https://doi.org/10.3311/PPTr.23576

Periodica Polytechnica Transportation Engineering

Early Perspectives: Exploring the Potential Impacts of Autonomous Vehicles Through the Lens of Urban Mobility and Urban Form

Mazdak Sadeghpour[1*], Eda Beyazıt[1, 2]

[1] Department of Urban and Regional Planning, Faculty of Architecture, Istanbul Technical University, Taşkışla Street, No 2, 34367, Istanbul, Türkiye
[2] Centre for Transport and Society, College of Arts, Technology and Environment, University of the West of England, Frenchay Campus, Coldharbour Lane, Bristol BS16 1QY, United Kingdom
* Corresponding author, e-mail: sadeghpour@itu.edu.tr

Received: 03 October 2023, Accepted: 13 March 2024, Published online: 23 April 2024

Abstract

The emergence of autonomous vehicles (AVs) is expected to significantly reshape urban mobility and travel behavior patterns. AVs have the potential to offer higher levels of convenience, safety, and accessibility while enabling users to spend their trip time on more efficient and productive tasks such as working or even relaxing. This transformation in the short- to mid-term could result in changes in the public's sensitivity and perception toward enduring longer travel times and consequently, in mid- to long-term, it could influence the willingness to reconsider their residential locations. Therefore, the objective of this study is to enhance the understanding of the potential effects of AVs on travel behavior and land use through the examination of stated preference queries. To achieve this objective, various multinomial logit models toward AVs adoption and residential relocation were estimated by employing a dataset from Istanbul, Türkiye, as an example of megacity in a developing country. While the study findings revealed a set of potential adoption barriers for AVs, they also indicated a notable propensity for adopting these vehicles. Furthermore, concerning individuals' willingness to reconsider their residential locations due to the emergence of AVs, a considerable positive attitude was evident, albeit guarded. This attitude suggests that individuals' decisions are still evolving and can be guided toward the desired future through well-timed and well-suited policies. The outcomes of the study can serve as valuable input for policymakers as well as transportation and urban planners, offering insights into the potential impacts of AVs on urban mobility and form.

Keywords

urban mobility, urban form, autonomous vehicles, automated vehicles, travel behavior, land use, AV adoption, residential relocation, discrete choice

1 Introduction

The interdependence between transportation and residential locations is a crucial aspect of urban life, with each influencing the other in a reciprocal manner. Specifically, the transformation of transportation demand is largely driven by the evolution of residential and job location patterns, and this complex and dynamic relationship is commonly referred to as the chicken-and-egg problem in the context of land use and urban transport (Picard, 2021). The emergence of autonomous vehicles (AVs) is expected to revolutionize both urban mobility (in the short- to mid-term) and urban form (in the mid- to long-term) by introducing new mobility options and the features they will bring along (Kim et al., 2020).

The potential impacts of AVs on urban mobility could be complex and twofold: AVs are expected to reduce travel time, improve safety, and provide more comfortable and convenient modes of transportation, which could transform individuals' travel behavior and mode choices. These outcomes could induce individuals to own personal cars and reduce their reliance on public transportation. This could make AVs act in a competing way with public transportation (PuT), meanwhile, it could also result in an increase in the rate of single-occupant cars. All of these factors potentially would lead to more traffic congestion and less sustainable, environmentally friendly outcomes (Llorca et al., 2022). Nevertheless, well-designed

Cite this article as: Sadeghpour, M., Beyazıt, E. (2024) "Early Perspectives: Exploring the Potential Impacts of Autonomous Vehicles Through the Lens of Urban Mobility and Urban Form", Periodica Polytechnica Transportation Engineering, https://doi.org/10.3311/PPTr.23576

policies and incentives that could popularize shared modes of AVs such as promoting their usage as feeders of PuT in an integrated manner with PuT systems, could have the potential to decrease the personal car ownership rates, and foster a culture of using shared transportation modes. Subsequently, this could result in less congestion and more sustainable and eco-friendly outcomes (Fagnant and Kockelman, 2014; Hui et al., 2019).

In the same vein, AVs have the potentiality of bringing two reverse impacts on urban form (Milakis et al., 2018). On the one hand, AVs could enable passengers to work or rest, and use their travel time in a less cumbersome way. This, in turn, has the potential to change individuals' perception toward long travel times and could prompt them to relocate away from their workplaces and other destinations to reside in larger or more affordable homes. Evidently, this potential has its own pitfalls as it increases urban sprawl and gives rise to sub-urbanization (Carrese et al., 2019; Wellik and Kockelman, 2020). On the other hand, the introduction of AVs, and particularly their shared modes could reduce the need for parking spaces and make central locations more attractive to live in. This could spark people to move to central urban areas, where parking spaces are limited, without worrying about finding a parking spot because an AV can park itself anywhere (Duarte and Ratti, 2018). Thus, contrariwise, AVs may stimulate re-urbanization and re-densification.

Therefore, the impacts of AVs on transport mode choices and residential relocations are two important dimensions that need to be explored in the context of urban mobility and urban form. Early and consistent monitoring of the market dynamics and public interest in AVs, and examining the determinants of heterogeneous groups and their different behaviors and choices would help assess possible public reactions and gain a clearer understanding in advance. This would maximize the potential benefits of AVs and mitigate their adverse effects, while enabling the early calibration of required policies to guide the desired AV future (Canıtez, 2021; Sener et al., 2019).

The current literature mainly focuses on the potential impacts of AVs on individuals' transport mode preferences, particularly in developed countries, while there are only few studies on the topic that have been conducted in developing countries. Furthermore, there are very limited number of studies on the potential effects of AVs on urban form and land use patterns compared to those related to urban mobility and transport mode choices. Hence, to address these gaps, the present study makes a two-fold contribution to the existing literature by examining these two critical aspects of AVs' widespread deployment on urban mobility and urban form, while utilizing a dataset collected from Istanbul, Türkiye, as an example of a developing mega city. To accomplish these goals, the study initially identifies the factors that influence individuals' willingness to adopt AVs in an effort to gain insight into the probable impacts of AVs on future urban mobility. Subsequently, the study sheds light on potential impacts of AVs on the future urban form, by exploring the likelihood of individuals' relocation from their current residential locations due to the convenience of commuting or travelling facilitated by AVs. The findings of this study could inform policymakers and transport/urban planners about the potential implications of AVs on urban mobility and form, aiding in the development of effective policies and strategies that support sustainable urban development.

The remaining sections of the paper are structured as follows: A review of the literature has been provided in Section 2, followed by explanations about the design of the employed questionnaire for the study at Section 3. Section 4 outlines the methodology of the study, while data analysis and estimated models have been presented in the subsequent section. Lastly, Section 6, has been devoted to policy implications and conclusions of the study.

2 Literature review

Numerous researchers have endeavored to examine the potential impacts of AVs on diverse aspects of our lives and societies, such as transportation systems (Naumov et al., 2020; Saha and Motuba, 2023), land use patterns (Wellik and Kockelman, 2020), employment and workforce (Nikitas et al., 2021), health and well-being (Singleton et al., 2020; Sohrabi et al., 2020), social equity (Emory et al., 2022; Kuzio, 2019), and so on. Among multitude of these direct and indirect consequences, urban mobility and urban form will undoubtedly be one of the first aspects to encounter numerous challenges and disruptions as a result of AVs' advent. Moreover, there is a consensus among urban designers and transport planners that AVs have the potential to significantly redefine and transform the patterns of urban mobility and urban form in short-, mid-, and long-term (Duarte and Ratti, 2018; Hiramatsu, 2022). Therefore, a clear comprehension of the public's potential behavior changes would assist to (re-)define and adopt required policies to manage the positive and negative implications of AVs.

As highlighted by Alawadhi et al. (2020), and Cho and Jung (2018), varying backgrounds, technological awareness, and social interactions in different countries could lead to diverse perceptions of AVs. To gain a comprehensive understanding of consumers' knowledge and their perspectives on AVs, it is crucial to assess and compare these aspects across various cultures and in different countries continuously. However, the majority of the existing literature belongs to developed countries. It is noteworthy that many developed countries have incorporated detailed questions regarding individuals' perceptions and the potential impacts of AVs in their national or regional transport-related surveys. These surveys aim to estimate and determine possible reactions of the public to different modes of AVs under different scenarios, and numerous researchers and scholars have benefitted from these datasets to delve more into various aspects of the domain (Behnood et al., 2022; Nazari et al., 2018; Tao and Cao, 2022; Wali et al., 2021).

