Article:

Wadud, Z orcid.org/0000-0003-2692-8299 and Chintakayala, PK (2021) To own or not to own – That is the question: The value of owning a (fully automated) vehicle. Transportation Research Part C: Emerging Technologies, 123. 102978. p. 102978. ISSN 0968-090X

https://doi.org/10.1016/j.trc.2021.102978

To own or not to own – that is the question: The value of owning a (fully automated) vehicle

Zia Wadud

Institute for Transport Studies and School of Chemical and Process Engineering

University of Leeds, Leeds, LS2 9JT, UK

Z.Wadud@leeds.ac.uk

Phani Kumar Chintakayala

Consumer Data Research Centre and Leeds University Business School

University of Leeds, Leeds, LS2 9JT, UK

P.Chintakayala@leeds.ac.uk

Forthcoming at Transportation Research Part C: Emerging Technologies

(there could be minor differences from the published version)

Please cite the published version

To own or not to own – that is the question: The value of owning a (fully automated) vehicle

Zia Wadud, Phani Kumar Chintakayala

Abstract

One of the largest uncertainties in modelling the impacts of autonomous vehicles in future is whether they will be owned or used as automated ride (hailing) services. This paper addresses this issue by modelling the inherent attractiveness or convenience value of ownership of a vehicle, beyond the regular convenience parameters such as journey time, waiting or access time and reliability. Using mixed logit model on a choice experimentation data, we find that ownership is inherently valued more compared to the ride services by women. However, we also report significant heterogeneity in this valuation depending on gender and other car-ownership related characteristics, which can diminish this inherent attractiveness to the point that most men may find ownership unattractive. We also find substantial inconvenience value associated with shared/pooled automated ride services compared to exclusive-use ride services. Implications of the results are illustrated using an example of the share of automated vehicle ownership, and exclusive-use and pooled use ride services.

Keywords

autonomous; driverless; ownership; sharing economy; convenience; willingness to pay

To own or not to own – that is the question: The value of owning a (fully automated) vehicle

1. Introduction

There are now several studies investigating the potential impacts of vehicle automation on different transport outcome, for example, on travel behaviour and travel patterns (Wadud et al. 2016, Krueger et al. 2016, Fagnant and Kockelman 2014, Spieser et al. 2014, Yap et al. 2016, Harb et al. 2018), on infrastructure (Farah et al. 2017), on accessibility (Meyer et al. 2017), on location choices (Milakis et al. 2018, Zhang and Guhathakurta 2018), on energy and carbon (Wadud et al. 2016, Taiebat et al. 2018), on time use (Wadud and Huda 2019) and on other societal outcomes (Correia et al. 2016). Nearly all of the studies agree that how an autonomous vehicle will be owned or used through e-hailed ride services is one of the largest uncertainty in modelling their impacts. While e-hailing or ridesourcing services provided by the Transportation Network Companies (TNCs) have rapidly increased in popularity in the past decade, their impact on vehicle ownership is still under debate with contradictory findings (Ward et al. 2020, Schaller 2019, Wadud 2020). However, the potential for significant reduction of the costs of e-hailing services through vehicle automation (Wadud et al. 2016, Wadud 2017, Bosch et al. 2018) raise the possibility of a move away from the current prevalence of owning (or leasing) vehicles to using vehicles that are shared among users through on-demand automated e-hail or ride services. Newspaper articles (Rowlatt 2018) and non-academic reports (e.g. Arbib and Seba, 2017) indeed suggest a near total transition from personal vehicle ownership to using automated ride services, although academic studies are more cautious (e.g. Wadud and Mattioli 2021, Nunes and Hernandez 2020).

On a purely financial – out-of-pocket – costs basis, there is much working in favour of the automated ride services: taking the driver away reduces the per mile operating costs and as such per mile ride service prices, as found by Arbib and Seba (2017), Wadud (2017) and Bosch et al. (2018). Beyond these financial costs – in transport appraisal and mode choice modelling – the time costs are also included in *generalized* cost calculations through the value of travel time saved (VTTS), which is expected to be lower in an automated vehicle compared to a manually driven vehicle. There is also a greater likelihood that time will be more useful in the private setting of an owned automated vehicle, compared to a shared-use automated vehicle, which is exactly what Steck et al. (2018) show quantitatively. As such, the purely financial advantages of shared-use (for ride services) automated vehicles over owned automated vehicles are substantially reduced once the relative benefits of usefulness of time is included in the calculations (Wadud and Mattioli 2021). However, this time-use and financial cost-based literature does not consider the value that one places on the convenience or inherent attractiveness of owning a vehicle. Although a number of choice experiment based studies involving the use of automated, manual, privately owned or shared-use vehicles have this consideration implicitly (see later), they do not explicitly calculate the value of ownership of a vehicle relative to using the automated ride services. This research addresses this gap by quantifying the convenience value of owning a vehicle (or inconvenience value of e-hailing services). We define this convenience or inherent attractiveness as something beyond the traditional (in)convenience elements such as wait time, journey time or reliability, as used extensively in the context of public transport. Such an inherent attractiveness value can be useful in modelling the future share of privately owned and shared-use automated vehicles using large, national scale datasets.

The paper is organized as follows. Section 2 reviews the literature on convenience, measures and value of convenience and mode choice between shared and owned automated vehicles. This is followed by the descriptions of the survey conducted and model used to decipher the value of convenience. Section 5 presents the results while section 6 presents an example of how incorporating the value of convenience can change the share of ownership and ride services in the context of vehicle automation. Section 7 draws conclusions and potential improvements.

2. Literature review

2.1 The role of convenience in transport decisions

The Oxford English Dictionary defines convenience as the “ease or absence of trouble in use or action”. In marketing literature, this *trouble* or (in)convenience is seen as the “expenditure of time, physical and nervous energy, and money required” in order to obtain goods and services (Kelly 1958). Berry et al. (2002) also suggest that the benefits of convenience or burdens of inconvenience relate to saving or wasting of time and/or effort. While convenience can be an absolute property of a product, service or action, its operationalisation often brings out its relative nature. For example, Brown and McEnally (1993) define convenience as “a reduction in the amount of consumer time and/or energy required to acquire, use and dispose of a product or service relative to the time and energy required by other offerings in the product/service class”. In the transport domain, the inconvenience of using public transport is often described *relative* to the convenience of car use.

Considerations for convenience play a big role in consumer or traveller decision making. Socio-economic changes, technological progress, and increased competition for the use of time and resources are resulting in a growing demand for and attention on consumer convenience (Berry et al. 2002). The growth in fast food, ‘convenience’ food, online shopping or click and collect shopping practices are clear examples that consumers value convenience and are willing to pay extra for it.

Similarly, GPS and cruise control are excellent examples of a convenience product for car travel. Advance driving assistance systems – and ultimately automation technology – can also be described as convenience products.

In transport literature, convenience and its modelling have received the most attention in the public transit context. The 'ease or absence of trouble' definition of convenience is quite similar to the concept of generalized cost and time in transport, which can encompass different dimensions of access, egress, travel time, wait time, congestion and reliability of the public transport service (Anderson et al. 2013). While time and effort are clearly the two most important dimensions of convenience, it is the time dimension which has received more attention in the transport context. An International Transport Forum (ITF) roundtable on valuing public transport convenience defined it as a function of a number of time aspects, such as walk time, wait time, time for interchange or transfer (except for scheduled in-vehicle time), along with the ability to travel at the desired time (Wardman 2014). The roundtable also found that late arrival (lack of reliability) and having to transfer clearly caused inconvenience to passengers. The inconvenience caused by additional effort, or energy expenditure, can have a physical, cognitive of emotional dimension, but has received less academic attention (Farquhar and Rowley 2009). In public transport literature, the effort dimension of convenience is generally incorporated by adding higher weights (multiplying factors) to the out-of-vehicle time elements compared to the value of in-vehicle travel time. There is also some overlap between various operationalization of convenience and public transport service quality objectives (Crockett and Hounsell 2005). The term hassle costs is sometimes used to convey the inconvenience of using a transport mode or purchasing a product (e.g. Chen et al. 2020 in transport or Hviid and Schaffer (1999) in management).

