.471***	16.291	0.308***	13.144	0.779***	57.846
HM → ATT	0.261***	8.276			0.261***	8.276
HM → BI			0.064***	5.354	0.064***	5.354

***p < 0.001.

Table 7
The moderating effect of Perceived Security Risk of Theft (PSRT).

Hypotheses	Moderated path	β	Standard Deviation	t-value	p-value	Result
H11(a)	PU→ATT	-0.027	0.033	0.823	0.411	Not significant
H11(b)	PEOU →ATT	-0.096	0.035	2.72	0.007	Supported
H11(c)	HM→ATT	0.097	0.036	2.717	0.007	Supported

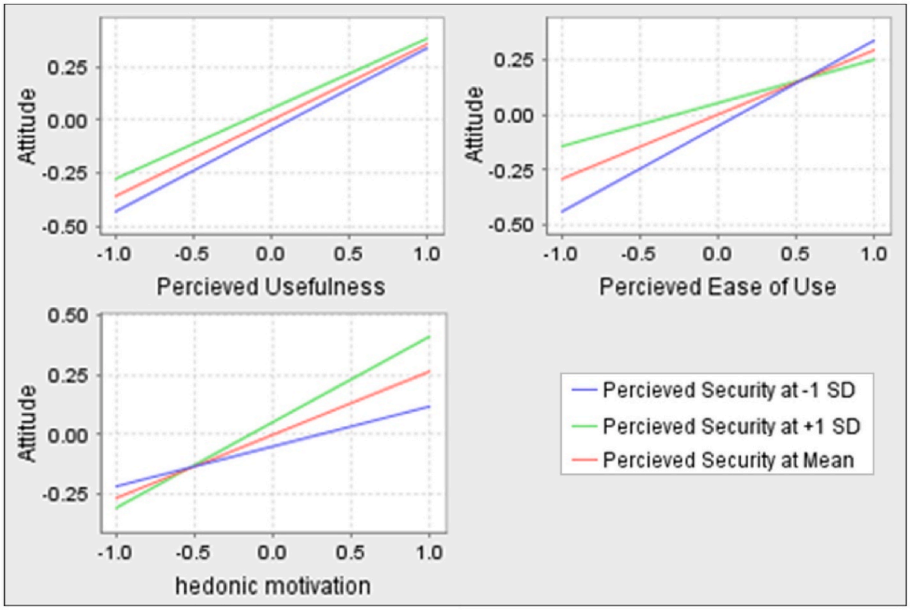

Fig. 4. Moderating effects of Perceived Security Risk of Theft (PSRT).

Table 8
Control beliefs which affect respondents' intentions to use ADVs.

Facilitators	n	Barriers	n
Reduce air and noise pollution	387	Possible risk of stealing the parcel or the ADV itself	389
Alleviate traffic	266	Hard to operate, considering the condition of sidewalks and streets	207
Contribute to a reduction in crashes	173	Threat to people working as deliverers	106
Low operating cost	124	Not suitable for long distances in cities	72
Reduce interaction with other people (during COVID-19)	96	Low speed	45
Higher accuracy than other delivery modes	82	Hard to operate for the elderly	40
		Low capacity for carrying goods	34
		Risk of collision with pedestrians or other road users	30

delivering goods than other modes of traffic, especially motorcycles, i.e., ADVs could "reduce air and noise pollution". Furthermore, 266 respondents mentioned that ADVs could "alleviate traffic". ". A total of 173 respondents mentioned that ADVs could "contribute to a reduction in crashes", especially motorcycle crashes. "Low operating cost" was mentioned by 124 participants. In addition, 96 participants mentioned that ADVs could "reduce interaction with other people (during COVID-19)". "Higher accuracy of ADVs compared to other delivery modes" was stated by 82 respondents. Examples of responses to the first open-ended question can be found in Table A4 (See Appendix).

The second open-ended question was answered by around two-thirds (64.5%) of respondents, which focused on the barriers of ADVs. Table 8 showed that 398 participants mentioned the "possible risk of stealing the parcel or the ADV itself" as a barrier to using ADVs. Moreover, 220 participants mentioned that ADVs are "hard to operate, considering the condition of sidewalks and streets". A total of 117 participants considered ADVs a "threat to people working as deliverers", while 83 respondents mentioned that ADVs are "not suitable for long distances in cities". "Low speed" of ADVs was stated by 56 respondents, while 51 respondents mentioned that ADVs could be "hard to operate for the elderly". "Low capacity for carrying goods" was mentioned by 45 participants. The possible "risk of collision with pedestrians or other road users" was mentioned by 41 respondents. Examples of responses to the second open-ended question can be found in Table A5 (See Appendix).