Several studies have investigated individuals' willingness to use AVs and their different forms such as privately owned or shared, through different levels of automation. Behnood et al., (2022) have deployed the 2017 California Vehicle Survey to determine the likelihood of consumers' affinity for purchasing fully (level 5) and partially (levels 3 and 4) AVs according to Society of Automotive Engineers (SAE) automation level definitions (SAE, 2021). By estimating random parameter logit models, they have revealed significant differences among the determinants of individuals' affinity toward fully and partially AVs. Among many variables they have evaluated, those related to education level, parking type, gender and perceptions toward the future of carsharing and ridesharing programs had significant degrees of heterogeneity. Furthermore, Nordhoff et al., (2022) have conducted an online survey among 18,631 respondents from 17 countries to explore the variations at individuals' acceptance of conditional AVs (level 3). They investigated differences in age, gender, awareness levels and frequency of receiving information, knowledge regarding the functionality of conditional AVs and expected benefits of these vehicles. Although participants from non-European countries had higher levels of acceptance compared to respondents from European countries, in general, individuals who were male, younger, and more knowledgeable about AVs had the highest levels of potential acceptance.

In most of the cases, the results of the studies which have analyzed common variables, have showed significant differences spatially. For instance, some studies have found the majority of participants to have high or somewhat positive attitudes toward AVs' safety or efficiency (Islam et al., 2022; Penmetsa et al., 2019). As a counter case, the result of a national survey among Irish people showed that only one-fifth of population had a high level of interest and people were mostly unsure about or not likely to trust in the level of safety and security offered by AVs (Rezaei and Caulfield, 2020). Individuals' exposure to technology, such as owning smart home devices, or availability of automation technologies in their existing vehicles such as lane assist also have been found to be positively correlated with owning an AV (Hossain and Fatmi, 2022).

Changes in urban transport, throughout urban history, have always been followed by changes in the urban form, which subsequently have resulted in changes in urban sustainability (Cugurullo et al., 2021; Sheller and Urry, 2000). However, the capability of AVs to trigger the changes in urban form and urban sustainability are still unknown and need further explorations. Studies regarding the effects of AVs on individuals' location preferences, particularly in relation to private AVs, mostly have indicated that these vehicles will result in emergence of sprawling settlement patterns and more dispersed developments (Fagnant and Kockelman, 2015; Meyer et al., 2017; Soteropoulos et al., 2019).

Hiramatsu (2022) developed a simulation model to evaluate the influence of AVs on residential preferences in Osaka, Japan. The study revealed that the increased adoption of AVs tends to shift people toward suburbs with limited public transportation. The response of high-income workers was more impacted by technological advancements, while the reaction of low-income workers was more influenced by the reduced costs of car ownership. By the same token, Nadafianshahamabadi et al., (2021) finds that AVs are likely to increase demand and greenhouse gas emissions as development patterns shift to the region's periphery and trips become longer.

In another study conducted by Moore et al., (2020), the propensity of commuters to relocate homes and/or jobs under various private AV scenarios has been modeled by deploying a survey in Dallas-Fort Worth Metropolitan Area in the US. Their findings revealed that individuals with a higher interest in productive time use, males and younger people were more willing to accept increases in commuting time and inclined to consider relocations. Additionally, the study highlighted further sprawl of suburban residents along with an increase in vehicle-scarce households.

In conclusion, a review of the relevant literature indicates that the majority of the existing studies have primarily focused on developed countries. Consequently, the

findings from these studies may not be directly applicable to developing countries due to the significant variations in cultural norms, distinct dynamics of urbanization and development, and disparities in existing infrastructures and transportation management methods. Hence, there is a considerable knowledge gap regarding the potential impacts of AVs within the context of developing countries, particularly in their rapidly growing metropolitan areas.

To address this research gap and enrich the existing literature from the perspective of a developing country, a meticulously designed questionnaire, explained in the following section, was deployed in Istanbul, Türkiye, as an example of a rapidly growing mega-city, to investigate the public's inclination toward adopting AVs and reconsidering their residential locations.

3 Questionnaire design

The questionnaire employed in the study was designed following a comprehensive review of the main topics addressed in the existing literature. Considering that the survey was intended to be distributed online among random individuals, and taking into account the emerging nature of the topic within Türkiye's landscape (notably lacking a position in the AVs Readiness Index reported by KPMG International (2020) among the top thirty countries and jurisdictions), the survey framework was defined carefully and with caution. Efforts were made to minimize complexity, optimize the length of the questions, provide clear explanations, and reduce the overall survey duration to get the highest efficiency from the participants.

The primary objective of the questionnaire was to examine the potential impacts of AVs on future urban mobility and form by analyzing the likelihood of individuals' willingness to adopt AVs, along with examining the probability of their intentions to relocate from their current residential locations due to the provided commuting comfort by AVs. Analyzing the determinants of these variables (i.e., willingness to adopt and willingness to relocate) for heterogeneous groups and different situations is crucial to make required and to-the-point policies in advance.

The questionnaire contains three main sections: The main intention of the first section was to gather socio-demographic information of respondents, such as gender, age, marital status, educational level, and occupational status. As well, a polytomous question was asked to assess respondents' technology savviness levels. In the second section, the major purpose was to understand the individual's current travel behavior and its details.

In the third section, following a comprehensive explanation of AVs, aligned with the definition of SAE for the level 5 automation technology and presenting an optional video about a real example of an AV in today's world, questions related to different aspects of AVs were presented. Measuring the knowledge and familiarity of respondents regarding AVs'concept before reading/watching the provided material in the questionnaire, evaluating their familiarity with the existing automation technologies such as adaptive cruise control, lane-keeping assistant, etc., and most importantly, assessing their willingness to adopt (WTA) an AV in the upcoming years, as well as a question asking about their willingness to relocate (WTR) due to the provided comfort by AVs, were the main milestones of the third part.

Before formally distributing the questionnaire, a face-to-face pilot study with 11 participants was conducted to ensure the comprehensibility and comprehensiveness of the questions, as well as to determine the average time required to complete the questionnaire. After making minor adjustments based on their feedback, and getting the ethical approval of the Istanbul Technical University, the designed questionnaire was distributed online between June-September 2021. In total, 351 fully completed responses have been collected. However, considering the fact that urban mobility and form patterns in Istanbul, as a developing mega city, are significantly different from other cities of Türkiye, to enhance the coherency and reliability of the collected data, the responses coming from other cities were removed. Moreover, attention control questions were employed to ensure the respondents attentiveness, inquiring about the availability of a car at household, and possessing a personal car in separate questions. Respondents who indicated no available car in their households, but possessed a personal car were excluded from the dataset. Hence, the final dataset consisted of 334 valid responses.

4 Methodology

The adoption willingness of AVs or the likelihood of reconsidering residential locations can be represented by discrete categories such as "not at all", "somewhat" or "extremely". Therefore, a discrete choice model within the framework of rational decision-making can be employed to investigate the likelihood of the outcomes. The underlying principle of a discrete choice model is that the utility associated with a choice, relies on the attributes of the alternatives and the characteristics of the decision-maker.

By characterizing this function for a given population, it becomes possible to make statistical inferences on the functional parameters (Behnood et al., 2022).

Multinomial logit (MNL) model is one of the efficient techniques in discrete choice modelling that is frequently used to interpret and calibrate choice data. The MNL model relies on the theory of random utility (Train, 2009). Based on the theory, individual i selects the alternative a from the available choice set c that maximizes the obtained utility of the individual. The utility that the individual obtains from the chosen alternative a is divided into two components, namely, the non-random systematic utility and the random error term (Ben-Akiva and Lerman, 1985; McFadden, 1973):

$$U_{ai} = V_{ai} + \epsilon_{ai} \tag{1}$$

where U_{ai} is the overall utility of the alternative a to the decision-maker i, V_{ai} is the non-random systematic utility function, and ϵ_{ai} is the random error, i.e., unobserved error component of the utility, which is assumed to have type I extreme value distribution while being independently and identically distributed (IID). The probability of alternative a being chosen by decision-maker i is calculated by using the following assumption:

$$\begin{aligned} Pr_{ai} &= Pr\left(U_{ai} > U_{ci}\right) \ \forall c \neq a \\ &= Pr\left(V_{ai} + \in_{ai} > V_{ci} + \in_{ci}\right) \ \forall c \neq a \end{aligned} \tag{2}$$

The systematic utility is derived by defining a function that incorporates observable attributes of the alternative and the decision-maker. Therefore:

$$V_{ai} = \beta X_{ai} \tag{3}$$

where X_{ai} represents the vector of observed attributes and β denotes a vector of unknown parameters. Consequently, Eq. 1 can be written as:

$$U_{ai} = \beta X_{ai} + \epsilon_{ai} \tag{4}$$

and as the general form of the MNL model, the logit choice probability in Eq. 2 is expressed as the following closed-form:

$$Pr_{ai} = \frac{e^{\beta Xai}}{\sum_{c} e^{\beta Xci}} \tag{5}$$

5 Data analysis and results

The socio-demographic attributes of 334 respondents are presented in Fig 1. While the gender distribution

