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Effects of shared autonomous vehicle supply on private car ownership behaviour and urban traffic flow

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This study is an investigation of the effect of shared autonomous vehicle (SAV) deployment on private car ownership among households in Tehran. Data from 318 households were collected through a field survey and analysed using a binary logistic regression model. The receiver operating characteristic curve, Hosmer–Lemeshow test and model coefficients confirmed the model's accuracy and goodness of fit. The findings show that familiarisation with SAVs significantly increases the willingness to use these vehicles and reduces the intention to own private cars. Specifically, 59% of respondents indicated a willingness to reduce their use of private vehicles, and 54% reported that they would reconsider purchasing a new car. Although socioeconomic variables, such as household income and the number of employed household members, remain influential, their effects diminish after the introduction of SAVs. Lower costs, improved accessibility and such issues as parking shortages were identified as the main drivers encouraging the substitution of SAVs for private vehicles. Furthermore, a random forest model revealed that household size and the number of employed members are most significant in predicting SAV usage. Overall, the results indicate that adopting SAVs can reduce dependence on private car ownership and contribute to notable improvements in urban traffic conditions.

Keywords: town & city planning/traffic engineering/transport/transport management/transport planning

1. Introduction

The rapid expansion of urbanisation and the growing demand for mobility in megacities such as Tehran have led to various challenges, including traffic congestion, air pollution, high energy consumption and limited parking availability. A major contributing factor is the widespread ownership of private vehicles, which reduces the use of public transportation and worsens congestion. With the development of innovative transportation technologies, shared autonomous vehicles (SAVs) have emerged as a promising solution to alleviate these issues. However, understanding public acceptance of this technology and its influence on household decisions regarding private vehicle ownership requires careful investigation. Tehran, as a developing megacity, offers a unique context, compared with developed countries. High private vehicle ownership, limited public transport coverage and diverse socioeconomic conditions shape travel behaviours and car dependency in a distinct way. This study provides insights into the potential adoption of SAVs as an alternative to private cars, while examining Tehran's specific urban and social characteristics.

Shared autonomous vehicles are defined as vehicles that can operate independently without a driver. These vehicles are mainly offered to users through two models. In the asynchronous sharing model, an individual utilises the vehicle solely for a specific trip; once the trip is completed, the vehicle is made available for the next user. Conversely, the synchronous sharing model allows several passengers to share a single vehicle at the same time, even if they are unfamiliar with one another. In addition to alleviating traffic congestion and air pollution, these systems can also reduce transportation costs and enhance access to mobility services for diverse demographic groups (Parkhurst and Seedhouse, 2019). At present, private vehicle ownership continues to be the predominant mode of transportation in numerous cities, as it is regarded by citizens as fast, safe, and convenient. However, the growing number of vehicles in urban environments has resulted in such issues as traffic congestion, environmental degradation and inefficient utilisation of urban spaces. As a result, numerous cities are implementing policies designed to decrease private vehicle ownership while encouraging alternative public and shared transportation systems (Galich and Stark, 2021). In this study, we conducted interviews with vehicle-owning households and analysed 318 questionnaire responses. This study offers three main contributions. First, it provides empirical evidence from Tehran, a developing megacity characterised by high private vehicle ownership and significant limitations in public transportation, thereby addressing a gap in the existing literature. Second, by focusing on key household socioeconomic variables – including number of employed household members, monthly household income, household size, family structure and number of privately owned vehicles – the study enables a detailed analysis of behavioural differences among various demographic groups in response to SAVs. Third, by employing a binary logistic regression model, we forecast the probability of changes in vehicle ownership behaviour following the introduction of SAVs, offering practical and policy-relevant insights for sustainable urban transport planning. In this study, a minimum of 318 households were selected, based on the Cochran formula, to be representative of Tehran's population. The samples were collected through fieldwork using purposive sampling across different urban areas to capture the social, economic and structural diversity of households in the analysis. The central research question is 'What impact might the introduction of SAVs have on the pattern of private car ownership and urban traffic reduction in Tehran?'.

The next section of this paper is focused on a thorough review of the literature, examining prior studies related to SAVs and private vehicle ownership. Section 3 provides a detailed description of the research methodology, which includes data collection by means of a field questionnaire and the application of a binary logistic regression model for analysing and forecasting vehicle ownership. Section 4 showcases the statistical analysis of the gathered data, offering descriptive and preliminary findings. Following this, Section 5 meticulously details the modelling process and presents the quantitative outcomes of the binary logistic regression model, along with validation tests for the model. The final section wraps up the paper by summarising the findings, discussing the results, and providing practical and policy recommendations.

2. Literature review

Despite the swift advance of intelligent shared mobility services, evidence indicates that these services do not necessarily result in a decrease in private vehicle ownership. In societies where the transportation framework relies on private cars, vehicle ownership is not only viewed as a means of mobility but also represents personal maturity, social status, freedom, independence, gender identity (especially among men), professional achievement and affiliation with specific social classes or groups (Bardhi and Eckhardt, 2012; Galich and Stark, 2021; Lutz, 2014; Sheller and Urry, 2000).

Research on car consumption and culture has remained relatively scarce, with much of the existing literature relying on broad generalisations about modernity. More recent scholarship, however, emphasises cultural and contextual perspectives, offering deeper insights into the social significance of automobiles) Miller, 2020). In many studies, it is argued that the adoption of SAVs could eventually reduce private car ownership by providing efficient and affordable mobility. However, car ownership is not merely instrumental but also carries symbolic and ideological significance, reflecting social status and identity. Recent findings suggest that these cultural and ideological functions of automobility might limit the expected transition towards shared mobility, positioning AVs more as a technological transformation than a paradigm shift) Mohammadzadeh, 2021). Recent studies have examined public attitudes towards AVs, yet most lack theory-driven and behaviourally consistent approaches to explain adoption decisions. Research highlights that AV acceptance depends on sociodemographic factors, perceived benefits and ease of use, as well as psychological aspects, such as fears, norms and attitudes. To address this gap, conceptual frameworks integrating these determinants have been proposed and empirically tested to better predict AV adoption across ownership, sharing and public transport modes (Acheampong and Cugurullo, 2019).

Studies indicate that the deployment of private autonomous vehicles (PAVs) can significantly reduce household vehicle ownership while maintaining current travel patterns. However, PAVs may induce substantial unoccupied vehicle miles travelled (VMT), primarily on highways and expressways, with the highest proportional increase on minor local roads. These findings provide insights for future household vehicle usage trends and the planning of dedicated AV lanes in PAV-dominated urban environments (Zhang *et al*., 2018). Autonomous vehicles offer significant potential benefits, including improved safety, reduced congestion, fuel efficiency and parking advantages, with estimated social savings of up to US$4000 per vehicle annually. However, such barriers as high initial costs, inconsistent licensing standards, unresolved liability, security and privacy issues limit their widespread adoption. Addressing these challenges requires expanded research and the development of nationally recognised regulatory frameworks to ensure safe and effective AV integration (Fagnant and Kockelman, 2015). Autonomous vehicles are expected to provide long-term benefits, including improved safety, reduced congestion, energy savings and independent mobility for various social groups. However, high initial costs, limited early performance and the need for dedicated AV infrastructure might delay widespread adoption. Significant societal impacts are likely to emerge only when AVs become common and affordable, probably between the 2040s and 2060s, raising important planning and social equity considerations (Litman, 2017).

Analyses of shared automated vehicle systems suggest that a fleet approximately one-third the size of existing passenger vehicles can meet the personal mobility needs of an entire city. This demonstrates the potential efficiency and financial benefits of mobility-on-demand carsharing solutions (Spieser *et al*., 2014). Long-term simulations indicate that the adoption of connected and autonomous vehicles in the US light-duty fleet will vary widely depending on technology costs, willingness to pay (WTP) and government policies. With modest price reductions and constant WTP, penetration of level 4 AVs might remain low, while rapid cost declines and increased WTP could result in high adoption rates. Overall, without significant policy or market changes, the fleet's technology composition is unlikely to become homogeneous by 2045 (Bansal and Kockelman, 2017).