6. Discussion and implications

As an emerging delivery technology, ADVs can potentially revolutionize the logistics industry by making last-mile delivery more efficient, sustainable and customer-oriented (Joerss et al., 2016; Kapser and Abdelrahman, 2020; Kapser et al., 2021). In addition, ADVs could mitigate the spread of COVID-19 and other viruses in the future by reducing human contact (Kapser et al., 2021; AlKheder et al., 2023). The objective of this study was to assess the acceptance of ADVs and identify key factors influencing their acceptance, specifically in a developing, middle-income country.

6.1. The extended TAM model

The results of the extended TAM showed that PU has the strongest direct effect on the intention to use ADVs. It is also a predictor of ATT toward using ADVs. Similar results were found in studies on the acceptance of AVs (Panagiotopoulos and Dimitrakopoulos, 2018), and ADVs (Kapser and Abdelrahman, 2020; Yuen et al., 2022; AlKheder et al., 2023), which highlights the important role of usefulness on behavioral intention in this context. It can be concluded that practical

benefits are an essential factor in accepting this emerging delivery technology (Kapser et al., 2021). Therefore, these benefits should be communicated to consumers at the market launch (Hinzmann and Bogatzki, 2020).

Furthermore, the results indicate a positive direct impact of SN on BI. Additionally, SN has the strongest total and indirect effects on intentions, among other constructs. This strong effect comes from its significant role in explaining PEOU and PU. These findings highlight the important role of participants' peers in their intention to use ADVs. This is consistent with Kapser et al. (2021) and Alkheder et al. (2023), who demonstrated that social influence positively impacts the intention to use ADVs. Also, SN was found to be important in other contexts like AVs (Madigan et al., 2017; Panagiotopoulos and Dimitrakopoulos, 2018; Rejali et al., 2023) and Electric Vehicle studies (Adu-Gyamfi et al., 2022). The significance of SN in this study might be attributed to the substantial proportion of participants who lacked prior awareness of ADVs before viewing the introductory video. With a lack of pre-existing knowledge, individuals' opinions more easily established by considering the perspectives of their family members, friends, and media sources (Rejali et al., 2021). Moreover, Iran's social values and cultural context are so that the opinions of people from their inner circle, like family members, have the potential to significantly influence an individual's perceptions. This is due to the collectivist culture of Iran, which causes people to express very strong loyalty to their families (Evason, 2016). This result implies that the influence of peer pressure should be taken seriously in marketing ADVs.

Additionally, it was found that ATT has a positive association with the intention to use ADVs, which is consistent with previous studies on ADVs (e.g., Said et al., 2023; Yuen et al., 2022). This result is also aligned with numerous studies in different contexts, such as the acceptance of AVs (Chen, 2019; Kaye et al., 2021; Payre et al., 2014) and EVs (Adu-Gyamfi et al., 2022; Glerum et al., 2014). However, in the present study, although the effect of ATT is significant, SN has a stronger effect than ATT. This difference could be due to culture. While eastern cultures tend to value collectivism, western cultures tend to exemplify individualism (Hofstede, 2011). Therefore, social factors related to family and peer groups could compel intentions in a collectivist culture, whereas personal desires and attitudes could drive people's intentions in a culture of individualism (Wong and Cheng, 2020). Thus, the effect of attitudes on behavioral intention is expected to be strong in western cultures. Investigating the literature in the context of AVs revealed the contrast between the effect of subjective norms and attitudes on intentions. While subjective norms were found significant in most eastern milieu studies (Alkheder et al., 2023; Liu et al., 2020; Rejali et al., 2023; Zhang et al., 2020), this effect was found insignificant in numerous studies in western culture (Kaye et al., 2020; Nordhoff et al., 2021).

The results also revealed the significant effect of PEOU on ATT and PU, indicating that effortless use of ADVs would lead to a positive attitude, which eventually propels their intention to use ADVs in the future. This finding follows previous studies on AVs (Chen, 2019; Gopinath and Narayanamurthy, 2022) and ADVs (Kapser and Abdelrahman, 2020; Yuen et al., 2022; Koh et al., 2024). The results also showed that most respondents considered ADVs to be attractive and entertaining objects. This characteristic of ADVs positively affects attitudes, which can affect their intentions positively, as the model results revealed. The impact of HM was also confirmed in previous studies in the context of AVs (Madigan et al., 2017; Moták et al., 2017) and ADVs (Kapser and Abdelrahman, 2020; AlKheder et al., 2023; Koh et al., 2024).