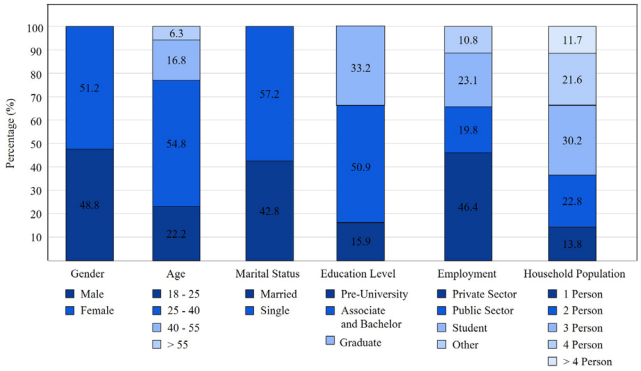

Fig. 1 Socio-demographic attributes of the respondents

is approximately equal, the age of respondents varies between 18 and 73, with a standard deviation of 33.7. The question regarding individuals' residency situation showed that almost 55% of the respondents either live in their own houses or do not pay rent. Additionally, while the great majority of the subjects indicated holding a valid driving license (84%), only around 50% of them own a personal car. Furthermore, respondents were asked to indicate their most frequently used transport modes during their weekday commute trips. Various transport modes were presented to the subjects, and the collected answers have been grouped under two main categories of public transport (PuT) users and private vehicle (PrT) users (i.e., driver or passenger of a private car). Almost 70% of the respondents have indicated that various PuT means (including subscription bus, metro, public bus, ferry, BRT, minibuses, tram, or taxi) were their primary used modes during their weekdays commuting trips. Respondents were also asked to indicate their average travel times during these trips. The average travel time for Istanbulites regardless of their transport mode is almost 30 minutes (Bimtaş, 2014); in the current survey, approximately 42% of the respondents indicated 30 minutes or less as the average travel time for their weekday commutes, while almost 40% indicated 30-45 minutes as their average weekday commute travel time.

In the third section of the questionnaire, after presenting a comprehensive definition of AVs, respondents were asked to indicate their pre-familiarity with the AVs' concept prior to reading/watching the provided material in the questionnaire. Furthermore, they were asked to indicate their familiarity level with the existing driver-assistance technologies, including "lane-keeping assistance", "adaptive cruise control", "automatic braking system" "and "parking assistant". As it has been depicted in Fig. 2, for pre-familiarity, approximately half of the respondents regarded themselves as somewhat familiar with the

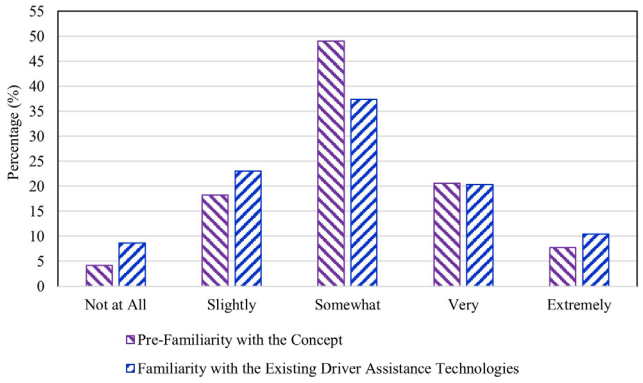

Fig. 2 Different levels of respondents' pre-familiarity with the AVs concept, and familiarity with the existing driver-assistance features

topic. Conversely, in terms of familiarity with the existing features, this percentage was almost equal to one-third. Overall, a substantial proportion (nearly 78%) of the respondents have indicated their prior familiarity with the concept and technology of AVs in advanced levels (i.e., somewhat, very, and extremely). Notably, this significant level of pre-familiarity with the concept persists despite the absence of any officially implemented or announced pilot AV project in Istanbul, Türkiye, unlike most of the developed countries and cities.

As one of the main aims of the survey, and also as the core of the current study, in two polytomous questions, respondents were asked to indicate their willingness to adopt (WTA) an AV in the future, when they are introduced to the market, and their willingness to relocate (WTR) to a further, but more convenient and (possibly) more affordable location, due to the travel convenience provided by AVs. Both queries were presented to respondents based on a 5-point Likert scale, ranged from "very unlikely" to "very likely". The percentage distribution of the responses to both questions are depicted in Fig. 3.

As it can be seen, 57% of the respondents have indicated their enthusiasm (i.e., likely and very likely) to adopt AVs

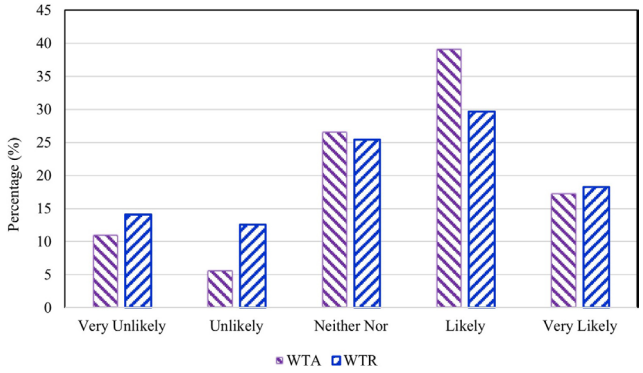

Fig. 3 Respondents percentages for each level of WTA and WTR

once they become available, and nearly 48% of them have declared their high willingness to reconsider their residential locations. Meanwhile, approximately a quarter of the respondents have expressed a cautious attitude (i.e., neither nor) toward both cases. The high levels of interest in AVs, despite the absence of officially announced pilot projects in the country, can be attributed to several factors. Particularly, the prevalence of high levels of traffic congestion could be among the primary reasons. Istanbul, as one of the busiest and most congested cities globally, ranks first in the 2022 TomTom Traffic Index among megacities in the Europe region, followed by Paris and London (TomTom, 2023), while for the year 2021, it held the title of world's most congested city (TomTom, 2022). Therefore, offering a transport mean which would be able to drive itself, and alleviating the burden of traffic congestion, could be very appealing in a car-oriented megacity like Istanbul. Also, similar to all other megacities, and developing countries, high rates of traffic accidents and safety concerns in Istanbul might have an influence as AVs present a promising solution to mitigate the traffic accidents' originating from human-driver errors, which correspond to nearly 90% of all traffic accidents (NHTSA, 2015).

To delve more into the intercorrelation between respondents' WTA and WTR at various levels, the chord diagram of these variables is depicted in Fig. 4 in order to visualize the differences in individuals' willingness likelihoods. The diagram represents individuals' propensity levels for

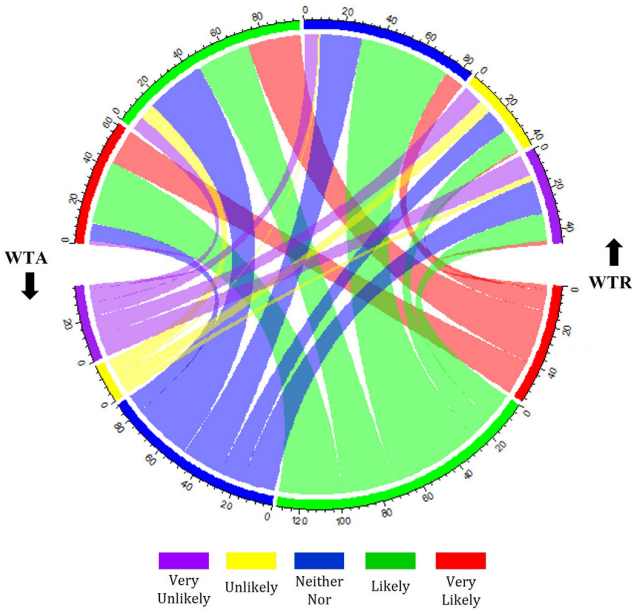

Fig. 4 Intercorrelation (chord) diagram of different levels of WTA and WTR

adoption and relocation on a complete circle. The outer ring is divided into willingness levels based on the number of individuals and their proportions in each level for AVs adoption (lower semi-circle) and residential relocation (upper semi-circle). The chords connecting different segments of the outer ring illustrate the proportion of individuals between pairs of interest levels for AVs adoption and inclination levels for relocation. At first glance, it can be observed that there is a notable discordance pattern across almost all levels, implying the existence of high degrees of heterogeneity in individuals' attitudes toward adoption and relocation. The majority of individuals with lower levels of interest in AVs adoption ("very unlikely" and "unlikely"), are less likely to be interested in relocation. However, a significant portion of those who are not interested in relocating, have somewhat or higher levels of inclination ("neither nor" and "likely") toward adopting an AV. More than half of the indecisive individuals toward relocation have positive attitudes (likely) toward embracing an AV. Meanwhile, almost one-third of eager individuals (very likely) to adopt an AV have the same level of eagerness toward relocating. Although this can be interpreted as a sign of being more cautious regarding residential location decisions than decisions for transport modes, it is also a strong sign of complex intercorrelation between dynamics of transport activities and land use, which works like a chicken-egg relation, and requires more in deep and detailed further investigations to comprehend the characteristics of heterogeneous groups.

5.1 Model estimations

As mentioned in the preceding sections, to enhance the understanding of the potential effects of AVs on travel behavior and land use, different MNL models have been estimated for WTA and WTR.