Research on zero-car households highlights important differences between those who choose not to own a car (carfree) and those constrained from owning one (carless). Carless households tend to have lower incomes and education levels and are disproportionately non-white, mirroring captive transit populations, while carfree households travel more frequently and farther. These findings suggest that expanding access to carsharing services can enhance mobility for both groups (Brown, 2017). Longitudinal analysis in the Paris metropolitan area shows that car ownership and car travel demand are influenced by income, fuel prices and urbanisation levels. Income has a decreasing effect on car ownership, being less significant for high-income households and in highly urbanised areas. Fuel price elasticity of car travel is higher in dense areas, where alternative modes of transport are available, allowing households to adapt more easily (Cornut, 2016).

Studies on WTP for autonomous vehicle automation show that households are prepared to pay substantial amounts for partial and full automation, though preferences vary widely. A significant share of consumers are willing to pay over US$10,000 for full automation, while many are unwilling to pay anything. Overall, demand is roughly split between high, moderate and no demand, highlighting the importance of modelling flexible consumer preferences for emerging vehicle technologies (Daziano *et al*., 2017). The mediating role of car ownership and travel distance in the relationship between the built environment and travel mode choice is highlighted. Using integrated structural equation modelling (SEM) and dynamic causal modelling approaches with data from Baltimore, Maryland, USA, both direct and indirect effects of the built environment on mode choice were revealed. Findings provide insights for transportation planners to design targeted strategies to reduce car use (Ding *et al*., 2017).

Agent-based modelling of SAVs shows that each SAV can replace approximately 11 conventional vehicles while providing efficient service across urban areas. Although SAVs may increase total travel distance by up to 10%, overall emissions benefits are realised when considering fleet efficiency and lifecycle emissions. These findings highlight the environmental potential and operational strategies of SAV systems, compared with traditional car ownership (Fagnant and Kockelman, 2014). In a review, Gkartzonikas and Gkritza (2019) categorise studies on AVs from 2012 onward, focusing on behavioural characteristics, perceptions and WTP. Surveys are analysed by population and attitudinal questions to identify factors influencing AV adoption. Gkartzonikas and Gkritza (2019) also discuss benefits, barriers and opportunities, highlighting lessons learnt and research gaps for future studies. In metropolitan Mexico City, higher income and car ownership do not necessarily drive suburbanisation. Wealthier households tend to reside in central areas and own cars, whereas lower-income households live farther from the urban centre and rely more on public transit. These findings indicate that increased income and car ownership do not lead to larger suburban homes or lots in the city (Guerra, 2015).

A review of the literature on AVs shows that first-order effects on road capacity, fuel efficiency, emissions and accidents are expected to be beneficial. Synergies between automation, sharing and electrification can amplify these benefits, though AVs might also increase travel demand. Long-term effects on land use, safety, economy, public health and social equity remain uncertain, leaving the balance between short-term benefits and long-term effects an open question (Milakis *et al*., 2017). An online choice experiment with 709 participants in Switzerland examined preferences for pooled versus PAVs. Results indicate that 61% of respondents preferred pooled AVs, supporting assumptions in the existing literature. Combined instruments affecting comfort, cost and time are likely to further increase the adoption of SAV use (Stoiber *et al*., 2019). Shared autonomous vehicles are expected to positively impact urban mobility, infrastructure, travel behaviour and the environment. In a systematic literature review (Greifenstein, 2024), 61 factors influencing users' intention and willingness to adopt SAVs were identified, categorised as user-related, service-related or time- or weather-related factors. Greifenstein (2024) highlighted neglected factors and proposed directions for future research to better predict and enhance SAV adoption.

Psychological factors influencing individuals' preference for owning autonomous vehicles (AVs) over using shared AVs (SAVs) have also been examined. Findings indicate that hedonic beliefs, reflecting perceived enjoyment, are the strongest driver of AV preference, followed by utilitarian beliefs and attitudes to car- and ridesharing (Nazari *et al*., 2023). These results offer insights for policymakers to develop strategies that encourage shared mobility adoption (Nazari *et al*., 2023). Research on AV adoption has identified diverse user segments based on ownership intentions and willingness to use self-driving services. Using the 2018 California Transportation Survey and *k*-means clustering, Le and Circella (2024) revealed seven distinct groups, ranging from tech-savvy adopters to car enthusiasts resistant to AVs. Several groups, such as those in transition or suburban dwellers, exhibit uncertain or latent demand, highlighting untapped market potential. These insights inform business model development, strategic planning and targeted marketing to promote AV ownership or shared mobility adoption (Le and Circella, 2024).

Shared autonomous vehicles can significantly affect transport systems and land use by replacing private vehicles, reducing parking demand and potentially increasing congestion, owing to empty fleet movements. Kumakoshi *et al*. (2021) simulated SAV operations at a local scale in Okinawa, Japan, highlighting heterogeneous impacts across transportation analysis zones. Their results show that parking reductions are greatest in residential zones by quantity and in office zones by proportion, while empty fleets increase congestion at city peripheries. These findings emphasise the need for zone-specific strategies in urban and transport planning to account for SAV-induced changes (Kumakoshi *et al*., 2021).

Etminani-Ghasrodashti *et al*. (2025) investigated individual acceptance of SAVs through a demonstration in downtown Arlington, Texas, USA, and a university campus, using survey data and SEM to examine factors influencing SAV adoption, including attitudes and travel habits. Their results show that younger and lower-income individuals are more likely to adopt SAVs, whereas habitual car users with limited ridesharing experience are less interested. These insights provide guidance for integrating SAVs with on-demand ridesharing and targeting early adopters in the market (Etminani-Ghasrodashti *et al*., 2025). A conceptual framework has been developed (Greifenstein *et al*., 2025) to evaluate cities' readiness for SAVs amid the transition from private ownership to shared mobility. An integrative literature review of 34 publications coded with ATLAS.ti software identified five key dimensions: infrastructure, security and privacy; policy; regulation and legality; innovation, collaboration and economics; and customer engagement (Greifenstein *et al*., 2025). Infrastructure and policy were highlighted as the most critical for successful SAV integration. Public acceptance of SAVs has been examined in developing countries; Wang *et al*. (2021) focused on Pakistan and China, using a stated preference survey with 910 respondents. Multinomial and mixed logit models revealed that generic attributes – such as waiting time, travel time and cost – significantly influence interest in SAVs, while sociodemographic factors, including education, income, travel frequency and car ownership, also play a key role. These findings provide insights into user preferences across different economic and cultural contexts, offering guidance for policymakers in designing effective strategies for SAV implementation (Wang *et al*., 2021).

In this study, we investigated the impact of SAVs on private car ownership in Tehran, Iran, addressing gaps in research that is mostly focused on more developed countries. We examine socioeconomic factors, behavioural attitudes and urban transport conditions to understand residents' adoption and usage patterns of SAVs. This research highlights how Tehran's unique sociocultural and infrastructural context shapes vehicle ownership decisions. Insights from this study provide practical guidance for policymakers and transportation planners. Overall, it contributes localised knowledge on emerging transport technologies and informs future studies in similar large cities.

3. Data collection method

To ascertain the minimum necessary sample size, Cochran's formula was employed, utilising a 95% confidence level, a 5% sampling error and an assumed proportion of 0.5 for the characteristic of interest. Through this formula, the initial sample size was computed and subsequently adjusted in accordance with the total population size of Tehran. Ultimately, a final sample size of 318 households was deemed suitable for the study. This research was carried out using field data gathered through questionnaires. The questionnaires were disseminated among 318 households throughout Tehran to capture the varied perspectives of the city's residents. Efforts were made to ensure representation from diverse demographic groups within the sample. The objective of this approach was to enhance the accuracy of the results and to reflect the opinions of a wide range of society. The questionnaire comprised inquiries regarding respondents' socioeconomic characteristics, patterns of SAV usage, their willingness to adopt this technology and their attitudes to personal car ownership. The aim of this research is to assess the effect of SAVs in reducing personal car ownership in Tehran.