Environmental Concern was another factor with a significant positive impact on the intention to use ADVs, meaning people who are more concerned with environmental problems tend to have a greater intention to use ADVs. Environmental awareness and concerns have been found to urge people to use environmentally friendly devices (Greaves et al., 2013; Wu et al., 2019; Lu et al., 2023). Autonomous and electric vehicles are expected to have an influential role in sustaining future transport, like altering the oil-based transport system, enhancing traffic efficiency, and decreasing air pollution (Anderson et al., 2014; Wu et al., 2019). Thus, most people consider ADVs more beneficial than harmful to the environment, and it is not surprising that people with higher EC are more inclined to use ADVs in the future. Moreover, responses to the open-ended questions show that many respondents believe that ADVs have lower air and noise pollution than other delivery options, confirming the latter explanation. The existing literature demonstrates a similar result in the context of autonomous delivery vehicles (Lu et al., 2023) and autonomous vehicles (Dirsehan and Can, 2020; Wu et al., 2019).

6.2. The moderating effect of the perceived security risk of theft

The moderating role of Perceived Security Risk of Theft (PSRT) was also investigated in this study. The results showed that PSRT negatively moderates the interactions between PEOU and ATT. This significant negative moderating effect indicates that increases in risk perception will attenuate the effect of perceived ease of use on attitudes. A possible explanation is that when security risk perceptions are high, easy-to-use devices are thought to be more targeted for theft. In other words, some individuals may worry that if something is easy to use, it can be misused by a third person with less effort, so the device or goods inside are more likely to be stolen. Therefore, the effect of ease of use on attitude will be weakened when perceived security risks are considerable. The results also revealed the significant positive moderating effect of PSRT on the interrelationship between HM and ATT. This implies that when the level of perceived security risk increases, the importance of hedonic value as a predictor of attitude toward using ADVs becomes more pronounced, consistent with the findings of Chiu et al. (2014) in the context of online shopping. Similarly, the positive moderating effect of perceived risk on the relationship between hedonic motivation and intention to play online games was found by Sharma et al. (2020).

According to Chiu et al. (2014), this result can be explained by online buyers' sensation-seeking personality, which emphasizes the importance of reaching and maintaining a certain level of arousal to use a service. In other words, when an activity is risky, the fun part becomes more important. According to the findings, risk plays an opposing role in the interaction of perceived ease of use and hedonic motivation with attitudes. This shows that to achieve a desirable, coupled effect of perceived ease of use and hedonic benefits, customers' risk perceptions need to be brought down to an acceptable level (Chiu et al., 2014). The potential for risk-seeking behavior was recognized by prospect theory. However, the explanation of prospect theory focuses on the cognitive aspects; hence it overlooks the potential of understanding risk-seeking behavior from the emotional or affective aspects such as hedonic motivations (Chiu et al., 2014).

6.3. The relationship between background variables and behavioral intention

The descriptive analysis revealed that people aged over 60 years are less likely to use ADVs. This result is contrary to Kapser and Abdelrahman's (2020) study in which the effect of age on behavioral intention was found to be insignificant. Nevertheless, other studies have found that age has a negative effect on the intention to use new technologies such as autonomous vehicles (Payre et al., 2014; Schoettle and Sivak, 2014). Older people feel barriers to accepting and start using new technologies (Klimova and Poulova, 2018; Tacken et al., 2005). Older people's lower cognitive and physical ability (e.g., sight, hearing, motor function) than younger people is one of these obstacles (Klimova and Poulova, 2018).

The effect of education level on intentions was also found to be significant, with higher education (bachelor or master's degree) being associated with more positive attitudes and greater intention to use ADVs. This is consistent with previous research on the intention to use AVs (Liljamo et al., 2018; Montoro et al., 2019). The explanation might

be that highly educated people potentially have higher knowledge about new technologies and trust them more (Golbabaei et al., 2020; Schoettle and Sivak, 2014). Furthermore, this may be related to the high-technology nature of autonomous delivery vehicles, so consumers with lower levels of education can find it challenging to understand and work with their interfaces (Hardman et al., 2019). In addition, the effect of employment status showed that unemployed people tend to have less intention to use ADVs, again consistent with previous research on AVs (Hudson et al., 2019; Nazari et al., 2018). Unemployed people have less social activity than employed people, which might reduce their intention to use new technologies considering the substantial role of subjective norms in the acceptance of ADVs. Additionally, the lower income of unemployed people could explain this result, as the effect of income on the acceptance of new technologies was found in previous studies (Howard and Dai, 2014; Tacken et al., 2005).

The findings indicate that despite a lack of prior knowledge about ADVs among many participants before viewing the introduction video, there is still acceptance among them to use ADVs if they were to become accessible. Nevertheless, the result showed that people with prior knowledge about ADVs expressed more tendency to use them in the future than those without prior knowledge before the survey. The greater awareness of people with prior knowledge about the advantages and applications of ADVs as a more sustainable and entertaining delivery option can explain this result.