In the original dataset, the questions related to WTA and WTR were formulated utilizing a 5-point Likert scale, comprising of the options of "very unlikely", "unlikely", "neither likely nor unlikely", "likely" and "very likely". However, to streamline the model estimation process and to provide a more focused discussion on the estimation results, the 5-point scale has been transformed to a 3-point scale, namely "unlikely", "neither likely nor unlikely", and "likely". Furthermore, to augment the practicality and straightforwardness of the findings, these categories were further normalized to "not interested", "wait and see", and "enthusiast", respectively.

For both WTA and WTR, a main MNL model has initially been estimated. Next, to further delve into each topic, additional stratified MNL models have been developed. From the perspective of urban mobility, to understand the potential factors influencing individuals' decisions regarding their inclination to adopt an AV, their primary transport mode has been considered as one of the most important factors to be examined further as a stratum. Hence, individuals were categorized under two mutually exclusive groups of PuT and PrT users. In the same vein, from the urban form viewpoint, the current dwelling situation of individuals has been assumed as one of the most important factors that could impact their future decisions regarding reconsidering their residential locations. Accordingly, after estimating the general MNL model based on the entire dataset, the dwelling situation of individuals has been considered as a stratum, by being categorized into two mutually exclusive groups of rent-payers (not house owners) and non-rent-payers (house owners). As a result, two additional stratified MNL models have been developed.

To ensure the most significant and robust models, various sets of variables have been examined for each model separately, and the most informative models were selected as the final models. Statistical significance for variables is provided in the form of t-statistics, with considering 10% as the threshold value. However, due to the respondents' lack of familiarity with the AVs concept, some studies such as Nodjomian and Kockelman (2019) used 20% as the statistical significance threshold for their estimations to account for greater errors in responses. This approach is also adopted in this study and the estimates are checked for both 10% and 20% levels. The estimation results of the final models are presented in Table 1 and Table 2.

5.2 WTA model

Table 1 presents the results of the estimated MNL models for WTA. All the variables in these models are dummy variables indicating binary outcomes (0 or 1). In general, the estimation results indicate plausible parameter signs and a satisfactory overall model fit, as reflected by McFadden's p^2 values.

The minimum level of inclination to adopting AVs, i.e., the "not-interested" group was selected as the reference level of the WTA model, resulting in two alternative specific constants (ASC) per model. The values of ASCs in Table 1 show that either in the entire sample, or in the stratified models, individuals exhibited more enthusiasm in adopting an AV, compared to being not-interested, ceteris paribus.

As one of the most important socio-demographic attributes, gender, has a significant impact on individuals' inclination toward adopting an AV. The negative

Table 1 Estimated MNL model for WTA.

	Entire Sample		PuT User		PrT User	
Variable	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
	Wait and See					
ASC	2.328*	1.745	1.747*	1.171	2.381	1.094
Gender (Male = 1; otherwise = 0)	–1.519*	–3.280	–2.274*	–3.187	–2.701*	–2.305
Age (Younger than 35 = 1; otherwise = 0)	0.858**	1.389	–1.434**	–1.511	0.317	0.310
Marital Status (Single = 1; otherwise = 0)	0.765**	1.315	1.784*	2.136	–2.586*	–1.676
Education Level (<= Bachelor = 1; otherwise = 0)	0.977**	1.388	0.967	1.200	–1.925*	–2.083
HH Size (< two member = 1; otherwise = 0)	–0.189	–0.368	–0.286	–0.350	–0.869	–0.752
HH Car Ownership (> one car = 1; otherwise = 0)	0.316	0.603	0.582	0.720	–1.090	–1.089
House Ownership (Being a rent-payer = 1)	–0.840*	–1.765	0.488	0.649	–0.367	–0.345
Tech Savviness (Yes = 1; otherwise = 0)	1.674*	3.637	2.841*	4.021	0.205	0.198
Holding Driver License (Yes = 1; otherwise = 0)	–2.256*	–2.023	–2.278*	–1.959	---	---
Personal Car Ownership (Yes = 1; otherwise = 0)	–0.030	–0.312	–0.466	–0.781	---	---
Primary Travel Mode (PuT User = 1; otherwise = 0)	–0.327**	–1.393	---	---	---	---
Avr. Travel Time (<= 30 minutes = 1; otherwise = 0)	–0.443**	–1.144	–0.191	–0.358	–0.883	–1.265
Pre-Familiarity with the AVs' Concept (Yes = 1; otherwise = 0)	0.229	0.468	–0.239	–0.386	2.422*	1.660
Familiarity with the Existing Driver Assistance Technologies (Yes = 1; otherwise = 0)	0.217	0.479	–1.255*	–2.005	2.542*	2.332
Car Renting Experience (Yes = 1; otherwise = 0)	1.143*	2.487	3.078*	3.989	0.043	0.049
	Enthusiast					
ASC	3.705*	2.968	3.832*	2.752	4.413*	2.328
Gender (Male = 1; otherwise = 0)	–0.525	–1.266	–1.011*	–1.780	–1.784*	–1.819
Age (Younger than 35 = 1; otherwise = 0)	1.067*	1.864	–1.958*	–2.283	1.323**	1.351
Marital Status (Single = 1; otherwise = 0)	0.421	0.793	1.479*	1.969	–3.572*	–2.520
Education Level (<= Bachelor = 1; otherwise = 0)	1.308*	1.980	1.199**	1.569	0.942	0.986
HH Size (< two member = 1; otherwise = 0)	–0.826*	–1.712	–0.797	–1.012	–1.470**	–1.443
HH Car Ownership (> one car = 1; otherwise = 0)	–0.248	–0.520	–0.386	–0.506	–1.639*	–1.874
House Ownership (Being a rent-payer = 1; otherwise = 0)	–0.569	–1.276	0.917**	1.295	–2.091*	–2.083
Tech Savviness (Yes = 1; otherwise = 0)	1.527*	3.630	2.529*	3.841	0.067	0.374
Holding Driver License (Yes = 1; otherwise = 0)	–3.153*	–2.897	–3.368*	–2.988	---	---
Personal Car Ownership (Yes = 1; otherwise = 0)	0.919*	2.162	0.565	1.068	---	---
Primary Travel Mode (PuT user = 1; otherwise = 0)	0.227	0.601	---	---	---	---
Avr. Travel Time (<= 30 minutes = 1; otherwise = 0)	–0.306	–0.876	–0.205	–0.418	–0.666	–1.076
Pre-Familiarity with the AVs' Concept (Yes = 1; otherwise = 0)	0.031	0.271	–0.606	–1.088	2.973*	2.232
Familiarity with the Existing Driver Assistance Technologies (Yes = 1; otherwise = 0)	0.238	0.582	–0.138	–0.247	1.820*	1.811
Car Renting Experience (Yes = 1; otherwise = 0)	0.802*	1.913	2.164*	3.020	0.006	0.107
Number of observations		334		230		104
Number of parameters		32		30		26
Log Likelihood (model)		–276.602		–174.093		–85.566
Log Likelihood (base)		–325.223		–219.428		–104.884
McFadden's p^2		0.149		0.207		0.203

* Significant at 90% confidence level

** Significant at 80% confidence level

Table 2 Estimated MNL model for WTR.