To improve respondents' comprehension of the concept of SAVs, an educational video was presented to them before completing the questionnaire. This video explained the key features of these vehicles, including their ability to drive autonomously without a human driver, the possibility of sharing the vehicle with other people, and the ease of access and booking through mobile applications.

3.1 Methodology

Binary logistic regression is a statistical model used to predict the probability of a dichotomous event based on one or more independent variables. This model is particularly suitable when the dependent variable has two possible outcomes, such as vehicle ownership versus non-ownership. In this study, the dependent variable represents household vehicle ownership; the objective is to predict the probability of changes in ownership behaviour following the introduction of SAVs. The general form of the model is

1.. $$\ln\left(\frac{1-P}{P}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n$$

where P is the probability of the event occurring, β_0 is the model intercept, and $\beta_1, \beta_2, \ldots, \beta_n$ are the coefficients of the independent variables $X_1, X_2, \ldots, X_n$ (Wright, 1995).

In addition to the binary logistic regression model, a random forest machine learning algorithm was employed as a supplementary analysis method to better visualise and validate the probability of household vehicle ownership in response to SAVs (Breiman, 2001; Hastie, 2009). This approach allows for a more precise analysis of non-linear interactions between household socioeconomic variables, including the number of employed household members, monthly household income, household size, family structure and number of privately owned vehicles. Figure 1 illustrates the methodological framework of the study, providing a clear overview of the research process. This flowchart illustrates the main steps of the study – data collection, data preparation, model selection, estimation, results analysis and conclusion – in a step-by-step manner. F1

4. Case study

Tehran, the capital city of Iran, has an approximate population of 9.4 million and a population density of about 129 people per hectare. The city is divided into 22 districts, with 26.7% of the population employed and 22.6% engaged in education. The total number of daily trips in Tehran is around 19.8 million. The

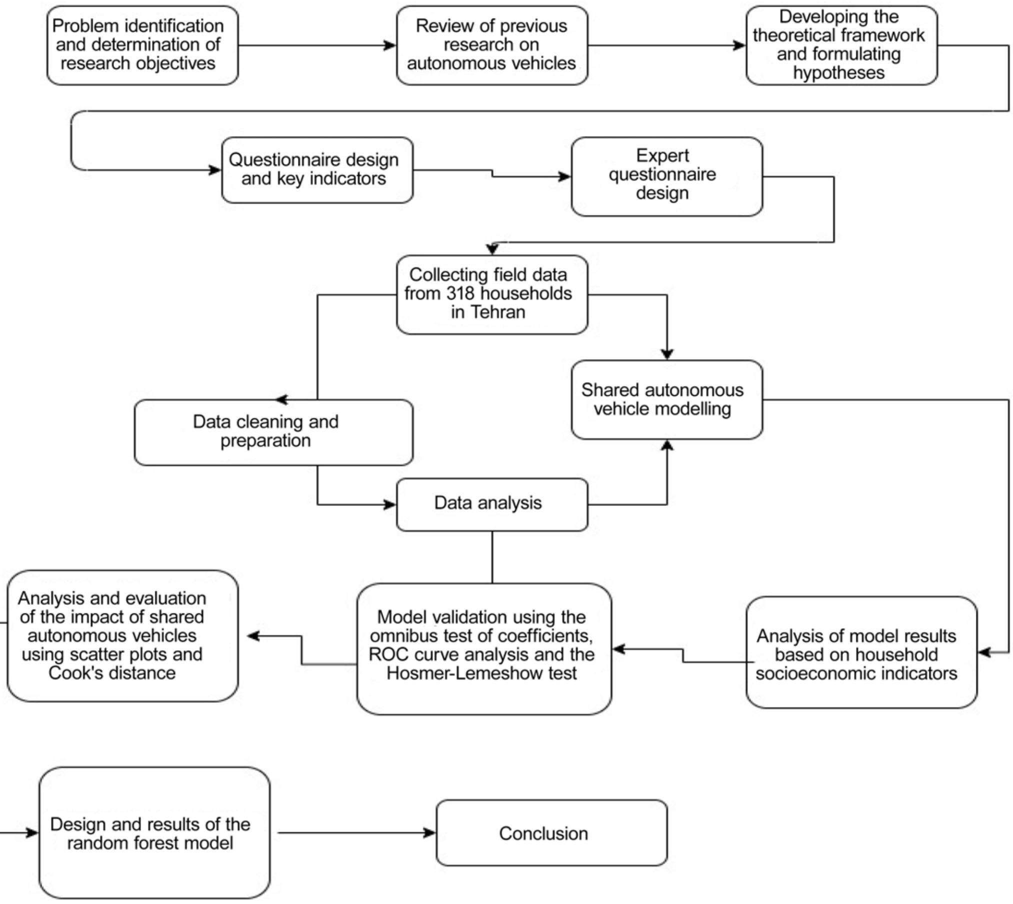

Figure 1. Flowchart of research methodology for analysing and evaluating the effects of shared autonomous vehicle deployment on changes in private vehicle ownership

distribution of trip purposes includes: 18% for educational purposes, 43% for work-related travel, 13% for shopping, 19% for recreational activities and 7% for other purposes. Regarding traffic composition during morning peak hours (excluding the metro), the contributions of different modes of transportation are as follows: city buses, 3%; various types of taxi, 20%; motorcycles, 2%; private cars and pickups, 71%; and other vehicles, 4%. The traffic impact percentages for each vehicle type on the road network during peak morning hours are: motorcycles, 2.6%. private cars and pickups, 70.8%; city buses, 2.7%; various types of taxi, 19.7%; and other vehicles, 3.4%. The modal share of urban transportation in Tehran includes: private cars and pickups, 49%; ride-hailing services, 2%; motorcycles, 7%; buses and metro, 19%;
F2 minibuses, 2%; taxis, 18%; and other modes, 3%. Figure 2 illustrates the geographical layout of the 22 districts of Tehran, providing a spatial context for the study area (Tehran City Council, Center for Statistics and Research, 2021).

For the purpose of this study, the 22 districts within the city of Tehran were defined as the study area and data were collected from residents residing in these districts.

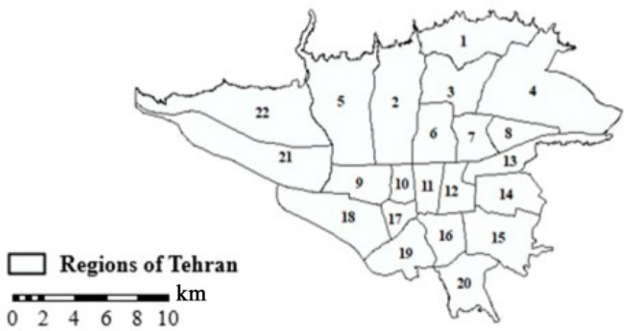

Figure 2. Map of the 22 districts of Tehran

4.1 Data analysis

The initial output of the data processing, including a summary AQ: 2
of the collected information, is presented in Table 1. In this T1
study, data from 318 households within the target groups were analysed. The questionnaires were specifically designed to examine the attitudes, preferences and needs of households in

Table 1. Summary of processed research data

Data analysis description	Count	Percentage
Selected sample data used in analysis	318	100
Data excluded from analysis	0	0
Total	318	100

Tehran, regarding SAVs. The processed data are summarised in Table 1.