6.4. Control beliefs

A qualitative approach permits the elicitation of deeper and novel insights into consumers' psychological behavior and reasoning, which cannot be attained by closed-ended questionnaire questions (Hinzmann and Bogatzki, 2020). Thus, this study included open-ended questions for further investigation of people's intentions toward adopting ADVs.

Several themes were extracted from the responses to open-ended questions, providing further insight for assessing the intention toward ADVs. Respondents believed that ADVs could alleviate air and noise pollution and considered them more environmentally friendly compared to other delivery options. This result indicates that although the manufacturing process of the ADVs may harm the environment, people still outweigh their positive effects on the environment over their harm. This opinion could shape positive attitudes and greater intention toward using ADVs, which was also verified by the result of the SEM model.

The main delivery option in Iran is motorcycles. The extremely high demand for motorcycles in Iran brought about various problems. For example, motorcycles are one of the main causes of air and noise pollution since most of the motorcycles in Iran have old technology with inefficient engines and are not environmentally adjusted (Safaei et al., 2021). In addition, traffic violations and crash rates are very high for motorcyclists, which makes them a dangerous mode of travel (Esmaeli et al., 2022).

As people are considerably afflicted by these issues, they are seeking ways to alleviate them. So, from their point of view, ADVs could therefore become a suitable replacement for motorcycles (the main delivery option in Iran) in some cases as they pose fewer environmental and safety problems. While respondents also mentioned "alleviating traffic issues" and "reducing collisions" as facilitators of ADVs, it is noted that ADVs could instead increase traffic on sidewalks, which can create new externalities and possible concerns related to pedestrian safety and sidewalk congestion (Jennings and Figliozzi, 2019). Therefore, policymakers and service providers should consider regulating traffic laws for human-robot shared space, restricting ADV operation in areas with narrow sidewalks, and placing limits on the number of operative ADVs in specific locations.

Moreover, some respondents considered that the operation cost of ADVs would be lower than other means of delivery. This view can positively affect their intention since operation cost was found as a significant factor in shaping the public's intention to new technologies (Pantano and Di Pietro, 2012; Rejali et al., 2021; Venkatesh et al., 2012). Moreover, the importance of delivery cost on consumers' intentions was also highlighted in previous research (Joerss et al., 2016; Kapser and Abdelrahman, 2020).

At first glance, people may speculate that ADVs are cheaper since they do not need drivers. This rationale is valid and confirmed by Aurambout et al. (2019) as they demonstrated that driverless electric means of transportation have operational cost advantages over vehicles with fuel and labor costs for drivers. Moreover, as stated in previous studies, ADVs can propose a resolution for retailers and logistics companies to enhance supply chain efficiency and lower costs (Hinzmann and Bogatzki, 2020; Hoffmann and Prause, 2018). Some respondents perceived ADVs' contribution to reducing interaction with other people as one of the facilitators. The main motive behind this answer is due to the lingering issues caused by the Covid-19 virus, which endangered many people's lives. Governments imposed various restrictions, such as stay-at-home orders to prevent the spread of this virus. This situation resulted in a significant increase in home delivery volume, which still involves the risk of human-human contact during the last stage of delivery (Kapser et al., 2021). However, ADVs have the advantage of being driverless, which gives them the potential to help stop the spread of viruses by reducing human contact in the delivery process (Hinzmann and Bogatzki, 2020; Kapser et al., 2021; AlKheder et al., 2023). This contact-less nature of ADVs will likely promote users' intention to use ADVs in the future since they may perceive them as more useful, especially with the Covid-19 experience in mind. Respondents also mentioned that ADVs offer higher accuracy compared to other delivery modes. This perspective could stem from the belief that ADVs are perceived as less error-prone than humans. ADVs could provide better service for consumers in a smaller and more accurate time window since they can typically avoid traffic congestion (Aurambout et al., 2019). This will help consumers plan better and miss fewer deliveries, which can positively affect people's intentions towards this emerging delivery option.

Responses to the second open-ended question regarding barriers show that many people expressed concern that the parcel or the ADV itself might be stolen. Previous studies have also acknowledged this concern (Gramatikov et al., 2019; Io and Lee, 2019). This result indicates that although ADVs in the market are equipped with various security measures (e.g., in-built cameras, GPS trackers, and alarms), many still believe they are not secure against theft. Alongside using ADVs with adequate security measures, advertising campaigns can help in assuring people of the secure nature of goods delivered by ADVs. Many participants also believe that ADVs are hard to operate, considering the condition of sidewalks and streets in Iran. This opinion is due to the poor condition of street and sidewalk surfaces in the built environment of Iran. In this case, people's perception of Iran's built environment and infrastructure affected their intention to use ADVs. However, considering the capabilities of ADVs to pass small obstacles, it is not expected to be a major problem. Nonetheless, service providers should test whether ADVs are capable of operating in Iran and use them in areas with acceptable built environment quality. Moreover, this study suggests that policymakers should improve the quality of infrastructure, which not only benefits pedestrians but also lays the foundation to make cities more sustainable by using innovative technologies such as ADVs or electric scooters.