Others suggest a narrower definition of convenience. For example, Ortuzar and Willumsen (2011) separated reliability from convenience in the context of mode choice decisions. In the context of bicycle travel, Noland and Kunreuther (1995) characterise convenience as independent of time, reliability and comfort, but still analogous with the door-to-door advantage of car travel.

Convenience plays a large role in transport decisions beyond just public transit services. Travellers consistently rank convenience as one of the most important factors in their choice of travel modes (Kenyon and Lyons 2003, Crockett and Hounsell 2005, Buys and Miller 2011), even though the term is not precisely defined in these studies. Several studies report convenience to be an important consideration in using bicycles or bikeshare schemes, too (Noland and Kunreuther 1995, Fishman et al. 2015, Shaheen et al. 2010). Melania et al. (2012) discusses the inconvenience of not having enough refuelling stations as an important barrier to adoption of alternative fuel vehicles, while Guo

(2013) shows that convenient parking at home encourages car usage. Of course, making car parking and driving inconvenient (and expensive) has long been at the heart of managing car travel in city centres.

2.2 Convenience and attractiveness of car ownership

With its ability to provide door-to-door mobility at all reasonable distances, the car symbolises the very essence of convenience for many (Anderson et al. 2013). Through qualitative research, Beirao and Cabral (2007) identify several advantages of cars in relation to public transport modes: freedom or independence, ability to go anywhere, convenience, rapidity, comfort, flexibility, safety, private space, listening to music and knowing what to expect. These advantages, along with the absence of ‘trouble’s such as walking to a transport stop, waiting for the transport, interchange (for public transport) or lack of reliability make cars the most attractive mode of transport (Beirao and Cabral 2007).

Beyond the utilitarian or instrumental reasons (such as convenience, comfort, safety etc.) for owning and using a car, travel behaviour researchers also suggest symbolic and affective motives as important factors to explain car ownership (Steg 2005, Anable 2005, Mokhtarian et al. 2001). These symbolic motives can be freedom or independence, symbol of status or power and can be manifested through the willingness to pay extra for premium cars. Recent research however shows that some of the symbolic motives (e.g. car as a symbol of status) are now less strong than argued before, especially among the younger generation (Delbosc and Currie 2013).

With the advent of e-hailing services provided by the Transport Network Companies (TNCs), many of the benefits of owning a car can now be afforded by these services. Specifically, door-to-door functionality, flexibility in terms of availability, hassle-free transactions, ease of hailing the service, increased reliability through tracking of vehicle arrival, safety features and less expensive fare than traditional taxis bring e-hailing services closer to the services offered by owned cars. E-hailing services also have other advantages over personal cars, e.g., no need for driving (which can be stressful, or risky under alcohol influence) or parking (which can be costly in terms of both time and money) and the ability to use time usefully while travelling (Clewlow and Mishra 2016). Because of these benefits, e-hailing services have rapidly become popular – especially in the urban areas (Alemi et al. 2018) – during the past decade. The prospects of further reduction of the costs of e-hailing services through full vehicle automation, whereby the human driver would no longer be needed, are expected to make these services even more attractive in the future (Wadud and Mattioli 2021).

Nonetheless, there are still some inconveniences of automated e-hailing services compared to owned cars due to the waiting time, time and cost reliability (dynamic pricing) or availability (during bad weather or such disruptions). On top of these differences, infrequent longer distance trip types (e.g. family holidays) can have a disproportionately larger role in the choice of vehicles to own (Choo and Mokhtarian 2004). Long distance trips are indeed an uncertainty for e-hailing business models, which fit well in the densely populated short-distance city environment, as seen from the limited availability in the rural environment. Vehicle owners can also value the overnight storage functions of owned cars, e.g. keeping the child's scooter or the golf bag in the boot.[1] Having the child-seat always fitted or the phone or music system automatically connected to the privately owned car (e.g. Bull 2004) is a convenience that can be attractive to vehicle owners. Ownership can also provide the peace of mind simply from having the car on the driveway, ready for an emergency. These added advantages may result in a willingness to pay extra for owning a vehicle.

2.3 Measures of the value of ownership

There is a lack of studies that explicitly reports a value of ownership of a car (be it AV or manually driven). The closest is possibly Wadud and Mattioli (2021), who calculated the annual costs of owning (manually-driven) vehicles in the National Travel Survey (NTS), and the costs of replacing those trips by e-hailing services like Uber. They report that it would have been cheaper to replace 217 of those vehicles by current manually driven e-hailing services. The annual mean difference between vehicle ownership costs and the costs of replacing the trips undertaken in those vehicles by e-hailing services was £2,516, potentially revealing the willingness to pay for the conveniences offered by owning a vehicle.

In the context of autonomous vehicles, Wadud and Mattioli (2021) also argue that an owned automated vehicle will offer substantially more useful use of in-vehicle time compared to an automated e-hailed vehicle. Steck et al. (2018) and Pudane and Correia (2020), find that the reductions in the value of travel time saved (VTTS) in a privately owned vehicle is significantly larger than that in an automated e-hailed vehicle. These differences in the usefulness of travel time could also be translated into a benefit of ownership, although it has not been attempted yet.

Fulton et al. (2020) also implicitly acknowledge the convenience value of ownership compared to e-hailing services, but follows a different approach. Extending Wadud's (2017) approach of including non-monetary time-costs in the costs of ownership and use of a vehicle, they include other non-monetary items such as the additional time spent for waiting, boarding and alighting and the costs of

[1] https://www.independent.co.uk/life-style/cars-weird-strange-things-kept-inside-driving-hoarding-possessions-survey-a8167426.html

reliability for e-hail services and the additional time for parking search, vehicle maintenance and driving stress for owned and driven cars. They report a difference of USD 0.28/mile of hedonic costs between owned automated vehicle and automated ride services, which translates to around USD 3,780 per year for average US driving distances. This does not directly represent the user's willingness to pay for ownership, though.

In this paper, we take the view that the most popular elements of convenience such as wait time, walk time and reliability are now almost standard elements of generalized costs and are often independent factors in travel mode choice in their own right. We are rather interested in the valuation of the *'rest of convenience'* of a privately owned car beyond those that arise from no wait or walk time or better reliability. In that sense, our definition of the convenience of car ownership is narrower than that used in the public transport area. We call this '*inherent attractiveness*' of car ownership.

We also take the view of Brown and McEnally (1993) that convenience of one mode is *relative* to another. Since we are primarily interested in comparing AV ownership with automated e-hailing services, which also provide door-to-door services like PAVs, our definition is thus narrower than Noland and Kunreuther (1995). We are thus interested in the value of ownership of a car after controlling for the traditional convenience factors.

2.4 Automated vehicle ownership vs. sharing

There are several stated preference studies on the willingness to pay for vehicle automation. They include Schoettle and Sivak (2014), Payre et al. (2014), Kyriakidis et al. (2015), Bansal and Kockelman (2016), Daziano et al. (2017), Shabanpour et al. (2018) or Liu et al. (2019). Gkartzonikas and Gkritza (2019) summarizes these studies. However, these studies generally address the willingness to pay for or the value of 'automation' rather than the value of 'ownership' since the comparison is often with respect to currently owned manually driven vehicles.