	Entire Sample		House Owners (non-rent-payers)		Rent-Payers (not house owners)	
Variable	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
	Wait and See					
ASC	–2.847*	–2.743	–3.566*	–2.208	–3.204**	–1.426
Gender (Male = 1; otherwise = 0)	0.226	0.592	0.180	0.452	1.759*	2.146
Age (Younger than 40 = 1; otherwise = 0)	0.787**	1.452	1.681*	1.913	2.361*	1.710
Marital Status (Single = 1; otherwise = 0)	–0.150	–0.337	–0.852	–1.154	0.605	0.992
Education Level (<= Bachelor = 1; otherwise = 0)	0.629*	1.711	0.561	1.063	1.300*	1.782
HH Size (More than two member = 1; otherwise = 0)	0.091	0.317	0.670	0.836	–0.636	–0.832
HH Car Ownership (Owning a car = 1; otherwise = 0)	0.298	0.597	---	---	---	---
House Ownership (Being a rent-payer = 1)	0.907*	1.883	---	---	---	---
Tech Savviness (Yes = 1; otherwise = 0)	0.709*	1.957	1.566*	2.792	0.799	1.141
Holding Driver License (Yes = 1; otherwise = 0)	1.594*	2.234	2.054*	1.655	–0.772	–0.685
Personal Car Ownership (Yes = 1; otherwise = 0)	–0.315	–0.566	–0.207	–0.360	0.461	0.593
Primary Travel Mode (PuT User = 1; otherwise = 0)	0.447	0.968	–1.450*	–2.114	–0.437	–0.531
Avr. Travel Time (<= 30 minutes = 1; otherwise = 0)	–0.572*	–1.690	0.106	0.229	–2.512*	–3.399
Pre-Familiarity with the AV's Concept (Yes = 1; otherwise = 0)	–0.769*	–1.719	–0.004	–0.007	–2.606*	–2.545
Familiarity with the Existing Driver Assistance Technologies (Yes = 1; otherwise = 0)	–0.168	–0.434	–0.940**	–1.519	0.107	0.144
Car Renting Experience (Yes = 1; otherwise = 0)	0.387	1.019	0.841**	1.408	0.833	1.240
	Enthusiast					
ASC	–0.208	–0.282	–0.219	–0.204	0.764	0.469
Gender (Male = 1; otherwise = 0)	0.216	0.644	0.960*	1.818	0.605*	1.940
Age (Younger than 40 = 1; otherwise = 0)	–0.500	–1.005	–1.520*	–1.775	–0.754	–0.576
Marital Status (Single = 1; otherwise = 0)	0.620**	1.529	1.259*	1.693	0.865**	1.405
Education Level (<= Bachelor = 1; otherwise = 0)	0.631*	2.020	0.179	0.372	1.114*	1.905
HH Size (More than two member = 1; otherwise = 0)	0.517**	1.416	–0.339	–0.495	0.872*	2.190
HH Car Ownership (Owning a car = 1; otherwise = 0)	0.993*	2.571	---	---	---	---
House Ownership (Being a rent-payer = 1)	–0.607**	–1.349	---	---	---	---
Tech Savviness (Yes = 1; otherwise = 0)	0.327	1.054	0.824*	1.798	0.400	0.759
Holding Driver License (Yes = 1; otherwise = 0)	–0.409	–0.998	–1.196*	–1.831	0.352	0.491
Personal Car Ownership (Yes = 1; otherwise = 0)	0.934*	1.792	–0.875*	–1.705	3.328*	3.485
Primary Travel Mode (PuT User = 1; otherwise = 0)	0.135	0.314	1.031**	1.548	0.577*	1.875
Avr. Travel Time (<= 30 minutes = 1; otherwise = 0)	–0.186	–0.643	0.495	1.159	–0.625	–1.225
Pre-Familiarity with the AV's Concept (Yes = 1; otherwise = 0)	0.603*	1.729	–0.111	–0.232	1.293*	1.832
Familiarity with the Existing Driver Assistance Technologies (Yes = 1; otherwise = 0)	0.186	0.579	–0.045	–0.092	0.026	0.043
Car Renting Experience (Yes = 1; otherwise = 0)	0.695*	2.092	1.665*	3.019	0.376	0.649
Number of observations	334		182		152	
Number of parameters	32		28		28	
Log Likelihood (model)	–301.149		–157.073		–114.021	
Log Likelihood (base)	–351.779		–196.462		–151.177	
McFadden's p^2	0.144		0.201		0.246	

* Significant at 90% confidence level

** Significant at 80% confidence level

sign of all estimated coefficients reveals that, overall, women have a higher propensity than men toward AVs' adoption. However, the magnitudes of coefficients in all segments reveal that the majority of women have a cautiously optimistic mindset, and mostly fall in the "wait and see" group. These results are in contrast with the most of the previous studies from other countries which generally have found out that men have higher propensity to adopt AVs (Othman, 2023; Tao and Cao, 2022; Xiao and Goulias, 2022). The reason of women's higher inclination toward AVs adoption in Istanbul, Türkiye, may be influenced by the significant role of androcentric language in shaping the automobile culture in Turkish society (Işık and Koçak Oksev, 2022). Meanwhile, in general, Turkish drivers are among the most aggressive drivers (Ersan et al., 2020; Özkan et al., 2011), and also women's share among the drivers of Istanbul (and Türkiye) is very less by comprising almost one-fourth of the total driver population (Dierks, 2023). Therefore, relinquishing the control and responsibility of the driving task to computers and the vehicle itself, could potentially lead to an increased sense of safety and confidence in women while driving.

Regarding age, younger individuals in general have exhibited higher degrees of tendency toward adopting AVs over the entire sample. However, individuals older than 35, who primarily rely on public transport modes have expressed more positive propensity toward AVs adoption than their younger counterparts. This indicates that although young people, in general, have more enthusiasm toward technological advancements, older adults, particularly those dependent on public transport, are aware of the potential benefits offered by these evolving mobility means. This finding underscores the importance of appropriate policies to control undesired shifts of any age range from public transport modes to these new emerging vehicles.

In the case of marital status, married individuals who are primarily dependent on private modes as drivers or passengers, have exhibited more excitement toward adopting AVs, compared to single individuals. This can be attributed to the family structure, and the convenience of owning a private vehicle. However, in the case of PuT users, as well as in the overall sample, single individuals have shown higher, albeit cautious, levels of willingness for adopting an AV, with respect to their married counterparts. This result aligns with the findings related to age, as the majority of the single individuals are likely to be younger, and they can be considered as potential future vehicle owners when the AVs become widely available in the market widely.

The estimated coefficients for education level attainment in Table 1 show that, over the entire sample, individuals with a bachelor's degree or lower as their highest attained education have expressed greater enthusiasm than their counterparts with higher degrees. However, PrT users with higher levels of education expressed a more positive, yet cautious inclination toward adopting an AV. There is no consensus regarding the impacts of education levels on the likelihood levels of individuals' willingness to adopt an AV in the literature. Some studies have reported that as the attained education level increases, the propensity to use and adopt AVs also increases, while others have revealed that there is no clear relationship between education level and the propensity toward AVs (Tao and Cao, 2022; Yap et al., 2016; Zmud and Sener, 2017).

Household (HH) car ownership could also influence individuals' excitement toward adopting an AV. Although the majority of the estimated coefficients for HH car ownership are statistically insignificant, it can be inferred from the sign of the estimated coefficients that individuals from HHs with no or at most one car, have expressed higher levels of enthusiasm, compared to those from HHs with more than one available car. Additionally, individuals who already own a personal car are more inclined to adopt an AV, compared to those who do not. Furthermore, possessing a driving license significantly impacts individuals' willingness to adopt an AV. In general, those without a driving license are much more thrilled to adopt an AV than those who possess a driving license. This finding could be attributed to the fact that individuals who do not possess a driving license, for any reason, are more excited about the opportunity to adopt a transportation mean that can drive them around independently.

Being a house owner, as an indicator of economic power, is another significant variable on individuals' likelihood to adopt an AV. Overall, house owners (i.e., non-rent-payers) are more interested in adopting an AV compared to rent-payers, albeit with a cautiously positive attitude. Also, those house owners who are dependent on PrT are more willing to adopt an AV. This could be attributed to their superior economic situation and being aware of and also used to the convenience of owning a personal car. Meanwhile, the negative sign of coefficients for rent-payers who are dependent on PuT modes reveal that they might have relatively high levels of enthusiasm toward adopting an AV, which may be an indicator of a potential shift from PuT to AVs.

As no surprise, respondents who consider themselves as tech savvy, have more inclination to adopt AVs, nonetheless, it is a slightly guarded inclination. This suggests their flexible viewpoints toward the topic, indicating that their decisions are still premature and can be influenced by appropriate, well-designed and effective policies aimed at shaping a desired AV future and a sustainable transport network.

The primary transport mode is only present in the entire sample model since it is the stratification variable. Its estimated coefficients reveal that PrT users have a more optimistic attitude, albeit with caution, toward adopting an AV, compared to PuT users. This finding is aligned with the study of Winter et al., (2020) in the Netherlands, where PuT users expressed the lowest preference for AVs.

Pre-familiarity with the AVs' concept is another important factor that can impact individuals' approach to the notion. As their knowledge and exposure to different sources and advertisements increase, they could become more interested in the technology, and more eager to adopt it. The significant estimated coefficients show the impact of this variable for PrT users, who are already reliant on personal vehicles, and as the pre-familiarity increases, the likelihood of trust and interest in AVs also increases. This suggests that over time, as AVs become more prevalent, individuals could become more inclined to adopt these vehicles, underscoring the need for awareness and the proactive implementation of appropriate policies in advance.

In the same vein, familiarity with existing driver assistance technologies also plays a role in individuals' likelihood to adopt an AV. Particularly, PrT users, who use personal cars on their daily commute trips and are more familiar with the technological features available in modern vehicles, have expressed higher levels of likelihood for adopting an AV, albeit with a cautiously optimistic mindset toward the notion. A parallel finding was also reported by (Hossain and Fatmi, 2022), indicating that increased familiarity with the existing driver assistance technologies raises the likelihood of AVs' adoption.

Having an experience of car renting for intra-city trips by individuals is believed to be related with their attitudes toward AVs and adopting them (Wang et al., 2020; Zmud and Sener, 2017). The estimated coefficients of this variable in Table 1 are in agree with the notion, that individuals with this experience have higher levels of positiveness toward adopting an AV, more than their counterparts who never had such an experience.

5.3 WTR model

The estimated MNL models for WTR are presented in Table 2. The estimation results exhibit reasonable parameter signs and acceptable overall model fits, as evidenced by McFadden's p^2 values.