Some participants also identified the threat of ADVs to courier jobs. This is based on a long-standing belief against robots, as many think they will eventually lose their jobs due to automation (Hawksworth et al., 2018). Hence, ADVs are no exception. This result is in line with previous studies that acknowledged similar concerns about ADVs (Hinzmann and Bogatzki, 2020; Io and Lee, 2019). Although automation technologies can potentially bring significant economic benefits, they could also bear various disruptions, particularly for the job markets (Hawksworth et al., 2018). Hawksworth et al. (2018) indicated that the transportation sector has the highest share of existing jobs that could potentially become

automated in the future compared to other sectors, not least due to driverless vehicles. Consequently, it is not surprising that ADVs' success in the market jeopardizes delivery jobs in the long run. The risk of unemployment due to ADVs could be critical in the context of Iran since the number of people who work as drivers or motorcyclists in delivery companies is very high, and most of them have low incomes. For example, it is claimed that over a million parcels are delivered each day in Tehran using solely motorcycles (Virgool, 2017). Considering that Iran is experiencing overwhelming economic issues, the cost of losing a job is critical, especially for people from low-income communities. It is therefore suggested that future studies investigate the effect of automation in transportation on the job market and economy. Also, governments should seek solutions to benefit from smart automation without harming specific groups of society. For instance, governments could consider using the tax returns from technology-driven development to support social safety nets for those who lose their jobs from automation (Hawksworth et al., 2018).

6.5. Policy implications

The adoption of ADVs in Iran presents significant opportunities to address various environmental and safety issues associated with the prevalent use of motorcycles for deliveries. The findings of the SEM model indicate that perceived usefulness has the strongest direct effect on the intention to use ADVs, suggesting that potential consumers are more likely to adopt this technology if they believe it offers practical benefits (Kapser et al., 2021). Therefore, policymakers should develop comprehensive marketing and public awareness campaigns that clearly communicate the advantages of ADVs, such as reduced delivery costs, environmental benefits, and enhanced safety compared to traditional motorcycle deliveries (Hinzmann and Bogatzki, 2020). Highlighting these practical benefits will likely enhance public acceptance and willingness to transition to ADVs.

Moreover, the influence of subjective norms on behavioral intentions underscores the importance of leveraging social influence in promoting ADVs. Policymakers should consider strategies that utilize social influence, such as endorsements from community leaders and targeted social media campaigns showcasing positive peer experiences with ADVs. Given that peer pressure significantly affects behavioral intentions, these approaches can accelerate the acceptance and adoption of ADVs among potential users (Jolai et al., 2021).

Addressing environmental and safety concerns is another critical aspect of fostering the adoption of ADVs. With motorcycles being a major source of air and noise pollution and associated with high rates of traffic violations and accidents, ADVs offer a safer and more environmentally friendly alternative (Safaei et al., 2021; Sadeghi-Bazargani et al., 2018; Esmaeli et al., 2022). However, the introduction of ADVs must also consider potential new challenges, such as increased sidewalk traffic and pedestrian safety risks. Policymakers should implement regulations to manage the human-robot shared space, including restrictions on ADV operations in areas with narrow sidewalks and limits on the number of operative ADVs in specific locations to prevent congestion and ensure pedestrian safety (Jennings and Figliozzi, 2019).

Additionally, the perception of ADVs' operational costs being lower than other delivery methods could positively influence public intention to adopt this technology. Policymakers should highlight the cost-efficiency of ADVs, especially as they do not require drivers, thus eliminating labor costs. This cost advantage can be further emphasized through studies demonstrating the operational cost benefits of driverless electric vehicles over traditional fuel-based and labor-intensive vehicles (Rejali et al., 2021; Pantano et al., 2012; Venkatesh et al., 2012; Aurambout et al., 2019).

Security concerns regarding the susceptibility of ADVs to theft also need to be addressed. Despite the implementation of preventive measures such as in-built cameras, GPS trackers, and alarms, there is a significant perception that these measures are inadequate. Policymakers and service providers should undertake efforts to assure the public of the security of ADVs through advertisement campaigns and demonstrations of their robust security features (Joerss et al., 2016; Kapser and Abdelrahman, 2020).