4.1.1 Dependent variable coding table

T2 Table 2 presents the coding method for the dependent variable used in the logistic regression model. In this study, the dependent variable is defined as ‘change in private car ownership’ and is coded in a binary form.

4.1.2 Descriptive analysis of research data

The data collection in this study was conducted through fieldwork by distributing questionnaires in various locations across Tehran. The questionnaires were handed directly to different groups of T3 individuals to ensure accurate data collection. Table 3 presents a AQ: 1 detailed summary of the frequency analysis of the socioeconomic variables.

In this study, economic and social data from households in Tehran were initially collected, including the number of employed members, household size, family structure, income, number of privately owned vehicles and other socioeconomic characteristics. The purpose of gathering this information was to gain a deeper understanding of household conditions and examine household behaviour in relation to potential changes in transportation patterns. After data collection, an educational video was produced and shown to the households, explaining the features and benefits of SAVs in a clear and accessible manner. The video was purely descriptive and educational, without exerting any pressure or recommendations on households regarding car ownership. Subsequently, a questionnaire was designed and administered to assess households’ attitudes to SAVs and potential changes in private vehicle ownership. Field-based purposive sampling was conducted across different urban areas to capture social, economic and structural diversity, providing a representative sample of Tehran’s population. These procedures minimised potential bias introduced by the video and enhanced the validity of the data. The questionnaire data were analysed to evaluate whether the introduction of a SAV system could reduce private car ownership among households. The findings from the questionnaire are presented in Table 4. T4

Table 2. Variable coding in the software

Dependent variable name	Coding	Description
Change in private car ownership	0	No change
Change in private car ownership	1	Ownership changes

In this study, it is assumed that SAVs have been made available to households; the questions in Table 4 were designed based on this assumption. Responses from 318 residents of Tehran regarding their willingness to use SAVs and potential changes in private car ownership patterns were analysed. The findings reveal that 59.43% of participants, after becoming acquainted with the characteristics of SAVs, are inclined to decrease their reliance on personal cars, indicating a relatively high acceptance of this technology. Furthermore, 54.71% expressed that they would contemplate abstaining from purchasing a new vehicle if SAVs were accessible. Likewise, 42.45% showed a readiness to sell their

Table 3. Frequency analysis of socioeconomic variables from collected questionnaire

Row	Variable	Category	Frequency	Percentage
1	Number of employed household members	1 person	123	38.7
1	Number of employed household members	2 persons	158	49.7
1	Number of employed household members	3 persons or more	37	11.6
1	Number of employed household members	Total	318	100
2	Monthly household income	Less than 10 million	33	10.4
2	Monthly household income	10–20 million	101	31.8
2	Monthly household income	20–30 million	78	24.5
2	Monthly household income	30–40 million	58	17.3
2	Monthly household income	40 million and more	51	16
2	Monthly household income	Total	318	100
3	Household size	2 persons	146	45.9
3	Household size	3 persons	103	32.4
3	Household size	4 persons and more	69	21.7
3	Household size	Total	318	100
4	Family structure	Married with children	172	54.2
4	Family structure	Married without children	146	45.8
4	Family structure	Total	318	100
5	Number of private vehicles owned by household	1 vehicle	118	37.1
5	Number of private vehicles owned by household	2 vehicles	136	42.8
5	Number of private vehicles owned by household	3 vehicles and more	64	20.1
5	Number of private vehicles owned by household	Total	318	100

AQ: 5 **Table 4.** Results of the questionnaire on the introduction of shared autonomous vehicles

Row	Question	Response	Frequency (%)
1	After learning about the features of shared autonomous vehicles, would you prefer not to use your personal car and instead use these vehicles?	Yes	189 (59.43)
1	After learning about the features of shared autonomous vehicles, would you prefer not to use your personal car and instead use these vehicles?	No	55 (17.30)
1	After learning about the features of shared autonomous vehicles, would you prefer not to use your personal car and instead use these vehicles?	To some extent	74 (23.27)
1	After learning about the features of shared autonomous vehicles, would you prefer not to use your personal car and instead use these vehicles?	Total	318 (100)
2	If shared autonomous vehicles were available, would you consider refraining from purchasing a new car?	Yes	174 (54.71)
2	If shared autonomous vehicles were available, would you consider refraining from purchasing a new car?	No	69 (21.69)
2	If shared autonomous vehicles were available, would you consider refraining from purchasing a new car?	To some extent	75 (23.6)
2	If shared autonomous vehicles were available, would you consider refraining from purchasing a new car?	Total	318 (100)
3	If shared autonomous vehicles were available, would you consider selling your personal vehicle?	Yes	135 (42.45)
3	If shared autonomous vehicles were available, would you consider selling your personal vehicle?	No	77 (24.21)
3	If shared autonomous vehicles were available, would you consider selling your personal vehicle?	To some extent	106 (33.33)
3	If shared autonomous vehicles were available, would you consider selling your personal vehicle?	Total	318 (100)
4	If the cost of using shared autonomous vehicles were lower than the maintenance cost of personal vehicles, would you be willing to sell or stop using your personal car?	Yes	157 (49.37)
4	If the cost of using shared autonomous vehicles were lower than the maintenance cost of personal vehicles, would you be willing to sell or stop using your personal car?	No	51 (16.03)
4	If the cost of using shared autonomous vehicles were lower than the maintenance cost of personal vehicles, would you be willing to sell or stop using your personal car?	To some extent	110 (34.59)
4	If the cost of using shared autonomous vehicles were lower than the maintenance cost of personal vehicles, would you be willing to sell or stop using your personal car?	Total	318 (100)
5	If shared autonomous vehicles were easily accessible throughout the city, would you still prefer to own a personal car?	Yes	161 (50.62)
5	If shared autonomous vehicles were easily accessible throughout the city, would you still prefer to own a personal car?	No	64 (20.12)
5	If shared autonomous vehicles were easily accessible throughout the city, would you still prefer to own a personal car?	To some extent	93 (29.24)
5	If shared autonomous vehicles were easily accessible throughout the city, would you still prefer to own a personal car?	Total	318 (100)
6	If financial incentives (such as tax reductions or government subsidies) were provided, would you consider using shared autonomous vehicles?	Yes	171 (53.77)
6	If financial incentives (such as tax reductions or government subsidies) were provided, would you consider using shared autonomous vehicles?	No	59 (18.55)
6	If financial incentives (such as tax reductions or government subsidies) were provided, would you consider using shared autonomous vehicles?	To some extent	88 (27.26)
6	If financial incentives (such as tax reductions or government subsidies) were provided, would you consider using shared autonomous vehicles?	Total	318 (100)
7	Could the lack of parking or high parking costs encourage you to use shared autonomous vehicles instead of your personal car?	Yes	165 (51.88)
7	Could the lack of parking or high parking costs encourage you to use shared autonomous vehicles instead of your personal car?	No	63 (19.81)
7	Could the lack of parking or high parking costs encourage you to use shared autonomous vehicles instead of your personal car?	To some extent	90 (28.30)
7	Could the lack of parking or high parking costs encourage you to use shared autonomous vehicles instead of your personal car?	Total	318 (100)
8	Do you think shared autonomous vehicles can reduce your living costs and influence your decision regarding personal car ownership?	Yes	183 (57.54)
8	Do you think shared autonomous vehicles can reduce your living costs and influence your decision regarding personal car ownership?	No	40 (12.57)
8	Do you think shared autonomous vehicles can reduce your living costs and influence your decision regarding personal car ownership?	To some extent	95 (29.87)
8	Do you think shared autonomous vehicles can reduce your living costs and influence your decision regarding personal car ownership?	Total	318 (100)
9	At your travel destinations, do you have access to public transportation (such as metro or bus)?	Yes	109 (34.27)
9	At your travel destinations, do you have access to public transportation (such as metro or bus)?	No	112 (35.22)
9	At your travel destinations, do you have access to public transportation (such as metro or bus)?	To some extent	97 (30.05)
9	At your travel destinations, do you have access to public transportation (such as metro or bus)?	Total	318 (100)