Gender plays a significant role in individuals' likelihood to reconsider their residential locations in the light of enhanced convenience that AVs will bring for longer trips. Men in general, and particularly rent-payer men exhibited a more positive, albeit guarded inclination toward relocation, compared to women. These findings align with the existing notion in the literature that women may have higher levels of stress vulnerability when it comes to residential mobility (Baldridge et al., 2006; Magdol, 2002) and may be more reluctant to be endure longer travel times (Moore et al., 2020).

Age is another crucial factor influencing individuals' attitudes toward relocation in anticipation of the AVs emergence. By and large, younger individuals across all segments demonstrated a positive, yet vigilant inclination toward moving to farther locations, with respect to older individuals. The estimated coefficients for the age variable also reveal that older individuals either expressed to be thrilled with the notion or showed no interest at all, which can be attributed to their overall economic situation. Meanwhile, the overall positiveness of younger individuals, particularly rent-payers, toward the notion of relocating and benefiting from more affordable houses, may stem from their job flexibilities and the higher likelihood of changing jobs compared to their older counterparts, who often have more stable career lives. These findings align with the results of Zhang and Guhathakurta (2021) who found that individuals younger than 40 are more likely to move than their older counterparts. It is important to consider that younger rent-payers represent the potential future homeowners, and their positive attitudes toward the notion can significantly influence the future urban form and the inducement of urban sprawl.

Marital status also could be among the determinants that influence the individuals' willingness to reconsider their residential location considering the forthcoming convenience from AVs for longer trips. The estimated coefficients indicate that, overall, single individuals, regardless of their dwelling situation, have exhibited relatively higher levels of likelihood to relocate in comparison to married counterparts. This suggests the higher flexibility of singles in relocating compared to married individuals.

The impact of HH size is more significant for individuals who do not own a house. Individuals living in more crowded HHs, particularly those without homeownership, have more propensity to accept longer commutes in exchange for owning an affordable home on account of the emergence of AVs. Meanwhile this result aligns with previous findings of Moore et al., (2020), it can be attributed to the challenges associated with tenancy and the desire to secure an affordable house even in more distant locations when mobility options are available.

Education level is among the variables which has significant impact on the willingness to move as a result of AVs'availability. The estimated coefficients reveal that individuals with lower education levels are more interested in moving farther locations. This can be attributed to the fact that individuals with a bachelor degree or more often have more stable jobs and/or economic conditions that might lead to an unwillingness to change. The results in Table 2 further support this finding, particularly among rent-payers who exhibited the highest likelihood of relocation.

Individuals who already own a personal car in their HHs are more thrilled with the idea of relocation in light of the potential convenience that AVs are expected to offer for longer trips. This enthusiasm could be attributed to their higher levels of awareness regarding the convenience of commuting with private vehicles, particularly, in car-oriented mega-cities like Istanbul. Additionally, owning a personal car by the individual is among the important variables that can make significant impact on their decisions toward relocating. The estimated coefficients show that individuals who own both a house and a personal car simultaneously, do not have a positive attitude toward relocation and have expressed their reluctance, whereas individuals who already own a car, but do not possess a house, have exhibited their great enthusiasm toward the notion.

Considering individuals' self-perception as tech-savvy, overall, and particularly the house owners who may tend to have a higher economic status compared to rent-payers, have demonstrated higher levels of positiveness, albeit in a cautious manner.

The rent-payers who predominantly depend on PuT modes, have expressed higher levels of inclination toward relocation, compared to those who already enjoy PrT. The rationale behind this inclination could be attributed to the fact that the majority of individuals who depend on PuT modes for their daily commutes, are used to longer travel times, more than the individuals who travel by PrT. Therefore, they tend to have a more positive attitude toward the notion on account of the presence of AVs. Conversely, among house owners or non-rent-payers, who are dependent on PrT, attitudes vary from a cautiously positive (wait and see) to not interested at all.

As expected, individuals with longer current travel times, particularly rent-payers, have more positive attitudes toward the relocating notion compared to those with shorter travel times. In the same vein of PuT dependent individuals, this can be attributed to the fact that they are already used to endeavor longer travel times, and hence, they will be more interested in benefiting the opportunity of having a more affordable property. Obviously, these findings raise concerns about potential urban sprawl in the future.

Pre-familiarity with the concept of AVs also has a significant impact on the overall sample, as well as for the rent-payers stratum. As individuals' knowledge regarding the AVs' concept increases, they tend to either become enthusiasts or express disinterest in relocating due to the anticipated convenience of AVs. It appears that increased knowledge eliminates hesitancy and allows for more straightforward decision-making.

Lastly, similar to the impact of car renting experience for intra-city trips on individuals' attitudes toward adopting an AV, the variable also has a positive impact on individuals' attitudes toward the notion of relocation within the overall sample.

6 Policy implications and conclusions

Urban mobility and urban form, as two key aspects of urban life are believed to encounter with numerous challenges and disruptions with the emergence of AVs. Although there are existing studies in the literature exploring the potential changes of individuals' travel behavior due to the rise of AVs, many uncertainties still remain regarding various aspects of urban mobility and urban form. Moreover, the number of studies exploring these aspects may fall far behind compared with the extensive research conducted on technological advancements of AVs. This knowledge gap is more evident when it is about the developing countries, as the majority of the existing studies have been conducted in developed countries. Hence, many more studies are required to be conducted beforehand, in the fields of transportation and urban planning for early calibration and formulation of the required policies, maximize the potential benefits of AVs, and to guide the future of urban mobility and urban form toward envisioned directions that align with AVs and urban sustainability.

Therefore, taking into consideration the transportation mode choice and residential location of individuals as the important indicators of urban mobility and urban form, this study aimed to contribute the existing literature by investigating the likelihood levels of adopting AVs by individuals once they become available. Additionally, it aimed to evaluate individuals' intentions to relocate to a farther, but more affordable or larger dwelling, while they can benefit from the convenience of traveling with an AV. To achieve these goals, the study administered a stated preference survey in Istanbul metropolitan area, Türkiye, involving 334 respondents. The conducted survey revealed that 57% of the respondents expressed their enthusiasm towards adopting an AV once they become available, while nearly 48% indicated a high willingness to reconsider their residential locations to a farther, but more affordable, and more convenient locations. Meanwhile, only 17% and 27% of respondents expressed their reluctance towards these notions, respectively.

Multinomial logit models were deployed to estimate various models to evaluate the potential factors influencing individuals' propensity toward adopting an AV and their willingness toward reconsidering their residential locations. From the perspective of urban mobility, after estimating a comprehensive model for WTA based on the entire sample, two additional stratified models were also estimated, by considering the primary transport mode of the individuals as a stratum. On the other hand, from the perspective of the urban form, a comprehensive model for WTR based on the entire sample was estimated first and, subsequently, to delve more into the topic, by considering the subjects' current dwelling situations as a stratum, two additional MNL models were estimated.

The results of the WTA models revealed the significant impact of various variables on individuals' attitudes toward adopting AVs. Age and gender as two of the most important socio-demographic characteristics, along with possessing a driver's license, being tech savvy, or being a house owner are among the parameters that have significant roles in shaping individuals' inclinations in this regard. Additionally, individuals' prior familiarity with the AVs' concept and their familiarity with the existing driver assistance technologies contribute to individuals' attitudes toward AV adoption and can positively impact their approaches toward the notion. These findings highlight the importance of understanding these factors to develop effective policies and strategies for promoting the adoption of AVs and shaping a sustainable future of transportation.

By the same token, the estimated models of WTR revealed another set of important variables that have significant impacts on individuals' propensity to reconsider their residential locations in the light of convenient trip with AVs. Individuals' gender, age, marital status, HH size, and education level were among the most important factors affecting this propensity. Meanwhile, personal car ownership, their primary transport mode, and average travel time also had a significant impact on the notion. It is important to bear in mind that, as evidenced by de Groot et al., (2011), there is a strong association between intentions to move and the occurrence of actual relocation. People, who express an intention to move, tend to relocate significantly more often than those who do not have such intentions. Therefore, although the impacts of AVs on urban form and residential locations are expected to be in mid- to long-term, taking into consideration the long-horizon of most the urban and transportation plans (e.g., 10-, 20-, or 30-years plans) it is crucial to assess individuals' intentions to relocate beforehand, and continuously to be able to get the most possible benefits of AVs and achieve a sustainable and green urban mobility and form.

The outcomes of this study present several insights to better comprehend the influencing factors behind individuals' WTA and WTR. These insights could serve as a foundation for devising strategies and policies aimed at overcoming the potential barriers for different segments in adopting these vehicles. Consequently, urban and transport planners, along with policymakers, who are dedicated to integrate sustainable transportation methods such as AVs, can effectively direct their efforts towards engaging the demographic that exhibits lower inclinations to embrace these innovative modes of transport.

As the limitations of the study, although the results of the questionnaires are based on stated preference questions, they are undoubtedly worth being explored in more detail, continuously and periodically. This significance arises from the current absence of AVs in the present day, which hinders the assessment of their potential impacts on both urban mobility and urban form. However, by the time they become available, it might be too late to alter the implementation methods to resolve any resulting disruptions, challenges and problems.