The potential impact of ADVs on the job market cannot be overlooked. The displacement of delivery jobs due to automation is a critical issue, particularly in Iran, where a large number of individuals rely on delivery jobs for their livelihood. Policymakers should consider strategies to mitigate the negative effects of automation, such as using tax revenues from technology-driven developments to support social safety nets for displaced workers (Hawksworth et al., 2018; Io and Lee, 2019). Additionally, the potential risk of collisions with pedestrians or other road users should be mitigated through preventive actions, such as new traffic laws for spaces shared by humans and ADVs, public education on interoperability with ADVs, and operational restrictions in risky areas (Jennings and Figliozzi, 2019). In summary, while the advantages of ADVs outweigh their disadvantages for many people, a comprehensive approach addressing marketing, regulatory, security, and socioeconomic aspects is needed for their successful integration into the delivery ecosystem in Iran.

The results and the proposed TAM can be adapted for countries with similar urban contexts and cultural characteristics, particularly in developing countries with collectivist cultures and densely populated urban environments, where the influence of subjective norms is particularly significant, as observed in our study. Additionally, the inclusion of perceived security risk related to theft in our study is especially relevant for regions with high rates of vandalism and theft. With appropriate adjustments, this model can also be extended to other contexts, such as the adoption of autonomous vehicles. However, it is crucial to acknowledge that each country has its unique context. Therefore, researchers should proceed with caution, thoroughly test the survey before deployment, and make necessary modifications to tailor it to the specific environment in which it will be applied.

7. Conclusion

7.1. Summary

This study has offered valuable insights into the adoption of ADVs in a developing country by employing the extended TAM. Beyond the original TAM scales, this study examined the influence of subjective norms, hedonic motivation, and environmental concern in shaping the intention to use ADVs. Moreover, this study investigated the moderating effect of the perceived security risk of theft, which, to the best of our knowledge, represents the first time it has been considered in technology acceptance studies. Differences in respondents' intentions by demographic variables were also assessed, alongside the use of a qualitative framework to acquire deeper and novel insights into consumers' psychological behavior and reasoning.

7.2. Limitations and future research

The present study also has some limitations that should be noted. First, the possibility of respondent bias from those who are more interested in a topic and, thus, more inclined to participate in research is common in surveys, particularly online surveys. Second, although the current study provided a brief video introducing the ADVs and their advantages and disadvantages, this video could only give an overview of ADVs. People's attitudes and perceptions concerning ADVs may change after utilizing them, i.e., since ADVs are currently unavailable in Iran, evaluating people's attitudes toward them is reliant on their stated preferences, which has limits for assessing the adoption of new technologies like ADVs. Hence, it is suggested to conduct studies based on the users' experience of using and interacting with ADVs in a simulated or real setting by specifying pilot zones to investigate the disclosed preferences in users' acceptance.

Third, the effect of hedonic motivations on the formation of behavioral intention was less than expected in this study; however, many people found ADVs attractive and fun (Table 6). Previous studies reported the fun aspect as one of the main motivations which lead people to use ADVs (Kapser and Abdelrahman, 2020; Kapser et al., 2021). It is recommended that future studies in a similar social context further assess the role of hedonic motivation in explaining intention. The analysis of control beliefs also demonstrated the risk perceptions of theft as a barrier to using ADVs. Also, it was found that the perceived security risk of theft has a significant moderating role in the extended model. While this study defined and incorporated this risk factor into the extended model to understand its moderating role in this context, future research could explore the direct effects of this factor, its potential interaction with trust, or their moderating influences on other variables, such as environmental concern or subjective norms.

Moreover, considering this study was carried out during the Covid-19 outbreak, a future research direction could be to examine how behavioral intentions change after society recovers from the COVID-19 pandemic. As the risk of interaction of ADVs with pedestrians was identified as a barrier in the open-ended responses, future research could also investigate the legal and practical aspects of sharing the space between pedestrians and ADVs. Additionally, some respondents in this study mentioned that the emergence of ADVs could be a risk for delivery jobs. Further studies could focus on smart automation threat to jobs and investigate their effect on behavioral intentions and public acceptance of emerging automated technology.

CRediT authorship contribution statement

Arsalan Esmaili: Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Sina Rejali:** Writing – review & editing, Validation, Methodology, Investigation, Data curation. **Kayvan Aghabayk:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Amin Mohammadi:** Investigation, Data curation. **Chris De Gruyter:** Writing – review & editing, Investigation.

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Declaration of competing interest

None.