personal vehicle if they had access to SAVs. Taking into account the cost aspect, nearly half of the respondents (49.37%) mentioned that if the expense of utilising SAVs were less than the maintenance costs of personal vehicles, they would prefer to sell or limit the use of their private car. The ease of access to these vehicles is also a significant factor; approximately 50.62% believe that if such vehicles were conveniently available throughout the city, their inclination to own a private car would diminish. Participants are also responsive to financial incentives; 53.77% indicated that incentives, such as tax breaks or government subsidies, could motivate them to adopt SAVs. The scarcity of parking spaces and the high costs associated with parking were also identified as influential factors for altering ownership patterns by 51.88% of the respondents. Regarding the reduction of living expenses, 57.54% believe that SAVs could decrease their overall costs and affect their decisions concerning private car ownership. Lastly, access to public transportation at travel destinations varies: only 34.27% of respondents reported having full access, while 35.22% experienced limited access to systems such as the metro or buses. This indicates that SAVs can serve as a complement to existing public transport systems. In summary, these results demonstrate that, when considering cost, accessibility and financial incentives, SAVs have the potential to reduce dependence on private cars and play a key role in reshaping urban transportation patterns.

5. Modelling and results

Here, we first provide a summary of the model and the estimated coefficients of the variables, followed by a presentation of the model results. The interpretation of the binary logistic regression model is typically carried out using a model summary table. One of the key indicators in this analysis is the negative log-likelihood coefficient, which reflects the probability of observing the actual data, given the model parameters. First, the model fit indices are
T5 presented in Table 5. The results indicate that, assuming that SAVs have been made available to individuals, the model fit has improved, as evidenced by a decrease in the negative log-likelihood value from 544.934 to 490.324. In addition, the Nagelkerke R^2 has increased, indicating better predictive power of the model.

As shown in Table 5, after the introduction of SAVs, the negative log-likelihood decreased from 544.934 to 490.324, indicating an improved model fit. The Cox and Snell R^2 increased slightly, from 0.383 to 0.414, while Nagelkerke R^2 rose, from 0.671 to 0.782, reflecting the enhanced predictive power of the model. The improvement in these indices suggests that incorporation of SAVs provides a better explanation of household car ownership patterns, confirming the significant impact of SAV availability on households' vehicle choices.

For a more precise interpretation, the model coefficients are also examined, as they are considered the most important outputs of
the modelling process. Table 6 presents the model coefficients T6
along with the standard errors (the standard deviation of the estimator) for each independent variable. In this table, the variable names are listed in the first column, the model coefficients and their standard errors are shown in the second and third columns, respectively, and the significance level is provided in the sixth column. If the significance value is less than 0.05, the null hypothesis that the variable has no effect is rejected and we conclude that the variable has a significant impact on predicting the dependent variable. These results indicate that, after the introduction of SAVs, the model's fit and predictive power have improved, although some explanatory indicators of data variation have decreased, which may be due to changes in the role of independent variables in explaining vehicle ownership behaviour.

In the analysis of Table 6, which presents the coefficients for SAVs, it is assumed that these vehicles have been made available; various variables were examined in relation to households' willingness to use SAVs. The findings indicate that, after the introduction of SAVs, the coefficients of economic variables, such as income (B = 0.601) and the number of employed household members (B = 0.529), decreased, compared with the previous scenario.

Table 5. Summary of model results before and after the introduction of shared autonomous vehicles

Condition	−2 log-likelihood	Cox and Snell R^2	Nagelkerke R^2
Before introduction	544.934	0.383	0.671
After introduction	490.324	0.414	0.782

Table 6. Coefficient results of the shared autonomous vehicle model

Variable	Coefficient, B	Standard error	Wald statistic	Degrees of freedom	Significance, p	Exp (B)
Constant	0.504	0.278	6.78	1	0.009	1.655
Share of shared autonomous vehicle usage	0.425	0.318	6.25	1	0.125	1.533
Number of employed household members	0.529	0.302	6.29	1	0.121	1.061
Household income	0.601	0.278	5.87	1	0.117	1.043
Number of household members	0.436	0.185	4.32	—	0.240	1.021
Family structure	0.512	0.266	4.91	1	0.214	2.072

The share of SAV usage (B = 0.425) shows a tendency to influence car ownership, although its significance level (p = 0.125) has not yet reached an acceptable threshold, possibly owing to users' uncertainty about the technology or infrastructural limitations. Additionally, household size (B = 0.436) and family structure (B = 0.512) also show tendencies to affect ownership, although they are not statistically significant. These results are consistent with the improvement in model fit indices (Table 6) and indicate that, with the introduction of SAVs, economic factors have become less influential in household car ownership decisions. Overall, the model results suggest that the expansion of SAVs can reduce the need for private car ownership, which could serve as an important basis for sustainable transportation policy.

5.1 Model validation

To validate the model, three tests were employed: the omnibus test of coefficients, the receiver operating characteristic (ROC) curve, and the Hosmer–Lemeshow test. The omnibus test of coefficients evaluates the overall significance of the model and indicates whether the independent variables have predictive power for the dependent variable. The ROC curve measures the model's accuracy in distinguishing between groups, with the area under the curve (AUC) reflecting the quality of the model's predictions. The Hosmer–Lemeshow test assesses the model fit against the observed data to ensure that the binary logistic regression model appropriately corresponds to the data. Together, these three tests guarantee the validity and effectiveness of the model.

5.1.1 Overall model test

To assess the model's accuracy in predicting car ownership, the omnibus test of the model was employed. This test evaluates the impact of the independent variables and contributes to the analysis of the model's validity and predictive accuracy, providing more precise results. The omnibus test of model coefficients is pre-
T7 sented in Table 7 for the periods before and after the introduction of SAVs.

The omnibus test of model coefficients before the introduction of SAVs also indicates statistically significant changes. In this test, the value of chi squared for the three components – step, block and model – was consistently reported as 723.193. Additionally, the significance level for all components was 0.000, strongly confirming the statistical significance of the observed changes. These results suggest that, prior to the deployment of SAVs, the variables examined in the model had a considerable impact and there were meaningful relationships between them. The coefficient test of the model after the introduction of SAVs revealed interesting results. In this analysis, the value of chi squared for all stages of the model is 800.775, indicating statistically significant changes in the model after the introduction of SAVs. This value remains consistent across the three sections – step, block and model – and, in all cases, the significance level is reported as 0.000. These results demonstrate that the effects and coefficients of the model are highly significant at a very high confidence level and reflect major changes in behaviour and preferences following the emergence of SAVs.