The study utilized MNL models, involving the conversion of a 5-point Likert scale to a 3-point scale. Although this transformation aimed to streamline the model estimation process, fostering a more concentrated discussion on the estimation outcomes, and enhancing the

interpretability of the results, it has to be noted that while this simplification facilitates clarity, it is not exempt from inherent trade-offs. Hence, future studies may consider adopting more sophisticated modeling approaches to delve deeper into the intricacies of the findings.

Considering potential directions for future studies, employing larger sample sizes would contribute to further enhancing the robustness of the estimated results. Meanwhile, since the current study only focused on privately owned AVs, future research should also examine shared modes of AVs. This examination also could include evaluating individuals' sensitivity to different price levels of these emerging transportation options and estimating their willingness-to-pay levels. Regarding the WTR, future studies could consider individuals' current residential locations, including whether they reside in central or non-central areas. Additionally, examining their past relocation history could help evaluate the likelihood of reconsidering their residential location due to the emergence of AVs and the associated travel convenience.

There are still many uncertainties regarding the potential challenges and disruptions that the advent of AVs may bring along in the context of urban mobility and urban form. Hence, it is imperative to conduct more comprehensive studies and ensure a balanced spatial distribution instead of concentrating solely on developed countries.

Acknowledgment

The authors would like to acknowledge that during the research period, Eda Beyazıt was affiliated with the Department of Urban and Regional Planning at Istanbul Technical University, Istanbul, Türkiye. Currently, she is based at the Centre for Transport and Society, College of Arts, Technology and Environment, University of the West of England, Bristol, United Kingdom.

References

Alawadhi, M., Almazrouie, J., Kamil, M., Khalil, K. A. (2020) "A systematic literature review of the factors influencing the adoption of autonomous driving", International Journal of System Assurance Engineering and Management, 11(6), pp. 1065–1082. https://doi.org/10.1007/s13198-020-00961-4

Baldridge, D. C., Eddleston, K. A., Veiga, J. F. (2006) "Saying no to being uprooted: the impact of family and gender on willingness to relocate", Journal of Occupational and Organizational Psychology, 79(1), pp. 131–149. https://doi.org/10.1348/096317905X53174

Behnood, A., Haghani, M., Golafshani, E. M. (2022) "Determinants of purchase likelihood for partially and fully automated vehicles: Insights from mixed logit model with heterogeneity in means and variances", Transportation Research Part A: Policy and Practice, 159, pp. 119–139. https://doi.org/10.1016/j.tra.2022.03.017

Ben-Akiva, M., Lerman, R. S. (1985) "Discrete choice analysis: theory and application to travel demand", The MIT Press, ISBN 0-262-02217-6 [pdf] Available at: https://books.google.hu/books?id=oL-C6ZYPs9UoC&printsec=copyright&hl=hu#v=onepage&q&f=false [Accessed: 27 May 2024]

Bimtaş. (2014) "Ulaşım Ana Planı Ulaşım Modeli Kalibrasyonu", (Calibration of the Travel Demand Model in the Istanbul Metropolitan Transportation Master Plan), Istanbul Metropolitan Municipality. (in Turkish)

Canıtez, F. (2021) "Transition to autonomous vehicles: a socio-technical transition perspective", Alphanumeric Journal, 9(2), pp. 143–162. https://doi.org/10.17093/alphanumeric.847241

Carrese, S., Nigro, M., Patella, S. M., Toniolo, E. (2019) "A preliminary study of the potential impact of autonomous vehicles on residential location in Rome", Research in Transportation Economics, 75, pp. 55–61. https://doi.org/10.1016/j.retrec.2019.02.005

Cho, E., Jung, Y. (2018) "Consumers' understanding of autonomous driving", Information Technology and People, 31(5), pp. 1035–1046. https://doi.org/10.1108/ITP-10-2017-0338

Cugurullo, F., Acheampong, R. A., Gueriau, M., Dusparic, I. (2021) "The transition to autonomous cars, the redesign of cities and the future of urban sustainability", Urban Geography, 42(6), pp. 833–859. https://doi.org/10.1080/02723638.2020.1746096

de Groot, C., Mulder, C. H., Manting, D. (2011) "Intentions to move and actual moving behaviour in the netherlands", Housing Studies, 26(3), pp. 307–328. https://doi.org/10.1080/02673037.2011.542094

Dierks, Z. (2023) "Distribution of driver's license ownership in Turkey from 2010 to 2022, by gender", Statistica, [online] Available at: https://www.statista.com/statistics/1332104/turkey-driver-s-licence-ownership-distribution-by-gender/ [Accessed: 05 May 2023]

Duarte, F., Ratti, C. (2018) "The impact of autonomous vehicles on cities: a review", Journal of Urban Technology, 25(4), pp. 3–18. https://doi.org/10.1080/10630732.2018.1493883

Emory, K., Douma, F., Cao, J. (2022) "Autonomous vehicle policies with equity implications: Patterns and gaps", Transportation Research Interdisciplinary Perspectives, 13, 100521. https://doi.org/10.1016/j.trip.2021.100521

Ersan, Ö., Üzümcüoğlu, Y., Azık, D., Fındık, G., Kaçan, B., Solmazer, G., Özkan, T., Lajunen, T., Öz, B., Pashkevich, A., Pashkevich, M., Danelli-Mylona, V., Georgogianni, D., Krasniqi, E. B., Krasniqi, M., Makris, E., Shubenkova, K., Xheladini, G. (2020) "Cross-cultural differences in driver aggression, aberrant, and positive driver behaviors", Transportation Research Part F: Traffic Psychology and Behaviour, 71, pp. 88–97. https://doi.org/10.1016/j.trf.2020.03.020

Fagnant, D. J., Kockelman, K. M. (2014) "The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios", Transportation Research Part C: Emerging Technologies, 40, pp. 1–13. https://doi.org/10.1016/j.trc.2013.12.001

Fagnant, D. J., Kockelman, K. (2015) "Preparing a nation for autonomous vehicles: Opportunities, barriers and policy recommendations", Transportation Research Part A: Policy and Practice, 77, pp. 167–181. https://doi.org/10.1016/j.tra.2015.04.003

Hiramatsu, T. (2022) "Impact of autonomous vehicles on the choice of residential locality", Transportation Planning and Technology, 45(3), pp. 268–288. https://doi.org/10.1080/03081060.2022.2105339

Hossain, M. S., Fatmi, M. R. (2022) "Modelling the adoption of autonomous vehicle: how historical experience inform the future preference", Travel Behaviour and Society, 26, pp. 57–66. https://doi.org/10.1016/j.tbs.2021.09.003

Hui, Y., Wang, Y., Sun, Q., Tang, L. (2019) "The impact of car-sharing on the willingness to postpone a car purchase: a case study in Hangzhou, China", Journal of Advanced Transportation, 2019, 9348496. https://doi.org/10.1155/2019/9348496

Işık, S., Koçak Oksev, B. (2022) "İktidara karşı sürmek: Türkiye'de otomobil kültüründeki cinsiyetçilik ve kadın sürücüler", (Driving against the Power: Sexism in Automobile Culture and Female Drivers in Türkiye) Journal of Economy Culture and Society, 66, pp. 73–92. (in Turkish) https://doi.org/10.26650/jecs2021-1012364

Islam, M. R., Abdel-Aty, M., Lee, J., Wu, Y., Yue, L., Cai, Q. (2022) "Perception of people from educational institution regarding autonomous vehicles", Transportation Research Interdisciplinary Perspectives, 14. https://doi.org/10.1016/j.trip.2022.100620

Kim, S. H., Mokhtarian, P. L., Circella, G. (2020) "Will autonomous vehicles change residential location and vehicle ownership? Glimpses from Georgia", Transportation Research Part D: Transport and Environment, 82, 102291. https://doi.org/10.1016/j.trd.2020.102291

KPMG International (2020) "2020 autonomous vehicles readiness index assessing the preparedness of 30 countries and jurisdictions in the race for autonomous vehicles", [pdf] KPMG International, London, UK. Available at: https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf [Accessed: 12 March 2024]

Kuzio, J. (2019) "Planning for social equity and emerging technologies", Transportation Research Record, 2673(11), pp. 693–703. https://doi.org/10.1177/0361198119852065

Llorca, C., Moreno, A., Ammar, G., Moeckel, R. (2022) "Impact of autonomous vehicles on household relocation: An agent-based simulation", Cities, 126, 103692. https://doi.org/10.1016/j.cities.2022.103692

Magdol, L. (2002) "Is moving gendered? The effects of residential mobility on the psychological well-being of men and women", Sex Roles, 47, pp. 553–560. https://doi.org/10.1023/A:1022025905755

McFadden, D. (1973) "Conditional logit analysis of qualitative choice behaviour", In: Frontiers in Econometrics, P. Zarembka (ed), Academic Press New York, pp. 105–142. ISBN 978-0127761503

Meyer, J., Becker, H., Bösch, P. M., Axhausen, K. W. (2017) "Autonomous vehicles: the next jump in accessibilities?", Research in Transportation Economics, 62, pp. 80–91. https://doi.org/10.1016/j.retrec.2017.03.005