Another strand of research – more frequent in the literature – investigates user acceptance and preferences of owned and shared automated vehicles, sometimes along with other options (mostly manually driven owned vehicles). Some of these – e.g. Nordhoff et al. (2018), Madigan et al. (2018) – focus primarily on the acceptance of the automation technology using the Unified Theory of Acceptance and Use of Technology (UTAUT) or its sub-variants. While a willingness to pay for ownership or convenience of automated vehicles cannot be established through these studies, they tend to indicate a strong aversion to sharing a ride with unknown passengers in the automated vehicle. Using stated preference surveys Clayton et al. (2020) report that respondents in their UKwide survey were three times more likely to own an automated vehicle compared to an exclusive-use automated ride service, which in turn is preferred by more compared to a pooled (shared-ride) automated ride service. Similarly, Wang et al. (2020) report a higher willingness to own an automated vehicle, compared to using automated ride services in the US.

In terms of on-demand ride services, Lavieri and Bhat (2019) report a disposition to avoid sharing a journey with strangers in automated ride-hailing services. For non-automated ride services, Azgari et al. (2018) also report an inclination toward exclusive-use services over pooled or shared rides, although Khaloei et al. (2019) report opposite findings. Krueger et al. (2016) report no significant differences for pooled and exclusive-use ride services in automated vehicles. As such there are still no consensus in this area.

The number of studies investigating ownership and automated e-hailed ride services (exclusive use or pooled) together is few, e.g. Haboucha et al. (2017), Steck et al. (2018). These studies use choice experiment methods to reveal the preferences among these alternatives, but none of these directly estimate the convenience value of ownership or inconvenience value of sharing a ride with a stranger.

3. Survey design

The survey questionnaire was designed to capture individuals' travel behaviour in general covering usage of personal, para and public transit, attitudes towards autonomous vehicles, preferences across autonomous vehicle usage and demographic characteristics such as age, gender, income, and employment status.

The experiments were designed so that each choice set consists of 3 alternatives: a privately owned automated vehicle (PAV), on-demand exclusive-use automated ride services (OEAR, similar to UberX, but automated)and on-demand pooled/shared automated ride services (OPAR, similar to UberPool, but automated). We asked the respondents about a generic trip that they undertake frequently, rather than a specific trip type and present the alternative attributes in general terms too (e.g. the trip taking 'y' minutes longer on average). D-optimal choice sets were designed and dominant choices were removed. Each respondent was presented with three choice situations to optimise the number of responses from each survey participant and maximise the number of observations for the analysis. Around halfway through the survey – before any AV-related questions appeared, participants were advised to view a short video about AVs so that they could understand the capabilities of these vehicles. Brief descriptions of all the three variants (PAV, OEAR and OPAR) of the AVs are then provided before the respondents get to answer the choice experiment questions.

Appendix A presents how these options are described to the respondents, while Table 1 shows the attributes and levels used for experimental design.

Table 1. Design of choice experiment

	a. PAV	b. OEAR	c. OPAR
Cost p/mile (including vehicle purchase + other running costs)	“90/100/110”	“70/80/90”	“50/60/70”
Journey time	As it is now	As it is now	On average “5/10/15” mins longer
Wait time	Nil	For most of the trips, additional “4/8/12” mins	For most of the trips, additional “5/12/20” mins
Reliability (wait time delays)	No unseen costs or wait times	The wait time above could be “5/10/15” mins longer during peak hours, bad weather, etc.	The wait time above could be “5/10/15” mins longer during peak hours, bad weather, etc.

The items within “…” are altered between the alternatives and choice sets.

The survey was conducted by QA Research (York) Ltd., UK using their representative online panel of respondents. The survey was web based and the total sample size was 800, 400 each in London and Manchester. Respondents were all above the age of 18 years. Table 2 presents the sample summary statistics. As can be seen, it has slightly higher proportion of women compared to the share in population. 49.7% of the responses were in favour of PAVs, 33.1% for OEARs and 17.2 % for OPARs. In addition to questions about access to cars we have also asked attitudinal questions such as agreement with statements such as ‘congestion is not a problem in my city’ or ‘air quality is not a problem in my city’ on a 5-point Likert scale (strongly agree to strongly disagree).

We have deliberately excluded the option of owning a manually driven vehicle in our experiment, although it is common in other studies (e.g. Haboucha et al. 2017, Gao et al. 2017). This is to avoid the potential effects of psychological apprehension about automation technology from some respondents. For example, Haboucha et al. (2017) found that a quarter of their respondents would not have used automated shared vehicles even if the costs were zero, which had more to do with the acceptance of automation than sharing. As mentioned earlier, several other stated preference studies have revealed a varying level of user confidence in and acceptance of this technology, necessitating the separation of the preferences for automation from the preferences for automated vehicle ownership and automated e-hailing services.

Table 2. Sample summary statistics

Variable	Categories	Share (%)*
Number of cars owned or have access to	No car	20
	One car	55
	Two cars	22
	Three or more cars	3
Parking facilities at home	No free car parking	24
	Parking permit	68
	On drive/garage	8
Gender	Male	43
	Female	57
Income	Income £10,000 or less	12
	Income £10,001-£15,000	10
	Income £15,001-£20,000	10
	Income £20,001-£25,000	12
	Income £25,001-£30,000	12
	Income £30,001-£35,000	7
	Income £35,001-£40,000	6
	Income £40,001-£50,000	7
	Income £50,001-£75,000	7
	Income more than £75,000	5
	Income Don't Know/Don't want to state	12
Current use of shared ride (incl. public transport)	3 or more times a week	15
	1-2 times a week	13
	Between once a week and once a month	13
	Between once a month and once a year	15
	Never	45
Education	Degree level qualification (or equivalent) or higher	39
	Higher educational qualification below degree	13
	A-Levels or Highers	18
	ONC / National Level BTEC	5
	O Level or GCSE equivalent	21
	Other/No qualification	4
Age	(continuous)	Mean 43.4, Std. Dev. 15.4

* may not always add to 100% due to rounding

4. Modelling method

We have employed the standard Multinomial Logit (MNL) and Mixed Logit (ML) models in this study, both of which are consistent with the Random Utility Maximization (RUM) approach to making discrete choices among different alternatives. In this approach, the utility (U_{nj}) of each alternative j in the choice set J for decision maker n includes an observed (deterministic) component (V_{nj}), which is a function of the explanatory factors and a random unobserved component (ε_{nj}):

$$U_{nj} = V_{nj} + \varepsilon_{nj} = \beta_n' x_{nj} + \varepsilon_{nj} \quad (1)$$

where x_{nj} are the full set of observed explanatory variables and the β_n is the vector of corresponding coefficients related to person n. An individual n chooses an alternative i where $U_{ni} > U_{nj}$ for all $j \neq i$.

The list of explanatory factors (x_{nj}) in the utility function in Eq. 1 generally (and here, too) include attributes of the different alternatives such as travel time and travel costs, which vary across different alternatives, and characteristics of the decision-maker, which remain the same across the alternatives. Within β_n, a vector of alternate specific constants (ASCs) is used to represent the attributes of the alternatives that are not included explicitly in the model (similar to a constant in a simple regression model). Interaction of some of these explanatory factors or selective appearance of some of the explanatory factors in some utility functions is also possible; this is often a matter of empirical investigation.

In this study the attributes are journey cost, journey time, wait time (for ride-services) and reliability (for ride-services). Together these attributes are assumed to represent the characteristics of a travel alternative that are important for decision-making. Some of these attributes (wait time and reliability) are used to describe convenience in the public transport literature. However, as we defined earlier, we are interested in factors beyond these popular attributes, and we interpret the ASCs to represent the 'rest of the convenience' or 'inherent attractiveness' in this study.[2] Since in choice experiments the probability of choosing an alternative is expressed in relation to a base alternative, this inherent attractiveness is relative to that base alternative, here the automated exclusive use ride service (OEAR).