5.1.2 ROC curve test

The ROC curve test is used to evaluate the performance of binary prediction models, such as the logit model. This curve illustrates the relationship between the model's sensitivity (true positive rate) and specificity (false positive rate). By plotting the ROC curve and calculating the AUC, the model's performance can be assessed; the closer the AUC value is to 1, the better the model
performs. Table 8 displays the outcomes of the logistic regression T8
model assessment prior to the implementation of SAVs. The AUC is recorded at 0.932, signifying a high level of accuracy in the
model's predictions. The standard error is 0.012, which affirms AQ: 3
the precision of the AUC estimate. The significance level stands at 0.000, which is below the threshold of 0.05, indicating that the model is statistically significant. The lower limit of 0.909 and the upper limit of 0.955 define the 95% confidence interval for the AUC. These findings illustrate that, prior to the introduction of SAVs, the model exhibited high predictive accuracy and variations in independent variables had a substantial effect on the dependent variable. Furthermore, the results of the logistic regression model assessment following the introduction of SAVs also indicate a high level of predictive accuracy. The area value is 0.960, reflecting the model's strong capability to differentiate between various categories. The standard error is 0.008, with the lower and upper bounds of the area being 0.945 and 0.976, respectively, which further demonstrates the accuracy of the area estimate and its 95% confidence interval. The asymptotic significance is 0.000, which is again below 0.05, confirming the statistical significance of the model. These results imply that the model maintains high predictive accuracy, even after the introduction of SAVs, and that changes in the independent variables significantly affect the depend-
ent variable. These results are represented in Figures 3 and 4, which F3 F4

Table 7. Omnibus test of model coefficients before and after the introduction of shared autonomous vehicles

Condition	Level 1	Chi squared, χ^2	Degrees of freedom	P
Before introduction of shared autonomous vehicles	Step	723.193	8	0.000
Before introduction of shared autonomous vehicles	Block	723.193	8	0.000
Before introduction of shared autonomous vehicles	Model	723.193	8	0.000
After introduction of shared autonomous vehicles	Step	800.775	8	0.000
After introduction of shared autonomous vehicles	Block	800.775	8	0.000
After introduction of shared autonomous vehicles	Model	800.775	8	0.000

Table 8. Outcome of test: predicted probability before and after introduction of shared autonomous vehicles

Condition	Area under curve	Standard error	Significance, sig. *b*	Lower bound	Upper bound
Before introduction of shared autonomous vehicles	0.932	0.012	0.000	0.909	0.955
After introduction of shared autonomous vehicles	0.960	0.008	0.000	0.945	0.976

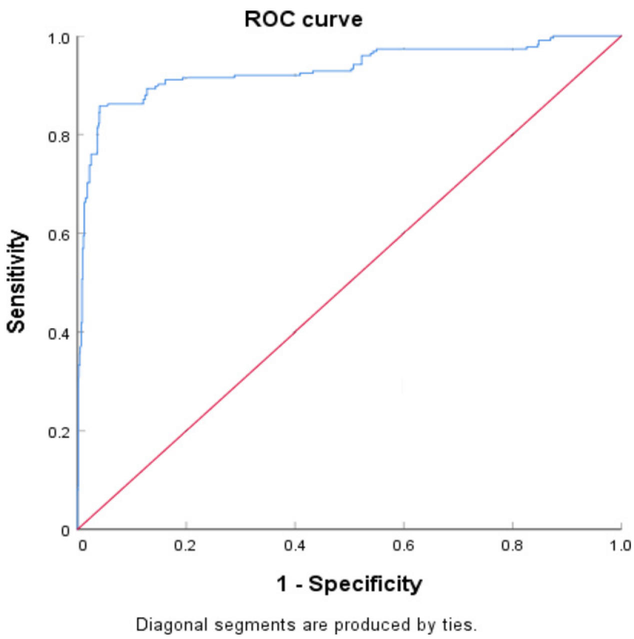

Figure 3. Area under the receiver operating characteristic (ROC) curve before the introduction of shared autonomous vehicles

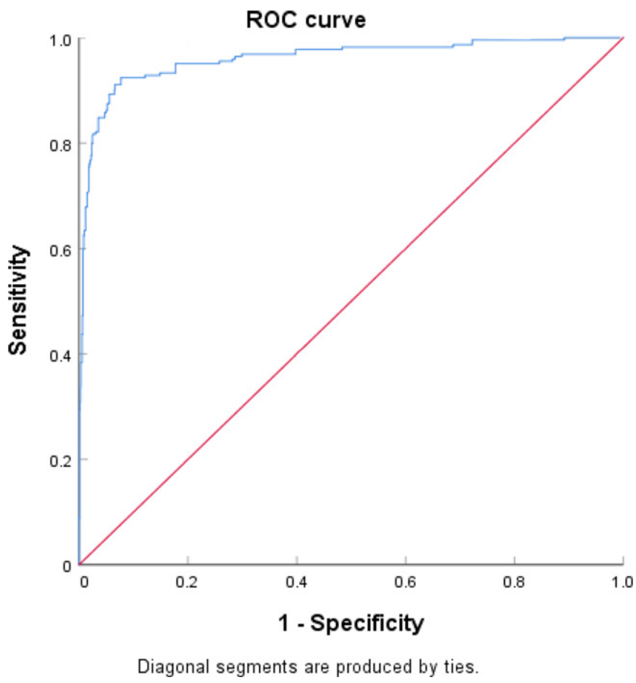

Figure 4. Area under the receiver operating characteristic (ROC) curve after the introduction of shared autonomous vehicles

illustrate the ROC curves for the model before and after the introduction of SAVs, respectively.

The results presented in Table 8 indicate that the binary logistic regression model exhibits high accuracy and a good overall fit. The AUC values in both scenarios – before and after the introduction of SAVs – demonstrate the model's strong capability in correctly predicting car ownership behaviour.

5.1.3 Hosmer–Lemeshow test

To assess the goodness of fit of the binary logistic regression model, the Hosmer–Lemeshow test was employed to ensure that the model appropriately corresponds to the observed data. The
T9 results of this test are presented in Table 9.

The results of the Hosmer–Lemeshow test indicate that the binary logistic regression model fits the observed data appropriately both before and after the introduction of SAVs, demonstrating an acceptable model fit.

5.2 Analysis of vehicle ownership scatter plot

In this section, the effect of SAVs on car ownership is examined.
F5 F6 To analyse these effects, scatter plots (Figures 5 and 6) were used. These plots illustrate the relationship between the variable 'chgdev', representing vehicle-related decisions, and the predicted probabilities before and after the introduction of SAVs.

The results indicate that, before the introduction of SAVs, individuals had a stronger tendency to own private vehicles. After the introduction of these vehicles, the propensity for private car ownership decreased, while the use of SAVs increased. These differences reflect significant changes in ownership behaviour and preferences.

Prior to the availability of SAVs, individuals with higher incomes and households living in areas with limited access to transportation were more inclined to own private cars. Additionally, larger households tended to own vehicles to meet daily travel needs. One key factor reducing the inclination to own a car was limited access to parking spaces at destinations. Households facing parking shortages or high parking costs were more likely to switch to using SAVs.

After the introduction of SAVs, ownership behaviour shifted, and more individuals showed a willingness to use these services. In

Table 9. Results of Hosmer–Lemeshow test before and after introduction of shared autonomous vehicles

Scenario	Step	Chi squared, χ^2	Degrees of freedom	Sig.
Before introduction of shared autonomous vehicles	1	47.929	8	0.129
After introduction of shared autonomous vehicles	1	63.25	9	0.173