Appendix

Table A1
Items for each factor proposed in the extended TAM

Sources	Items	Constructs
Davis (1985)	ATT1: "Using autonomous delivery vehicles is a good idea as a delivery option." ATT2: "Using autonomous delivery vehicles is a wise idea as a delivery option." ATT3: "Using autonomous delivery vehicles is pleasant as a delivery option."	Attitude (ATT)
Davis (1985)	PU1. "Using autonomous delivery vehicles as a delivery option would improve my shopping efficiency." PU2. "Using autonomous delivery vehicles as a delivery option would save my shopping time." PU3. "Using autonomous delivery vehicles as a delivery option would make my shopping more convenient." PU4. "Overall, I find that autonomous delivery vehicles as a delivery option are useful."	Perceived Usefulness (PU)
Davis (1985)	PEOU1. "Learning how to use autonomous delivery vehicles will be easy for me." PEOU2. "I will find it easy to get autonomous delivery vehicles to do what I want them to do. " PEOU3. "It will be easy for me to become skillful at using autonomous delivery vehicles." PEOU4. "Overall, I will find autonomous delivery vehicles easy to use."	Perceived Ease of Use (PEOU)
Ajzen (1991)	SN1. "People whose opinions are important to me would like autonomous delivery vehicles too." SN2. "In general, people who I like would encourage me to use autonomous delivery vehicles." SN3. "I think I am more likely to use autonomous delivery vehicles if my friends or family used them."	Subjective Norm (SN)
Venkatesh and Davis (2000)	HM1. "Using autonomous delivery vehicles would be fun." HM2. "Using autonomous delivery vehicles would be enjoyable." HM3. "Using autonomous delivery vehicles would be very entertaining."	Hedonic Motivation (HM)
Wu et al. (2019)	EC1. "I'm very concerned about current environmental pollution in Iran and its impact on health." EC2. "Automobile and motorcycles exhaust emission is one of the primary sources of air pollution." EC3. "I have the responsibility to adopt a low-carbon delivery option."	Environmental Concern (EC)
Roca et al. (2009), Hartono et al. (2014)	PSRT1. "I think autonomous delivery vehicles do not have sufficient technical capacity to ensure that my delivery cannot be modified by a third party." PSRT2. "Autonomous delivery vehicles do not have enough security measures to protect my delivery." PSRT3. "When I want to receive my delivery with an autonomous delivery vehicle, I am not sure that it will not be intercepted by unauthorized third parties."	Perceived Security Risk of Theft (PSRT)
Davis (1985)	BI1. "I predict I would use autonomous delivery vehicles as a delivery option in the future." BI2. "I plan to use autonomous delivery vehicles as a delivery option in the future." BI3. "I intend to use autonomous delivery vehicles as a delivery option in the future, if they are available."	Behavioral Intention (BI)

Table A2
Variance Inflation Factors (VIFs).

Construct	ATT	BI	EC	PEOU	PSRT	PU	SN	HM
ATT	–	3.590	–	–	–	–	–	–
BI	–	–	–	–	–	–	–	–
EC	–	2.142	–	–	–	–	–	–
PEOU	2.903	–	–	–	–	2.142	–	–
PSRT	1.324	–	–	–	–	–	–	–
PU	3.242	3.681	–	–	–	–	–	–
SN	–	2.984	–	1.000	–	2.142	–	–
HM	3.310	–	–	–	–	–	–	–

Table A3
Mean, Standard Deviation (SD) and discriminant validity.

	Mean	SD	ATT	BI	EC	PEOU	PSRT	PU	SN	HM
ATT	5.385	1.162	**0.833**							
BI	5.401	1.049	0.787	**0.865**						
EC	5.331	1.164	0.695	0.676	**0.814**					
PEOU	5.366	1.138	0.786	0.769	0.664	**0.825**				
PSRT	5.371	1.118	0.453	0.433	0.447	0.428	**0.765**			
PU	5.346	1.154	0.810	0.802	0.676	0.766	0.443	**0.847**		
SN	5.607	1.109	0.760	0.778	0.649	0.730	0.488	0.779	**0.834**	
HM	5.117	1.105	0.784	0.778	0.661	0.761	0.472	0.782	0.760	**0.848**

$1 \leq$ Mean ≤ 7; AVE square oots = on-diagonal; correlation = off-diagonal; Bold = AVE square roots.

Table A4
Examples of typical answers to the first open-ended question (facilitators)