If the errors, ε_{nj}, in Eq. 1 are assumed to follow extreme value type I, it leads to the well-known multinomial logit specification. For a given set of values of β_n, the conditional probability for choice i is the standard logit:

$$L_{ni}(\beta_n) = \frac{e^{\beta_n' x_{ni}}}{\sum_j e^{\beta_n' x_{nj}}} \quad (2)$$

If the β_n are assumed to be the same (i.e. $\beta_n = \beta$ for all n) for all decision makers, Eq. 2 represents the probability of choosing alternative i in the well-known multinomial logit model (MNL). In the mixed logit (ML) model, the coefficients β_n are assumed to vary over the decision makers with a density of $f(\beta)$. The density function is characterized by parameters θ, which could represent the mean and

[2] It can be argued that the ASCs represent the 'inherent attractiveness' of the option, which contains both – the 'rest of convenience' and 'some symbolic function' and thus is broader in scope. Given the symbolic motives for car ownership is less strong now (Delbosc and Currie 2013), in this paper, we use 'inherent attractiveness' and 'rest of convenience' interchangeably.

covariance of all βs in the population. Various density functions are possible, e.g. normal, lognormal, uniform or triangular, although normal is the most common one used in practice. Given β_n is not known, the unconditional probability of choosing alternative i is the integral of the probability $L_{ni}(\beta_n)$ in Eq. 2 over all possible values of β_n (Train 2009):

$$P_{ni} = \int L_{ni}(\beta_n)\, f(\beta) d\beta \qquad (3a)$$

$$\text{Or, } P_{ni} = \int \left(\frac{e^{\beta' x_{ni}}}{\sum_j e^{\beta' x_{nj}}} \right) f(\beta) d\beta \qquad (3b)$$

The probability is approximated through simulation (Brownstone and Train 1999). Maximization is then conducted on the simulated log-likelihood function (Train 2000). In the present analysis we considered the key alternate specific attributes and the ASCs to follow normal distribution (i.e. parameters θ would refer to a normal distribution).

Equation 3a or 3b holds when a single choice response is elicited from each individual. However, both the MNL and ML can be extended to multiple choice situations faced by each respondent in a panel data context, which requires treatment for possible correlation between choices made by the same individuals. This is our case, as each respondent is given three choice situations in our experiment. In such cases, the conditional probability of observing a sequence of choices (t=$1....T$) from the T choice situations is the product of logit formulas:

$$L_{ni}(\beta_n) = \prod_{t=1}^{T} \frac{e^{\beta_n' x_{nit}}}{\sum_j e^{\beta_n' x_{njt}}} \qquad (4)$$

In mixed logit (ML) framework with multiple choice situations faced by each individual, the integral in Eq. 3a or 3b involves this product of logit formulas from Eq. 4. From our analysis, the model with the best fit is presented in Section 5.

5. Results

Table 3 presents the results of the MNL and ML models. Model 1, MNL, does not consider any random effects reflecting taste heterogeneity, while Model 2 does consider this effects. Model 2 shows a large improvement over Model 1 (LR test statistic = 902.3, p<0.001; significant reduction in AIC and BIC), indicating there is indeed variations in preferences.[3] We note that although the estimated parameters can vary between the two models, the broad conclusions (signs and significance) are the same. Other explanatory factors tested in the model were income (continuous)

[3] We have also estimated a nested logit (NL) model given the potential nested structure between owned and non-owned modes, however, MNL was superior to NL. Both ML and MNL are substantially better than a constant only model too (LL -2439.37 and Rho-sq 0.074).

or income groups, education groups, economic (working) status, disability conditions, perceptions whether air quality is a problem or not (correlated with whether congestion is a problem or not), enjoyment of driving, attitudes toward new technology, current use of Uberpool, personality types and city locations. However, each of these variables were statistically insignificant and also failed to improve the model fit significantly. For the ML model, normal distributions of parameters were included for the alternative specific constants (ASCs, our main interest). Attempts with journey time, wait time and reliability as random parameters have neither produced statistically significant standard deviations not statistically significantly better models (based on LR test) than the one presented in Table 3. Given the better model fit, the discussion below will be based on results from Model 2, the ML model with random taste heterogeneity in ASCs.

Table 3. Parameter estimates of Multinomial and Mixed Logit models

Explanatory factors¤	Model 1: Multinomial Logit	Model 2: Mixed Logit
Cost (p/mile)	-0.014***	-0.032***
Journey time (min)	-0.027*	-0.078***
Wait time (min)	-0.037***	-0.074***
Reliability (min of delay)	-0.041***	-0.056***
Male§ in ownership alternative	-0.376***	-1.057***
No car§ in ownership alternative	-0.496***	-1.340***
Car owners × No free parking§ in ownership alternative	-0.481***	-1.157***
Congestion not a problem§ in ownership alternative	0.599***	1.725**
Public transport§ in pooled ride alternative	0.355***	0.577**
60 year+§ in pooled ride alternative	0.754***	1.269***
ASC_{own}	0.337*	1.005***
ASC_{pool}	-0.931***	-1.835***
SD (ASC_{own})		3.691***
SD (ASC_{pool})		2.432***
Log likelihood	-2334.16	-1882.99
AIC	4692.3	3793.98
Rho-sq	0.108	0.28
N	2400	2400

*** Statistically significant at 99%, ** at 95%, * at 90%

¤ Base alternative is on-demand exclusive-use automated ride services (OEAR)

§ All the respondent-specific characteristics are dummy variables: Male = 1, if respondent is male; No car = 1 if respondent do not own or do not have exclusive use of a car; Car owners = 1 - No car; No free parking = 1 if those with car access do not have free parking at home; Congestion not a problem = 1 for those who agree or strongly agree with the statement (converted from 5-point Likert scale); Public transport = 1 for those who use public transport frequently, 60 year+ = 1 if respondent is above 60 years of age

The parameter estimates for costs, journey time, wait time and reliability (in terms of variations in wait time) are all statistically significant at 95% confidence level. All of these parameter estimates are negative, indicating that an increase in the value of any of these attributes will reduce the attractiveness of any mode in consideration. These results follow expectations, and are staple findings in the mode choice or travel behaviour literature.

Wait time is valued almost at the same rate as journey time (ratio of parameters for wait time to journey time – also known as a wait time multiplier – of 0.94, but statistically not any different), which is lower than the walk, wait and access time multipliers for public transport modes found typically in literature (e.g. 1.6 in Table 2 of Wardman et al. 2014). We hypothesize that the wait and access time for ride-hailing services will be less onerous (compared to typical public transport modes investigated in the review) since the user is generally picked up from his/her own comfortable surrounding (home or office), the pick-up time is generally more reliable (due to real time tracking), and the walk time is less anxious as the vehicles can be tracked in real time. Reliability is valued at a slightly lower rate than the journey time. The reliability multiplier (ratio of parameters for reliability to journey time) of 0.71 here is smaller than 1.02 as found in Wardman et al. (2014) review; this is possibly because the consequences of a slight delay in arrival in case of pooled services is not as grave in the context of ride services (as missing a train, for example). Alonso-Gonzales et al. (2020) also report less onerous wait time and reliability costs for manually driven pooled ride services compared to other public transit modes, providing support to these findings.

The value of travel time saved (VTTS) – defined as the rate of substitution between journey time and cost parameters – is an important parameter in transport decision making and appraisal. Given our cost choices were presented as p/mile, the calculation of VTTS requires the average trip length. Average trip length in a car in London and Manchester in 2016-2017 was 8 miles (calculated from National Travel Survey of England), which leads to an average VTTS of 19.5p/min (0.078/0.032×8) or £11.7 per hour. This falls between UK Department for Transports recommendations of £21.0 per hour for work time across all modes (year 2018), £10.9 for commuting and £5.0 for other uses. Although our focus was not at a specific individual trip level, the choice scenarios were presented in general terms (not a specific trip) and the in-vehicle travel time is varied only for the pooled ride services, this agreement provides confidence in the results.