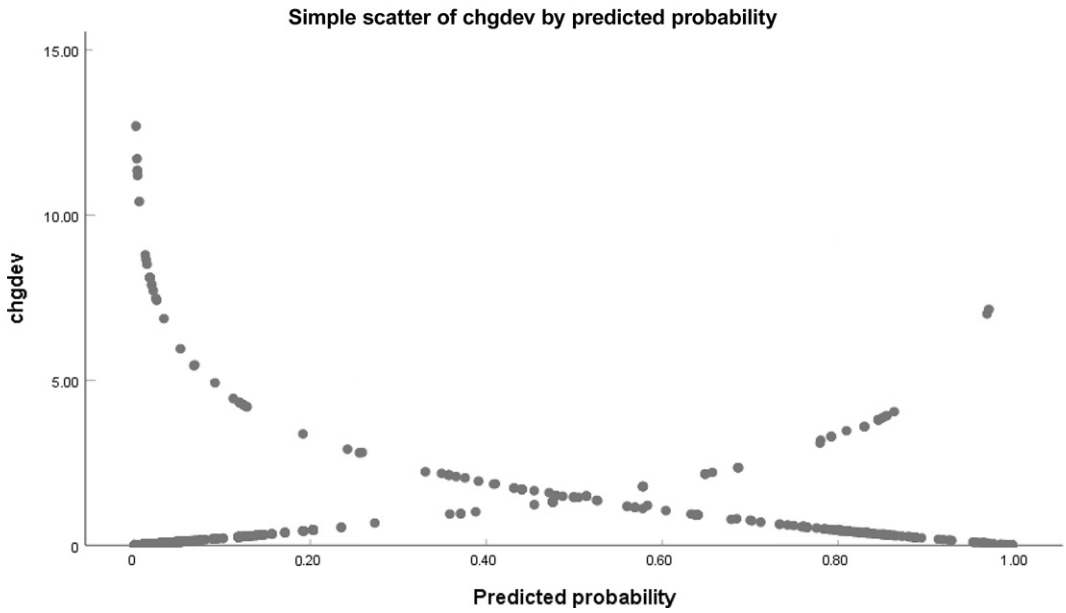

Figure 5. Scatter plot before introduction of autonomous shared vehicles

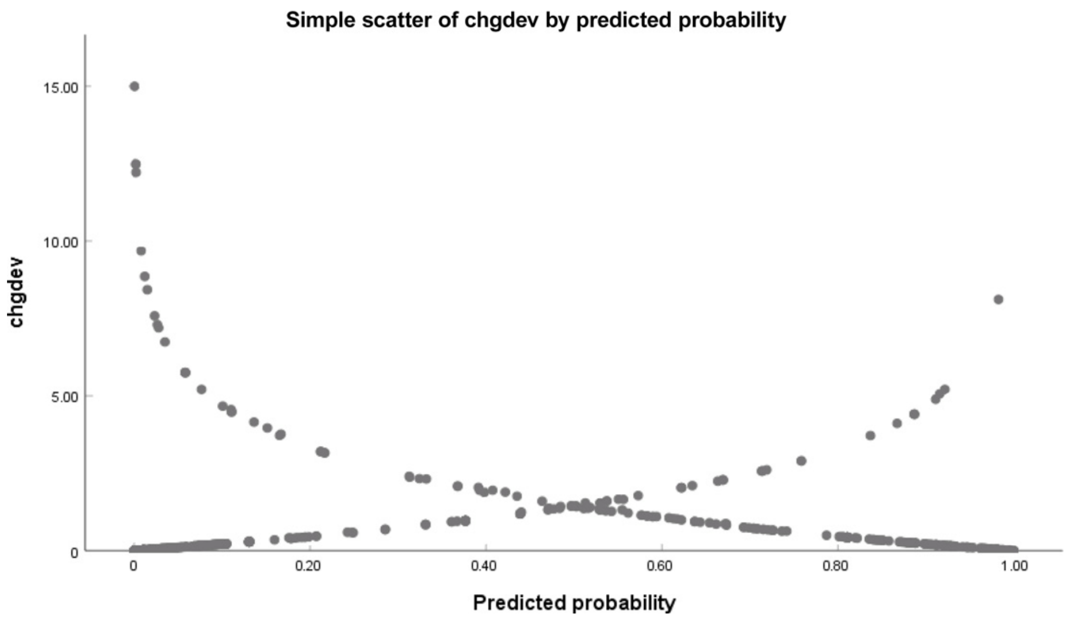

Figure 6. Scatter plot after introduction of autonomous shared vehicles

addition to lowering the costs of maintaining and repairing private vehicles, SAVs provided easier and faster access to transportation. This is particularly beneficial in congested cities like Tehran, where traffic problems and high vehicle maintenance costs make SAVs an economical and practical option for citizens.

In conclusion, this analysis indicates that the introduction of SAVs has had a significant impact on ownership behaviour and travel preferences. Before their availability, private car ownership was considered a necessity for many; however, after their introduction, the desire for ownership declined, and SAVs became a cost-effective and practical alternative. This trend is clearly observable in Figures 5 and 6.

5.3 Descriptive analysis of the Cook's distance scatter plot

The Cook's distance plot indicates that after the introduction of SAVs, the influence of certain data points, which previously had the greatest impact on the private car ownership model, has decreased. Before the availability of these vehicles, individuals with a higher propensity for private car ownership – typically those with higher incomes, a need for travel independence and limited access to public transportation – had the largest weights in the model.

With the introduction of SAVs, the Cook's distance plot shows a reduction in the weight and influence of some of these points. This reflects a change in consumer behaviour and a decreased inclination towards private car ownership. In other words, more individuals have shifted towards using SAVs; these changes are clearly observable in the car ownership prediction models.

Overall, the analysis of the Cook's distance plot confirms that household dependence on private vehicles has decreased and car ownership levels among households have been reduced. This trend can play an important role in future urban transportation planning and policymaking aimed at reducing traffic congestion and optimising the use of public transport.

These changes are clearly illustrated in Figures 7 and 8, which depict the situation before and after the introduction of SAVs. F7 F8

5.4 Random forest model

In this study, a random forest model was employed to analyse the effect of households' socioeconomic characteristics on the use of SAVs. The random forest method is an ensemble machine learning method that constructs a number of decision trees during the training phase, with the class among the trees having the highest frequency selected as the predicted output. This approach is particularly suitable for identifying non-linear relationships, handling both numerical and categorical variables and providing feature importance.

The dependent variable in this model was the share of SAV usage, categorised into three levels: low, medium or high. The independent variables included:

- number of employed household members
- household income
- household size
- family structure.

Data from 318 respondents were randomly split into training (70%) and testing (30%) sets to evaluate model performance.