Response	Respondent
Reduce air and noise pollution (N = 387)	
"I think ADVs do not pollute the air, which is really important."	Female, 18–24 years old, metropolitan area
"Delivery motorists are very annoying. Using ADV can help with that and reduce noise and air pollution."	Female, 25–39 years old, metropolitan area
"ADVs do not need gasoline so they can help the environment."	Male, 40–60 years old, metropolitan area
"No pollution"	Male, 18–24 years old, non-metropolitan area
Alleviate traffic (N = 266)	
"Using them can reduce the traffic by reducing the number of delivery vehicles"	Male, 40–60 years old, metropolitan area
"They help the traffic since they move on sidewalks"	Female, 25–39 years old, metropolitan area
"Too many motorcycles and cars have congested the streets, using technologies like this could help with that"	Female, 40–60 years old, metropolitan area
Contribute to a reduction in crashes (N = 173)	
"They can replace the dangerous motorcycles"	Female, 25–39 years old, non-metropolitan area
"ADVs are much safer than cars and motorcycles"	Male, over 60 years old, metropolitan area
"In my opinion, ADVs are very safe and can reduce the crash risks"	Male, 18–24 years old, non-metropolitan area
Low operation cost (N = 124)	
"They don't need drivers so they are cheaper"	Female, over 60 years old, non-metropolitan area
"ADVs are cheaper since they do not need a delivery person"	Male, 18–24 years old, metropolitan area
"ADVs can reduce cost as they don't need fuel"	Male, 25–39 years old, non-metropolitan area
"In my opinion, these cutting-edge technologies are normally more efficient and accurate, and they can become cheaper than traditional methods."	Male, 25–39 years old, metropolitan area
Reduce interaction with other people (during COVID-19) (N = 96)	
"You don't need to interact with anyone when using them, which is interesting"	Female, over 60 years old, metropolitan area
"I think they don't bear the risk of COVID because you don't interact with delivery person … "	Male, 25–39 years old, metropolitan area
Higher accuracy of ADVs compared to other delivery modes (N = 82)	
"In my opinion, these cutting-edge technologies are normally more efficient and accurate"	Male, 25–39 years old, metropolitan area
"High accuracy"	Female, 40–60, non-metropolitan area

Table A5
Examples of typical answers to the second open-ended question (barriers):

Response	Respondent
Possible risk of stealing the parcel or the ADV itself (N = 398)	
"They can be easily carried and robbed"	Male, 25–39 years old, metropolitan area
"I think the most important issue is that they can be stolen, especially in deserted places"	Female, 18–24 years old, metropolitan area
"Thieves can easily open it and steal everything"	Female, 40–60 years old, metropolitan area
"Risk of robbery is very high"	Male, 18–24 years old, non-metropolitan area
"In my opinion, ADVs can be targeted by thieves because they can easily open it or move it "	Female, 25–39 years old, non-metropolitan area

(*continued on next page*)

Table A5 (*continued*)

Response	Respondent
Hard to operate, considering the condition of sidewalks and streets (N = 220)	
"They can't move in sidewalks of Tehran because of their small wheels "	Female, 40–60 years old, metropolitan area
"Sidewalks condition in Iran is not appropriate for these kinds of technologies"	Male, 18–24 years old, metropolitan area
"They are not useable in Iran because of weak infrastructure and uneven sidewalks"	Male, 24–39 years old, non-metropolitan area
"I think, the most important problem is that they cannot operate in Iran because of road surface problems"	Female, 18–24 years old, metropolitan area
Threat to people working as deliverers (N = 117)	
"I think they are not suitable for Iran because many young delivery people can lose their jobs"	Female, 40–60 years old, metropolitan area
"These days many people live by delivery, they can lose their jobs which is not good at all"	Male, 18–24 years old, metropolitan area
"A lot of delivery people will lose their jobs"	Male, 18–24 years old, non-metropolitan area
Not suitable for long distances in cities (N = 83)	
"I don't think ADVs have the electric power to operate in long distances"	Male, 18–24 years old, metropolitan area
"In my opinion, ADVs are only suitable for very short distance deliveries and cannot operate in long distances"	Female, 18–24 years old, metropolitan area
"They might encounter a lot of problems in long distance deliveries"	Male, 40–60 years old, non-metropolitan area
Low speed (N = 56)	
"I think they are very slow"	Female, 18–24 years old, non-metropolitan area
"low speed"	Male, 18–24 years old, metropolitan area
"They have much lower speed than motorcycles"	Male, 25–39 years old, non-metropolitan area
Hard to operate for the elderly (N = 51)	
"I think getting your delivery from a delivery person is much easier."	Male, 25–39 years old, metropolitan area
"Interacting with them can be hard, especially for older people"	Female, 40–60 years old, non-metropolitan area
"They seem hard to use"	Male, over 40–60 years old, metropolitan area
Low capacity for carrying goods (N = 45)	
"They can't carry large packages"	Male, 40–60 years old, non-metropolitan area
"In my opinion, their small size and limited capacity can be problematic"	Male, 25–39 years old, metropolitan area
Risk of collision with pedestrians or other road users (N = 41)	
"I believe ADVs can become a problem for pedestrians"	Female, 40–60 years old, metropolitan area
"ADVs can collide with pedestrians in crowded sidewalks"	Male, 18–24 years old, metropolitan area

Data availability

Data will be made available on request.

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