Our key parameters of interest are the alternate specific constants (ASC), which reflect the attractiveness or convenience of the mode after controlling for the other costs, time and convenience factors. We have chosen automated exclusive-use ride services as the baseline, so that the alternate specific constants directly reveal the differences from this mode. The statistically significant positive estimate for ASC_{own} reveals that – in general – vehicle ownership is preferred to the exclusive-use ride services. This establishes that there is an additional willingness to pay for the convenience of owning a vehicle, even after controlling for (potentially cheaper) costs, (additional) journey times, (additional) wait times and (lower) reliability of the exclusive-use ride services. Exclusive-use ride services are also preferred to pooled ride service (ASC_{pool} negative), supporting similar findings as discussed earlier. Combining the two ASCs, ownership is also clearly favoured over pooled ride services. Although the absolute value of ASC_{pool} appears larger than ASC_{own}, the differences are statistically not significant indicating a similar level of affinity toward ownership and aversion to sharing a ride with a stranger, both calculated in comparison to exclusive use ride services.

The statistically significant parameter estimates for the random effects (standard deviations of alternate specific constants) also reveal significant heterogeneity in the preference toward ownership or exclusive-use ride services. Despite a positive mean value of 1.0 for ASC_{own}, a standard deviation of 3.69 means nearly 39% of the respondents may not have an additional inclination toward owning AVs over exclusive-use ride services, other things remaining the same. This heterogeneity in the preferences about AV ownership is not surprising: there are exploratory studies that find a willingness – at least in some segment of the population – to get rid of an owned vehicle if automated e-hailing services become available (Menon et al. 2018, Clayton et al. 2020). The use of random effects instead of the fixed parameters of an MNL model therefore is revealing in this context. Once again, the standard deviations of ownership and pooled services are statistically not different.

The respondent-specific socio-economic characteristics, entered as dummy variables, provide further insights into the attractiveness (or not) of car ownership (PAV). Men find AV ownership less attractive than women – to the point that they are statistically indifferent between owning an AV and using the ride services (mean=-0.05, p=0.90, also see Table 4). Although this appears counterintuitive at first, women's travel patterns can shed some light on this. In general, women often have a complex trip-chaining pattern, which is associated with household support activities such as chauffeuring children and shopping (Lavieri and Bhat 2020, Fan 2017), making AV ownership more attractive compared to using the automated ride services (OEAR or OPAR). Gender did not have any significant effect on the preference between exclusive-use and pooled ride services, so this variable was dropped for these alternatives for the sake of parsimony.

Those who currently do not own a vehicle are less likely to value the convenience of owning an automated vehicle, which is possibly expected. This group is also statistically indifferent between owning and using automated ride services (mean=-0.34, p=0.48, Table 4). Respondents who do own vehicles at present, but do not have free parking available at home, also have a lower preference toward ownership compared to those who have access to free on-street parking at home. It may appear counterintuitive since those who currently own vehicles despite not having free parking likely value their ownership more than those who have access to easy parking. Yet, it is also possible that these respondents are captive car owners at present. What our results show is that in the presence of automated ride services, they do not have any additional willingness toward owning an automated vehicle (mean=-0.15, p=0.75, Table 4).

Respondents who are older than 60 years have a larger inclination toward using the pooled ride services (OPAR) compared to the rest of the population, so much so that they are indifferent between exclusive use- and pooled-ride service (mean=-0.56, p=0.23). This age group may be anxious to use driverless vehicles (Bansal et al. 2016) and may find comfort in numbers in a pooled service. Age groups were not significant for other options. Current use of public transport modes is also positively correlated with using the automated pooled ride services, as can possibly be expected. Respondents who believe that congestion is not a problem tend to be more receptive toward owning.

The implicit value for the convenience or attractiveness of ownership – our key research interest – is the rate of substitution between the ASCs and the cost parameter, which is around £0.31/mile (1.005/0.032×100). Given the costs are presented on a per mile basis, this ratio need to be multiplied by annual mileage to get the willingness to pay for the convenience of owning an automated vehicle instead of using an exclusive-use ride service. Average per capita annual mileage in England in 2017 was 6,480 miles. This results in a mean annual willingness to pay £2,020 (0.31×6480) for the convenience of ownership over exclusive-use ride services. It is interesting to note that this value is not too far off the £2,516 that Wadud and Mattioli (2021) suggested for those with a high valuation of car ownership in London, as mentioned earlier. In Germany, Steck et al. (2018) regression results can be used to calculate a value of ownership of around €2,270 (GBP 2,040).

The mean estimate (£2,020) above also possibly reflect the higher end given this number reflects the willingness to pay of female car owners with free parking facilities at home. Considering our previous findings on socio-economic effects, Table 4 presents the mean value of attractiveness of owning an automated vehicle for different socio-economic groups in the presence of automated ride services. Women with no car or women who have cars, but do not have free parking at home do not have any additional willingness to pay for the convenience of owning a car. Men with similar characteristics prefer not to own an automated car and prefer using automated ride services, as revealed by the negative willingness to pay. Considering all the characteristics and the heterogeneity in the valuation of convenience, the mean valuation over the whole sample will likely be much smaller in magnitude than these group-wise values.

Table 4. Convenience value of ownership for different groups

	Mean ASC_{own}	Mean value of ownership (p/mile)	Mean value of ownership (£/year)#	% of sample
Women (base)	1.00***	31***	£2020	57.3
Women, car owner, but no free parking	-0.15	-4.71	£0	10.7
Women, no car	-0.34	-10.42	£0	10.9
Women, believe congestion is not a problem	2.73***	84.7***	£5490	2.0
Men	-0.05	-1.62	£0	42.7
Men, car owner, but no free parking	-1.21**	-37.5**	- £2430	9.5
Men, no car	-1.39***	-43.21***	- £2800	8.9
Men, believe congestion is not a problem	1.67*	51.91*	£3360	2.1

#assuming annual average miles of travel of 6,480, £0 for statistically insignificant parameters

*** Statistically significant at 99%, ** at 95%, * at 90%

Similarly there is an additional inconvenience cost of £3,690 for using a pooled/shared ride service compared to using an exclusive-use ride service. This inconvenience is much less for frequent public transport users, at £2,530. The only comparable number is Lavieri et al. (2020) finding of a WTP of USD 0.50-0.90 each trip, which when converted to US average of 1,230 trips a year become USD 615 to USD 1,110 (£590-£1,060). Aside from inherent differences in attitudes and preferences between the two countries, one possible reason for such high aversion to pooled rides in the UK is possibly the lack of awareness of pooled services in the UK (UberPool is offered only in London). Considering the differences in preferences, the mean inconvenience of pooled ride services over the whole sample is valued at £2,390.

6. Implications

While choice experiments such as conducted here are useful to reveal the underlying preferences and predict the share between automated vehicle ownership and automated ride-hailing services, often these surveys are done using a relatively small sample, which may not be fully representative. National level travel surveys are more representative of the population and also involve more detail information on travel patterns and (sometimes) costs. In this section we illustrate the usefulness of having a 'value' assigned to the convenience and inconvenience of automated vehicle ownership.

We recalculate the potential modal share (among automated vehicle ownership and ride-services) as presented in Wadud and Mattioli (2021) after incorporating the additional convenience for ownership and inconvenience for shared automated ride services.

Wadud and Mattioli (2021) used the travel pattern of 7,262 vehicles in UK's National Travel Survey (NTS) to determine the annual financial and time costs (total costs of ownership and use, TCOU) associated with each of these vehicles. Then, TCOUs are estimated assuming that the trips undertaken in each of those private manually-driven vehicles (PMDV) are replaced by a privately-owned automated vehicle (PAV) or an on-demand, exclusive-use, automate ride service (OEAR) or an on-demand pooled automated ride service (OPAR) in order to determine the least-cost alternative. Wadud and Mattioli (2021) then reported shares for four alternatives – PMDVs, s, PAVs, OEARs and OPARs. For the exercise here, we remove the manually driven alternative and recalculate the least expensive of the three automated alternatives – PAVs, OEARs and OPARs. The first column is Fig. 1 presents the recalculated share of the three alternatives being the least-cost option, without any considerations given to the convenience or inherent attractiveness of ownership. This shows a roughly 60-20-20 split for ownership (PAV), exclusive ride (OEAR) and pooled ride (OPAR) services. The second column on Fig. 1 assumes everyone having a fixed £500 convenience benefit for ownership and a fixed £500 inconvenience cost for pooled ride services.