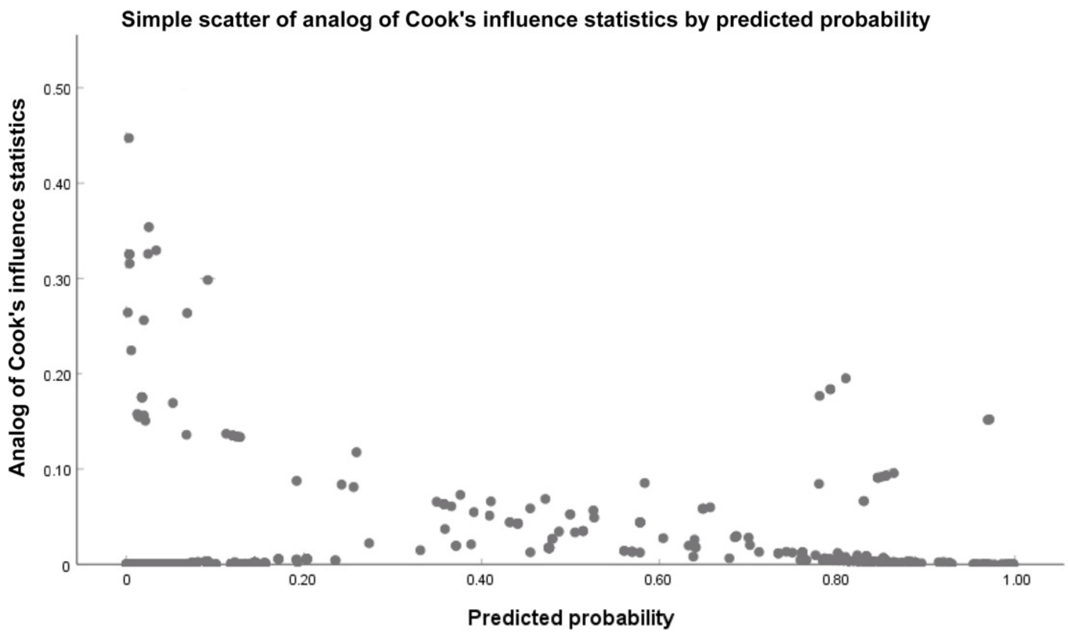

Figure 7. Cook's distance plot before introduction of autonomous shared vehicles

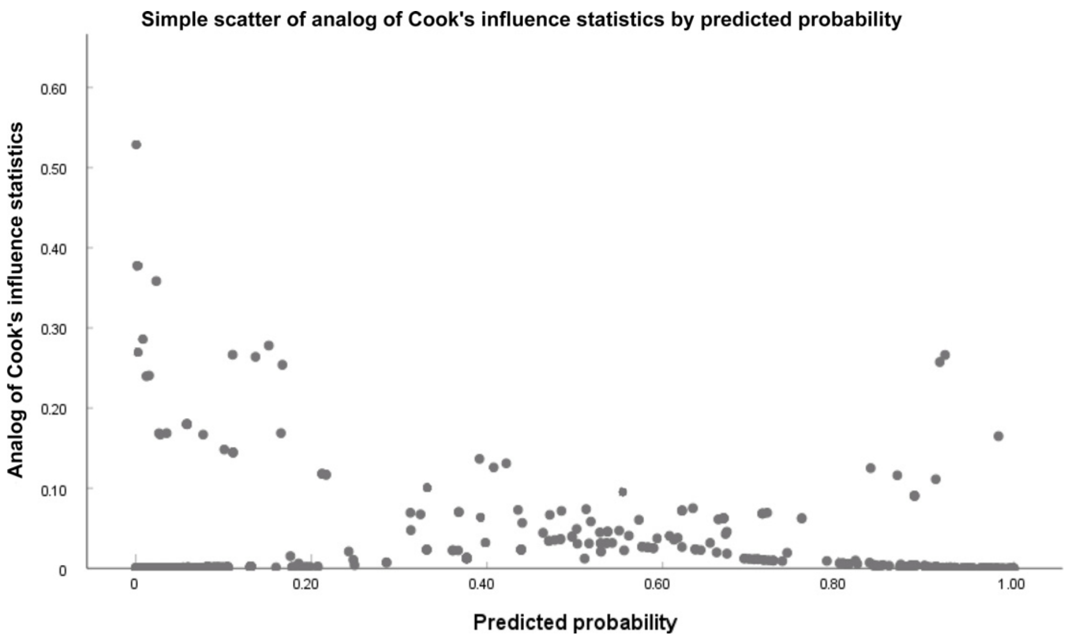

Figure 8. Cook's distance plot after introduction of autonomous shared vehicles

Using this model, the importance of each feature in predicting
T10 SAV usage was determined. Table 10 presents the importance of each household socioeconomic characteristic in predicting the share of SAV usage.

As observed, household size and the number of employed household members have the greatest influence on the share of SAV usage. Household income also has a significant impact, while family structure shows the least effect in the model.

5.4.1 Model accuracy

T11 Table 11 presents the predictive accuracy of the random forest model for the three levels of SAV usage: low, medium and high.

Table 10. Importance of household socioeconomic features in influencing the use of shared autonomous vehicles

Feature	Importance
Household size	0.384
Working members	0.273
Household income	0.235
Family structure	0.108

Table 11. Performance metrics of the random forest model for predicting shared autonomous vehicle usage

Class	Precision	Recall	F1 score	Support
Low	0.435	0.278	0.339	36
Medium	0.158	0.222	0.185	27
High	0.343	0.364	0.353	33

As observed, the model performs relatively better in predicting the low and high usage classes, while the medium usage class is predicted less accurately. The overall model accuracy is 80%, based on the actual data collected from 318 households. Table 12 T12
presents the confusion matrix of the random forest model for predicting the three levels of SAV usage. The rows represent the actual class values, while the columns indicate the model's predictions. As observed, the largest errors occurred in predicting the medium usage class, while higher accuracy was achieved for the low and high usage classes. This pattern indicates that distinguishing households with medium-level ownership from the other groups was more challenging for the model.

6. Discussion

The findings of this study reveal a significant shift in transportation preferences among households in Tehran following the introduction of SAVs, demonstrating a notable reduction in the propensity for private car ownership. This trend agrees closely with findings from studies in developed countries, which consistently indicate that SAVs serve as a viable alternative to individual car ownership, potentially reshaping urban mobility patterns. However, this study uncovers critical distinctions in the factors influencing this shift. In contrast to international research, where

Table 12. Confusion matrix of random forest model for predicting shared autonomous vehicle usage

	Pred 0	Pred 1	Pred 2
True 0	10	18	8
True 1	6	6	15
True 2	7	14	12

economic variables such as household income and transportation costs are typically dominant drivers, in this study, we find that the influence of these economic factors diminishes after the introduction of SAVs in Tehran. Instead, household-related variables – such as family size, travel frequency and preferences for shared mobility – and the intensity of SAV usage emerge as more significant determinants of behaviour.

These differences can be attributed to Tehran's unique socioeconomic and infrastructural context. Such factors as limited urban infrastructure, congested road networks, distinct household travel patterns and varying levels of public trust in autonomous technologies probably contribute to this divergence. For instance, the lower emphasis on economic factors might reflect the perceived affordability and accessibility of SAVs in a developing urban setting, where cost savings from shared mobility outweigh traditional ownership expenses. Additionally, the prominence of household-related variables underscores the importance of cultural and behavioural factors in shaping technology adoption in Tehran, a dimension less explored in studies from developed nations.

This study makes a significant contribution to the global literature by addressing a critical gap: the impact of SAVs on car ownership in developing cities. While much of the existing research is focused on developed urban environments with advanced infrastructure, this study provides a pioneering perspective by examining a major developing city with unique socioeconomic dynamics. By highlighting the interplay of local contextual factors and technology adoption, the findings offer a more nuanced understanding of how SAVs can influence mobility behaviours in diverse urban settings. Furthermore, the study underscores the need for tailored policy frameworks that account for local conditions to maximise the benefits of SAVs, such as reduced traffic congestion, lower environmental impacts and enhanced urban mobility equity.

7. Conclusion

This study is an investigation of the impact of SAVs on private car ownership in Tehran, utilising data from 318 households. Data analysis, conducted using a binary logistic regression model and the random forest machine learning algorithm, reveals that the introduction of SAVs significantly reduces households' inclination to own private vehicles. The extent of SAV usage emerged as the most influential factor in decreasing car ownership, while the impact of economic variables, such as household income and the number of employed members, diminished, compared with pre-SAV scenarios. Household-related factors, including family size and structure, retained notable significance, though their influence slightly waned following SAV adoption. The random forest model further identified household size and the number of employed members as the primary predictors of SAV usage share.

Both models yielded consistent results, underscoring the potential of SAVs as a viable alternative to private cars, which could contribute to reduced traffic congestion and enhanced urban mobility. These findings offer critical insights for policymakers and urban planners, illuminating shifts in household behaviour concerning car ownership before and after SAV implementation. The study's strengths include its reliance on real-world field data, its comparative analysis of pre- and post-SAV deployment behaviours and its focus on specific socioeconomic variables. This approach provides a robust framework for evaluating the impact of emerging transportation technologies on car ownership patterns.

8. Limitations and future research

The primary limitation of this study lies in the lack of direct experience with SAVs among households, as data were gathered solely through video observations and questionnaire responses. Consequently, actual user behaviour might diverge from these findings. To address this point, future research should prioritise collecting real-world data following the practical implementation of SAVs to enable more precise predictions of shifts in car ownership behaviour. Furthermore, expanding the study to include other cities and comparing results with those from major urban centres in developed countries would enhance the generalisability of the findings. Additionally, leveraging advanced machine learning models to analyse influencing factors and predict user behaviour offers a promising avenue for future investigations.

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AQ2—Production: It might be more appropriate to delete Table 1, rewriting the text and renumbering the remaining tables and their citations in the text.

AQ3—The figures in the text did not match the figures in Table 8 and have been corrected. Please check carefully.

AQ4—The details for Wright (1995) were not supplied in the submitted manuscript. Please check that I have included the correct details.

AQ5—The first row in Table 4 had a mathematical error, which I corrected. I have not checked the rest of the table. Please check the whole table and make any necessary corrections.