Milakis, D., Kroesen, M., van Wee, B. (2018) "Implications of automated vehicles for accessibility and location choices: evidence from an expert-based experiment", Journal of Transport Geography, 68, pp. 142–148. https://doi.org/10.1016/j.jtrangeo.2018.03.010

Moore, M. A., Lavieri, P. S., Dias, F. F., Bhat, C. R. (2020) "On investigating the potential effects of private autonomous vehicle use on home/work relocations and commute times", Transportation Research Part C: Emerging Technologies, 110, pp. 166–185. https://doi.org/10.1016/j.trc.2019.11.013

Nadafianshahamabadi, R., Tayarani, M., Rowangould, G. (2021) "A closer look at urban development under the emergence of autonomous vehicles: Traffic, land use and air quality impacts", Journal of Transport Geography, 94, 103113. https://doi.org/10.1016/j.jtrangeo.2021.103113

Naumov, S., Keith, D. R., Fine, C. H. (2020) "Unintended consequences of automated vehicles and pooling for urban transportation systems", Production and Operations Management, 29(5), pp. 1354–1371. https://doi.org/10.1111/poms.13166

Nazari, F., Noruzoliaee, M., Mohammadian, A. K. (2018) "Shared versus private mobility: modeling public interest in autonomous vehicles accounting for latent attitudes", Transportation Research Part C: Emerging Technologies, 97, pp. 456–477. https://doi.org/10.1016/j.trc.2018.11.005

NHTSA (2015) "Critical reasons for crashes investigated in the national motor vehicle crash causation survey", [pdf] NHTSA, Washington DC., USA, Available at: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115 [Accessed: 16 March 2023]

Nikitas, A., Vitel, A. E., Cotet, C. (2021) "Autonomous vehicles and employment: an urban futures revolution or catastrophe?", Cities, 114, 103203. https://doi.org/10.1016/j.cities.2021.103203

Nodjomian, A. T., Kockelman, K. (2019) "How does the built environment affect interest in the ownership and use of self-driving vehicles?", Journal of Transport Geography, 78, pp. 115–134. https://doi.org/10.1016/j.jtrangeo.2019.05.016

Nordhoff, S., Louw, T., Madigan, R., Lee, Y. M., Innamaa, S., Lehtonen, E., Malin, F., Bjorvatn, A., Beuster, A., Happee, R., Kessel, T., Merat, N. (2022) "Profiling the enthusiastic, neutral, and sceptical users of conditionally automated cars in 17 countries: a questionnaire study", Journal of Advanced Transportation, 2022, 8053228. https://doi.org/10.1155/2022/8053228

Othman, K. (2023) "Public attitude towards autonomous vehicles before and after crashes: A detailed analysis based on the demographic characteristics", Cogent Engineering, 10(1), 2156063. https://doi.org/10.1080/23311916.2022.2156063

Özkan, T., Lajunen, T., Parker, D., Sumer, N., Summala, H. (2011) "Aggressive driving among British, Dutch, Finnish and Turkish drivers", International Journal of Crashworthiness, 16(3), pp. 233–238. https://doi.org/10.1080/13588265.2010.536687

Penmetsa, P., Adanu, E. K., Wood, D., Wang, T., Jones, S. L. (2019) "Perceptions and expectations of autonomous vehicles – A snapshot of vulnerable road user opinion", Technological Forecasting and Social Change, 143, pp. 9–13. https://doi.org/10.1016/j.techfore.2019.02.010

Picard, N. (2021) "What drives transport and mobility trends? The chicken-and-egg problem", In: Vicerman, R. (ed), International Encyclopedia of Transportation, Elsevier, pp. 89–94, ISBN: 978-0-08-102672-4 https://doi.org/https://doi.org/10.1016/B978-0-08-102671-7.10015-6

Rezaei, A., Caulfield, B. (2020) "Examining public acceptance of autonomous mobility", Travel Behaviour and Society, 21, pp. 235–246. https://doi.org/10.1016/j.tbs.2020.07.002

SAE (2021) "SAE levels of driving automation™ refined for clarity and international audience", US, [online] Available at: https://www.sae.org/blog/sae-j3016-update [Accessed: 23 February 2023]

Saha, N., Motuba, D. (2023) "Estimating the impacts of AV and CAV and technologies transportation systems for medium, long, and buildout transportation planning horizons", Future Transportation, 3(2), pp. 457–478. https://doi.org/10.3390/futuretransp3020027

Sener, I. N., Zmud, J., Williams, T. (2019) "Measures of baseline intent to use automated vehicles: a case study of Texas cities", Transportation Research Part F: Traffic Psychology and Behaviour, 62, pp. 66–77. https://doi.org/10.1016/j.trf.2018.12.014

Sheller, M., Urry, J. (2000) "The city and the car", International Journal of Urban and Regional Research, 24(4), pp. 737–757. https://doi.org/10.1111/1468-2427.00276

Singleton, P. A., De Vos, J., Heinen, E., Pudāne, B. (2020) "Potential health and well-being implications of autonomous vehicles", In: Milakis, D., Thomopoulos, N. (eds.), Advances in Transport Policy and Planning, Academic Press, pp. 163–190, ISBN 978-0-12-820191-6 https://doi.org/10.1016/bs.atpp.2020.02.002

Sohrabi, S., Khreis, H., Lord, D. (2020). "Impacts of autonomous vehicles on public health: a conceptual model and policy recommendations", Sustainable Cities and Society, 63, 102457. https://doi.org/10.1016/j.scs.2020.102457

Soteropoulos, A., Berger, M., Ciari, F. (2019) "Impacts of automated vehicles on travel behaviour and land use: an international review of modelling studies", Transport Reviews, 39(1), pp. 29–49. https://doi.org/10.1080/01441647.2018.1523253

Tao, T., Cao, J. (2022) "Examining motivations for owning autonomous vehicles: Implications for land use and transportation", Journal of Transport Geography, 102, 103361. https://doi.org/10.1016/j.jtrangeo.2022.103361

TomTom (2022) "Annual TomTom traffic index: the World at the Pace of the Pandemic", [online] Available at: https://www.tomtom.com/newsroom/press-releases/general/234213780/annual-tomtom-traffic-index-the-world-at-the-pace-of-the-pandemic/ [Accessed: 14 March 2023]

TomTom (2023) "Ranking 2023", [online] Available at: https://www.tomtom.com/traffic-index/ranking/?population=MEGA&country=AT%2CBE%2CBG%2CCZ%2CDK%2CEE%2CFI%2CFR%2CDE%2CGR%2CHU%2CIS%2CIE%2CIT%2CLV%2CLT%2CLU%2CNL%2CNO%2CPL%2CPT%2CRO%2CSK%2CSI%2CES%2CSE%2CCH%2CTR%2CUK [Accessed: 14 March 2023]

Train, K. E. (2009) "Discrete choice methods with simulation", Cambridge University Press, ISBN 9780511805271

Wali, B., Santi, P., Ratti, C. (2021) "Modeling consumer affinity towards adopting partially and fully automated vehicles – the role of preference heterogeneity at different geographic levels", Transportation Research Part C: Emerging Technologies, 129, 103276. https://doi.org/10.1016/j.trc.2021.103276

Wang, S., Jiang, Z., Noland, R. B., Mondschein, A. S. (2020) "Attitudes towards privately-owned and shared autonomous vehicles", Transportation Research Part F: Traffic Psychology and Behaviour, 72, pp. 297–306. https://doi.org/10.1016/j.trf.2020.05.014

Wellik, T., Kockelman, K. (2020) "Anticipating land-use impacts of self-driving vehicles in the Austin, Texas, region", Journal of Transport and Land Use, 13(1), pp. 185–205. https://doi.org/10.5198/jtlu.2020.1717

Winter, K., Cats, O., Martens, K., van Arem, B. (2020) "Identifying user classes for shared and automated mobility services", European Transport Research Review, 12(1), 36. https://doi.org/10.1186/s12544-020-00420-y

Xiao, J., Goulias, K. G. (2022) "Perceived usefulness and intentions to adopt autonomous vehicles", Transportation Research Part A: Policy and Practice, 161, pp. 170–185. https://doi.org/10.1016/j.tra.2022.05.007

Yap, M. D., Correia, G., van Arem, B. (2016) "Preferences of travellers for using automated vehicles as last mile public transport of multimodal train trips", Transportation Research Part A: Policy and Practice, 94, pp. 1–16. https://doi.org/10.1016/j.tra.2016.09.003

Zhang, W., Guhathakurta, S. (2021) "Residential location choice in the era of shared autonomous vehicles", Journal of Planning Education and Research, 41(2), pp. 135–148. https://doi.org/10.1177/0739456X18776062

Zmud, J. P., Sener, I. N. (2017) "Towards an understanding of the travel behavior impact of autonomous vehicles", Transportation Research Procedia, 25, pp. 2500–2519. https://doi.org/10.1016/j.trpro.2017.05.281