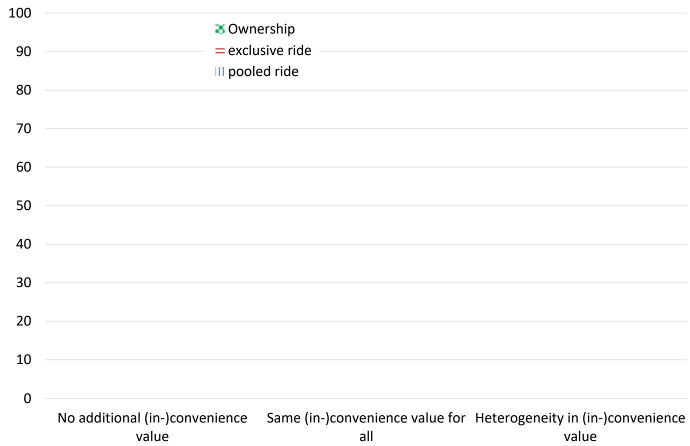

Fig. 1 Share of cases when ownership (PAV), excusive-use ride (OEAR) and pooled ride services (OPAR) are the least cost options, while replacing current travel by personal vehicles

Finally in the last column, we use a heterogeneous value of convenience or inconvenience calculated using the estimated parameters earlier, after considering each vehicle's mileage and gender of the main driver using the original dataset. Given parking types and perception of congestion are not present in the NTS dataset (but significant in our model), we use random draws from two separate uniform distributions and assign the values to each vehicle in the dataset so that the resulting shares are the same as the share in the estimation sample. Similarly, the baseline parameter for convenience is assigned randomly to the 7,262 vehicles from the estimated normal distributions of ASC_{own} and ASC_{pool}. This process is repeated 5,000 times and the last column of Fig. 1 presents the mean shares of these 5,000 draws.

Clearly, using the same value of convenience or inconvenience for all substantially increases the ownership (PAV) and reduces the share of shared/pooled automated ride services (OPAR). More importantly, considering the heterogeneity in the values of convenience (or inconvenience) – as we see in the third column – reduces the share of ownership by 11 percentage points, from 61% to 50%.[4] Similarly, the share of exclusive use automated ride services increases from 20% to 34%. These results clearly show the importance of considering the additional value of convenience (or inconvenience) as well as the heterogeneity in these values.[5]

7. Conclusions

This research set out to determine the convenience value of owning an automated vehicle. We find that there is a significant willingness to pay (£2020 a year) among women for the convenience of owning an automated vehicle over exclusive-use automated ride services, even after considering the differences in the costs, wait time and reliability of the two options. As such, previous approaches of calculating the financial costs, reliability and wait times of different services in order to predict the future modal share should be modified to reflect this additional convenience value. There is, however, substantial heterogeneity in this valuation as around 60% had a positive valuation in our sample. Women tend to value ownership significantly more compared to men, who – on average – are almost indifferent between owning and using automated ride services; only 37% of men value ownership more. It is very important to explicitly consider this heterogeneity since assuming the same value of convenience for all will lead to erroneous results while calculating the share of ownership and ride-services in an autonomous vehicle era.

As can be expected, those who do not currently own a vehicle or those vehicle-owners who do not have free parking do not value the benefits of ownership any more than that of automated ride services. This reveals that in dense cities where parking is often restricted and public transport provision is good, substantial modal switch to automated ride services is indeed possible as long as

[4] This reduction in the share or ownership is intriguing, but possible since there are more male vehicle owners in the NTS sub-sample, and only 37% of them have a positive value of ownership. The shares in Fig. 1 should not be directly used for future projections (since some variables were not available in NTS), the example serves to demonstrate the need to consider heterogeneity in the value of convenience.

[5] Note that if we had included the costs of additional time and reliability, these would change further. However, the original study already had the costs of wait time for ride services included and a direct value of wait time and reliability could not be implemented in this example.

the wait time and reliability penalties are not too large. Conversely, in rural and suburban areas where the availability of parking is not a constraint and ride-hailing wait times could be longer due to a less dense network, ownership of automated vehicles will continue to be preferred.

There is also a substantial inconvenience *cost* associated with using pooled or shared automated ride services, the mean of which is £2390 over the sample. This confirms the previous strand of findings on people's aversion to sharing rides with strangers and seriously questions the potential of pooled-automated ride services to reduce congestion or carbon emissions in an autonomous vehicle future. Our survey was conducted before the COVID19 pandemic, and this aversion to pooled ride services has certainly increased even more now (Bhaduri et al. 2020), although the longer term impact is still unclear. There is heterogeneity in the aversion to pooled automated ride services too, although more than three-fourths still have a negative valuation.

To our knowledge, this is the first attempt to put a 'value' on the convenience or inherent attractiveness of owning a vehicle, and there is scope for further improvements in understanding this important topic. We have interpreted alternate specific constants as inherent attractiveness or convenience, yet these may incorporate other quantifiable factors that may have been omitted in the experiment design. The sample here was from two of the largest cities in the UK; a more representative, countrywide sample will reveal how the results can vary by geographic locations. Including a wider range of attitudinal variables may improve the results further – with the caveat that such attitudinal variables are often not available in large scale transport surveys for the results of such models to be readily applicable in practice. The use of per-mile costs in the choice experiment may have inflated the valuation: using annual costs and computer adaptive experiments using respondents' own mileage and cost estimates and connected choice situations can also fine-tune the findings further. Also, the use of trip-based experimentation may not have fully captured some of the longer term convenience attributes that can be important during vehicle ownership decisions. As such, the convenience values derived directly from models of vehicle ownership decisions will provide useful comparisons in future.

Acknowledgement

The authors thank Georgina Wells for including the choice experiments and related questions in the larger survey on attitudes toward vehicle sharing. Thanks are also extended to Charisma Choudhury for stimulating discussion around choice modelling. We also thank the two anonymous reviewers for their excellent feedback in improving the paper.

Appendix A: Description of automated vehicle alternatives as presented to the respondents:

Imagine that the autonomous vehicles become available to you to take you around in three options.

a. PAV- Personal Automated Vehicle. You can own/lease the vehicle like your regular car now. You will have 24 hour access to your car. You can get some work done, or do other activities (rest, snooze, watch TV etc.) in the comfort of your own car. You can store your stuff in the car, and have all other conveniences of having a car at your own disposal. You are responsible for all the associated costs (purchase/lease costs + running & maintenance costs). You may be able to avoid parking costs or walks to/from parking as the vehicle can drop you off at destination and park itself in a free-parking zone (which could be your home, too). There are no restrictions on the trip distances.

b. ODAV- On-Demand Automated Vehicle. You can subscribe to a minicab-type taxi hire service (minicab, Uber, Addison Lee etc.) on-demand service provided by autonomous vehicles, where you call a vehicle via an app or over internet for each of your trips. It will be for your exclusive use during the trip. There will be some wait in being picked up. You can use your time usefully, too. You are not responsible for the upkeep of the vehicle and you pay a monthly/annual/per trip-based charge (which will likely be lower than your own car costs). There may be restrictions on long-distance trips and/or additional costs may apply. [Note for readers: we have converted this to OEAR services in the paper in order to be consistent with our other papers]

c. RSAV- Ride Shared Autonomous Vehicle. You can subscribe to an Uber-pool type service provided by autonomous vehicles, where you pay a monthly/annual/per trip-based fee and call a vehicle via an app or over the internet. The vehicle will not be for your exclusive use and you will have to share the rides with other, unknown passengers for at least part of the trip. There will be some wait in being picked up. There will likely be some walk to and from the nearest pick-up and drop-off points. There will likely be slight detour for pick-up/drop-off of other passengers along the way. You will likely be able to carry on with some activities on-board, but in the presence of other passengers. The costs will likely be lower than option 2 above. There may be restrictions on long distance trips and/or additional costs may apply. [Note for readers: we have converted this to OPAR services in the paper in order to be consistent with our other papers]

In light of these descriptions, can you please choose one option for the next three questions? [Note for readers: respondents are then given the choice alternatives, described in Table 1 in the main text].

References

Alemi F, Circella G, Handy S and Mokhtarian P 2018. What influences travelers to us Uber? Exploring the factors affecting the adoption of on demand ride services in California, Travel Behaviour and Society, 13, 88-104

Alonso-Gonzales M.J., van Oort, N., Cats, O., Hoogendoorn-Lanser, S., and Hoogendoorn, S. 2020. Value of time and reliability for urban pooled on-demand services, Transportation Research Part C: Emerging Technologies, 115, 102621

Anable, J. 2005. 'Complacent car addicts' or 'aspiring environmentalists'? Identifying travel behavior segments using attitude theory, Transport Policy, 12 (1), 65-78

Anderson, R., Condry, B., Findlay, N., Brage-Ardao, R. and Li, H., 2013. Measuring and valuing convenience and service quality, A review of global practices and challenges from mass transit operators and railways industries, International Transport Forum Discussion papers No. 2013-16

Arbib, J. and Seba, T. 2017. Rethinking transportation 2020-2030, RethinkX sector disruption report, available at: https://www.rethinkx.com/executive-summary/, accessed June 2018

Azgari H., Jin, X., and Corkery, T., 2018. A stated preference survey approach to understanding mobility choices in light of shared mobility services and automated vehicle technologies in the US, Transportation Research Record

Bansal, P. and Kockelman, K.M., 2016. Forecasting American's long-term adoption of connected and autonomous vehicle technologies, 95th Annual Meeting of the Transportation Research Board, Washington, January

Bansal, P., Kockelman, K.M., and Singh, A. 2016. Assessing Public Opinions of and Interest in New Vehicle Technologies: An Austin Perspective, Transportation Research Part C, 67, 1–14

Beirao, G. and Cabral, J.A.S., 2007. Understanding attitudes toward public transport and private car: A qualitative study, Transport Policy, 14, 478-489

Berry, L.L., Seiders, K., and Grewal, D., 2002. Understanding service convenience, Journal of Marketing, 66 (July), 1-17

Bhaduri, E., Manoj, B.S., Wadud, Z., Goswami, A., and Choudhury, C., 2020. Modelling the effects of COVID19 on mode choice behaviour in India, Transportation Research Interdisciplinary Perspective, https://www.sciencedirect.com/science/article/pii/S2590198220301846

Bosch, P.M., Becker, F., Becker, H., Axhausen K.W., 2018. Cost-based analysis of autonomous mobility services, Transport Policy, 64, 76-91

Brown, L.G. and McEnally, M.R., 1993. Convenience: definition, structure and application, Journal of Marketing Management, 2 (2), 47-56

Bull, M., 2004. Automobility and the Power of Sound, Theory, Culture & Society, 21, 243–59

Buys, L. and Miller, Y. 2011. Conceptualising convenience: Transportation practices and perceptions of inner-urban high density residents in Brisbane, Australia, Transport Policy, 18, 289-297

Chen, Y., Zha, Y., Wang, D., Li, H. and Gongbing, B 2020. Optimal pricing strategy of a bike-sharing firm in the presence of customers with convenience perceptions, Journal of Cleaner Production, 253, 119905

Choo S and Mokhtarian P 2004. What type of vehicles do people drive? The role of attitude and lifestyle in influencing vehicle type choice, Transportation Research Part A: Policy and Practice, 38, 201-222

Choo, S., Mokhtarian, P.L., 2004. What type of vehicle do people drive? The role of attitude and lifestyle in influencing vehicle type choice, Transportation Research Part A, 38, 201-222

Clayton, W., Paddeu, D., Parkhurst, G., Marauri, M.G.S., 2018. Autonomous vehicles: Willingness to pay and willingness to share, 50th Annual UTSG Conference, London, January

Clewlow, R.R., Mishra, G.S., 2017. Disruptive transportation: the adoption, utilization and impacts of ride-hailing in the United States, University of California, Davis

Cohn, J., Ezike, R., Martin, J., Donkor, K., Ridgway, M., & Balding, M. (2019). Examining the equity impacts of autonomous vehicles: a travel demand model approach. *Transportation Research Record*, 2673(5), 23-35.

Correia, G.H.A., Milakis, D., van Arem, B., Hoogendoorn, R. 2016. Vehicle automation and transport system performance, in Bliemer, M.C.J., Mulley, C., Moutou, C.J., (Eds) Handbook of Transport and Urban Planning in the Developed World, Edward Elgar, Cheltenham

Crockett, J. and Hounsell, N. 2005. Role of travel factor convenience in rail travel and a framework for its assessment, Transport Reviews, 25, 535-555

Daziano, R.A., Sarrias, M., Leard, B., 2017. Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles, Transportation Research Part C, Vol. 78, pp. 150-164

Delbosc A and Currie G 2015. Cause of youth licensing decline: A synthesis of evidence, Transport Reviews, 33, 271-290

Fagnant, D., 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, 1-13

Fan, Y., 2017. Household structure and gender differences in travel time: spouse/partner presence, parenthood, and breadwinner status. Transportation 44 (2), 271–291

Farah, H., Erkens, S., Alkim, T., van Arem, B., 2017. Infrastructure for automated and connected driving, in Meyer, G., Beiker, S., (eds.) Road Vehicle Automation 4, Springer, 187-197

Farquhar, J.D. and Rowley J. 2009. Convenience: A service perspective, Marketing Theory, 9 (4), 425-438

Fishman, E., Washington, S., Haworth N., and Watson, A. 2015. Factors influencing bike share membership: An analysis of Melbourne and Brisbane, Transportation Research Part A, 71, 17-30

Fulton, L., Compostela, J. and Kotawhala, A. 2020. Estimating the Costs of New Mobility Travel Options: Monetary and Non-Monetary Factors, University of California Davis Research Report, available at: https://ncst.ucdavis.edu/research-product/estimating-costs-new-mobility-travel-options-monetary-and-non-monetary-factors, accessed: Nov

Gao, J., Ranjbari, A., and MacKenzie D., 2019. Would being driven by other affect the value of travel time? Ridehailing as an analogy for automated vehicles, Transportation, 46, 2103-2116

Gkartzonikas, C and Gkritza K 2019. What have we learned? A review of stated preference and choice studies on autonomous vehicles, Transportation Research Part C: Emerging Technologies, 98, 323-337

Guo, Z. 2013. Home parking convenience, household car usage, and implications to residential parking policies, Transport Policy, 29, 97-109

Haboucha, C.J., Ishaq, R., Shiftan, Y., 2017. User preferences regarding autonomous vehicles, Transportation Research Part C, 78, 37-49

Harb, M., Yu, X., Circella, G., Mokhtarian, P., and Walker, J.L., 2018. Projecting travellers into a world of self-driving vehicles: estimating travel behaviour implications via a naturistic experiment, Transportation, 45, 1671-1685

Hviid, M., Shaffer, G. 1999. Hassle costs: the Achilles' Heel of price-matching guarantees, Journal of Economics and Management Strategy, 8(4), 489-521

Kelley, E.J. 1958. The importance of convenience in consumer purchasing, Journal of Marketing, 23 (1), 32-38

Kenyon, S., Lyons, G. 2003. The value of integrated multimodal traveller information and its potential contribution to modal change. Transportation Research Part F, 6, 1–21.

Khaloei M, Ranjbari A and MacKenzie D 2019. Where will your magic carpet take you? Year 2 Final report, University of Washington

Krueger, R., Rashidi, T.H., Rose, J.M., 2016. Preferences for shared autonomous vehicles, Transportation Research Part C: Emerging Technologies, 69, pp. 343-355

Kyriakidis, M. & Happee, Riender & de Winter, Joost. 2015. Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. Transportation Research Part F: Traffic Psychology and Behaviour, 32, 127-140

Lavieri, P.S., Bhat, C.R. 2019. Modeling individuals' willingness to share trips with strangers in an autonomous vehicles future, Transportation Research Part A, 124, 242-261

Lavieri, P.S., Garikapati, V.M., Bhat, C.R., Pendyala, R.M., Astroza, S., Dias, F.F., 2017. Modeling individual preferences for ownership and sharing of autonomous vehicle technologies, Transportation Research Record, No. 2665, pp. 1-10

Madigan R, Louw T, Wilbrink M, Schieben, A and Merat N 2018. What influences the decision to use automated public transport? Using UTAUT to understand public acceptance of automated road transport systems, Transportation Research Part F: Traffic Psychology and Behaviour, 50, 55-64

Melania, M., Bremson, J. and Solo, K. 2012 [online]. Consumer convenience and the availability of retail stations as a market barrier for alternative fuel vehicles, available at: https://afdc.energy.gov/files/u/publication/56898.pdf, accessed: June

Menon, N., Barbour, N, Zhang, Y., Pinjari, A.R., Mannering, F., 2018. Shared autonomous vehicles and their potential impacts on household vehicle ownership: An exploratory empirical study, International Journal of Sustainable Transportation, https://doi.org/10.1080/15568318.2018.1443178

Meyer, J., Becker, H., Bosch, P.M., Axhausen K.W., 2017. Autonomous vehicles: The next jump in accessibilities, Research in Transport Economics, 62, 80-91

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, 142-148

Mokhtarian, P.L., Salomon, I., Redmond, L.S., 2001. Understanding the demand for travel: it's not purely 'derived'. Innovation: The European Journal of Social Sciences 14 (1), 355–380.

Noland, R.B., and Kunreuther, H., 1995. Short-run and long-run policies for increasing bicycle transportation for daily commuter trips, Transport Policy, 2 (1), 67-79

Nordhoff, S., de Winter, J., Kyriakidis, M., van Arem, B., Happee, R., 2018. Acceptance of driverless vehicles: Results from a large cross-national questionnaire study, Journal of Advanced Transportation, https://doi.org/10.1155/2018/5382192

Nunes A and Hernandez KD 2020. Autonomous taxis and public health: High cost or high opportunity cost? Transportation Research Part A: Policy and Practice, 138, 28-36

Ortuzar, J. De D. and Willumsen, L.G. 2011. Modal split and direct demand models, in: Modelling Transport, 4th edn, pp. 207-225 (Chichester: Wiley).

Pudane B and Correia G 2020. On the impact of vehicle automation on the value of travel time while performing work and leisure activities in a car: Theoretical insights and results from a stated preference survey, Transportation Research Part A: Policy and Practice, 38, 201-222

Rowlatt, J. 2018 [online]. Why you have (probably) already bought your last car, available at: https://www.bbc.co.uk/news/business-45786690; accessed: Mar 2019.

SAE International 2018 [online]. Taxonomy and definitions for terms related to shared mobility and enabling technologies, Surface transportation recommended practice, available at: https://www.sae.org/standards/content/j3163_201809/, accessed: Mar 2020

Schaller B 2019 [online]. In a reversal, car-rich households are growing, available: https://www.citylab.com/perspective/2019/01/uber-lyft-make-traffic-worse-more-people-own-cars-transit/579481/; accessed: Nov 2019

Schoettle, B. and Sivak, M., 2014. A survey of public opinion about connected vehicles in the U.S., the U.K., and Australia. 687-692. 10.1109/ International Conference on Connected Vehicles and Expo (ICCVE).

Shabanpour, R., Golshani, Shamshiripour, A. and Mohammadian, A. 2018. Eliciting preferences for adoption of fully automated vehicles using best-worst analysis. Transportation Research Part C Emerging Technologies. 93. 10.1016/j.trc.2018.06.014.

Shaheen, S. and Cohen, A. 2019. Shared ride services in North America: definitions, impacts, and the future of pooling, Transport Reviews, 39, 427-442

Shaheen, S.A., Guzman, S., Zhang, H., 2010. Bikesharing in europe, the americas, and asia: past, present, and future, Transportation Research Record 2143 (1), 159-167.

Spieser, K., K. Treleaven, R. Zhang, E. Frazzoli, D. Morton and M. Pavone, (2014). Toward a systematic approach to the design and evaluation of automated mobility-on-demand systems: A case study in Singapore, in Road Vehicle Automation, Springer Lecture Notes in Mobility (G. Meyer and S. Beiker, eds.), 229-245

Steck, F., Kolarova, V., Bahamonde-Birke, F., Trommer, S., Lenz, B., 2018. How autonomous driving may affect the value of travel time savings for commuting, Transportation Research Record, pp. 1-10

Steg, L., 2005. Car use: lust and must. Instrumental, symbolic and affective motives for car use, Transportation Research Part A, 39, 147-162

Taiebat, M., Brown, A.L., Safford, H.R., Qu, S. and Xu, M. 2018. A review on energy, environmental and sustainability implications of connected and automated vehicles, Environmental Science and Technology, 11449-11465

Train, K. 1998. Recreation demand models with taste differences over people. Land Economics 74: 230-239

Train K., 1999. Halton Sequences for Mixed Logit. Working paper. Department of Economics, University of California, Berkeley.

Wadud, Z., 2017. Full automated vehicles: A cost of ownership analysis to inform early adoption, Transportation Research Part A, 101, 163-176

Wadud, Z., 2020. The effects of e-ridehailing on motorcycle ownership in an emerging-country megacity, Transportation Research Part A: Policy and Practice, 137, 301-312

Wadud, Z and Mattioli, G. 2021. Fully automated vehicles: A cost-based analysis of the share of ownership and mobility services, and its socio-economic determinants, Transportation Research Part A: Policy and Practice (revision under review)

Wadud, Z., Huda, F.Y., 2019. Fully automated vehicles: The use of travel time and its association with intention to use, Proceedings of the Institution of Civil Engineers: Transport

Wadud, Z., MacKenzie, D.W., Leiby, P.N., 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles, Transportation Research Part A: Policy and Practice, Vol. 86, pp. 1-18

Wang S, Jiang Z, Noland RB and Mondshein AS 2020. Attitudes towards privately-owned and shared autonomous vehicles, Transportation Research part F: Traffic Psychology and Behaviour, 72, 297-306

Ward JC, Michalek JJ, Avezedo IL, Samaras C and Ferreira 2019. Effects of on-demand ridesourcing on vehicle ownership, fuel consumption, vehicle miles travelled, and emissions per capita in US states, Transportation Research Part C, 108, 289-301

Wardman, M. 2014. Valuing convenience in public transport, Roundtable summary and conclusions, International Transport Forum Discussion Paper No. 2014-02

Yap, M.D., Correia, G., van Arem, B., 2016. Preferences for travellers for using automated vehicles as last mile public transit of multimodal train trips, Transportation Research Part A: Policy and Practice, Vol. 94, pp. 1-16

Zhang, W. and Guhathakurta S 2018. Residential location choice in the era of shared autonomous vehicles, Journal of Planning Education and Research, https://doi.org/10.1177/0739456X18776062