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Dynamics of car consumption and attitudes towards car characteristics: Insights from a large-scale panel model in the United Kingdom

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A R T I C L E I N F O

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A B S T R A C T

The current study aims to understand the dynamics between the importance people place on different car characteristics when purchasing a car (labelled as *car-related attitudes* in this study) and their car consumption (car use and the number of cars owned) over time. Using data from the UK Household Longitudinal Study (UKHLS), we conceptualize bidirectional effects between car-related attitudes, the number of cars owned, and car use among those who access at least a car in their households and test how and which element comes first in impacting the other elements over time. Employing a two-wave cross-lagged panel model with a two-year lag on a large-scale sample (n = 17,198), and considering covariates, the results reveal existence of bidirectional but asymmetric effects between these three elements. Interestingly, the number of cars has the greatest effect on the two other elements. Car consumption influences car-related attitudes larger than the reverse effect. In particular, over time, a higher number of cars and higher levels of car use more strongly affect declines in the weight individuals place on environmental considerations when purchasing a car (e.g., engine size, CO_2 emissions, or electric propulsion). This effect is larger than that of environmental considerations on shedding cars or reducing car use.

1. Introduction

1.1. Problem statement and motivation

Over the past 50 years, car ownership in Great Britain and England has steadily risen. In 1971, 52% of households had access to at least one car, growing to 78% by 2022 (Bhagat et al., 2024). During this time, the share of households with a single car has remained relatively stable at around 45%, while those with two or more cars have surged from 8% to 34% (Bhagat et al., 2024). Meanwhile, according to the National Travel Survey, although the average number of car trips per person per year, both as drivers and passengers, remains high, it has gradually declined over time. In England, these figures dropped from 438 and 241 trips in 2002 to 337 and 165 trips in 2022, respectively. These differing trends in car ownership and use, which can be observed in many car-oriented countries worldwide (e.g., Moody et al., 2021), might be attributed to intrinsic values and attitudes towards car characteristics or push transport policies that discourage car use. Therefore, it is essential to understand whether car-related attitudes have been actually shaping car consumption elements, including the number of cars owned and car use, or car consumption, reversely, is affecting attitudes towards

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car attributes over time as well as understanding the mutual effects between the number of cars and car use.

Many studies based on theoretical frameworks via the lens of psychological action models such as the theory of planned behavior (TPB) or newer extensions of economic perspectives, particularly hybrid choice models that incorporate latent psychological variables (e.g., Ben-Akiva et al., 2002), have suggested that policies (e.g., "nudging") need to be developed in order to work on individuals' attitudes (or perceptions/motives) with the hope that behavioral change in terms of car consumption happens. However, most studies overlooked the possibility of existing the reverse effect or bidirectionality. In this line, there has been a few argumental studies challenging such conventional assumptions to some extent (see Kroesen et al., 2017; Moody and Zhao, 2020). However, the study by Moody and Zhao (2020) was limited to cross-sectional data, and the study by Kroesen et al. (2017) even though was a panel model, it did not conceptualize the cross-lagged effect of number of cars in the model, and it was limited to the relation between attitude and car use. We add to the current literature by investigating longitudinal bidirectional effects between car-related attitudes and car consumption including the number of cars owned and car use. In this study, "car-related attitudes" refer to individuals' evaluations of the importance of different car characteristics when purchasing a car/van. These evaluations include multiple dimensions, including image/hedonic-related attributes, utilitarian aspects, and environmental considerations. We employ a two-wave panel model from a large-scale sample of individuals in the UK (over 17,000) to give a better picture of bidirectional (causal) effects between car-related attitude, the number of cars and car use.

1.2. Theoretical foundation

The state of the art of knowledge regarding car consumption shows that the topic has been evaluated from both economic and social science (e.g., psychology) perspectives or a multidisciplinary one. In the economic theory, through the lens of random utility-based behavioral models (Ben-Akiva and Lerman, 1985), instrumental or utilitarian aspects (e.g., travel time, cost) alongside decision-maker characteristics have been assumed influencing car consumption (Ortúzar and Willumsen, 2024). Other aspects such as symbolic and affective values/motives alongside attitudinal elements have been theorized via psychological theories and been assumed that influence car consumption (e.g., Steg et al., 2001; Anable, 2005; Gärling and Loukopoulos, 2008). Some other efforts have also tried to combine economic and psychological theories to simultaneously investigate the role of utilitarians and attitudinal aspects but still through cross-sectional study design (Vij and Walker, 2016; Haustein and Hunecke, 2007). Anyway, different psychological elements are often collectively labelled or assumed as attitudes in many studies, and for the sake of parsimony in summarizing past studies, we also refer them to attitude in this section. Therefore, the review of other aspects (e.g., sociodemographic, trip attributes, built-environment) is beyond the scope of this study.

In general, commonly held views from cross-sectional empirical studies consistently show that attitudes towards car explain car consumption (see Soza-Parra and Cats, 2024). Most past research is rooted in general psychological frameworks, with the TPB (Ajzen, 1991) being the most frequently applied. Most studies almost hypothesize that attitude can unidirectionally be the predictor of behavior and their findings also to large extent support their hypothesis. These studies have examined different kinds of attitudes towards cars (symbolic, affective, instrumental, environmental aspects) including aspects such as image, brand, comfort, reliability, availability or flexibility, safety, timesaving, cost aspects, and environmental considerations (Anable, 2005). From a policy perspective, nearly all studies based on this unidirectional premise, using cross-sectional designs and assuming a link from motives or attitudes to behavior/intention, conclude that changing people's attitudes and motives can reduce car consumption, given the significant effects observed in their findings. To sum up, as illustrated in Fig. 1, common assumption, based on such studies, suggests that the most expected links between car use/ownership attitude, car ownership, and car use are those from attitude to car consumption (ownership and use). However, a few studies acknowledge the existence of reverse effects (e.g., Tardiff, 1977; Kroesen et al., 2017; Mehdizadeh and Kroesen, 2025).

In modern travel behavior research, there have been few studies suggesting or testing bidirectional effects between car attitude and car consumption. Employing the Netherlands Mobility Panel data (n = 1,376), Kroesen et al. (2017) tested bidirectional effects between attitude and travel behavior and found reciprocal effects between car use attitude and car use behavior. Another study by Moody and Zhao (2019), using a cross-sectional survey design and a sample of 1,236 commuters in the New York City and Houston metropolitan areas, tested the bidirectional relationship between car pride (image) and car ownership status. Their two-stage least squares (2SLS) or instrumental-variable analysis revealed that the influence of car pride on household car ownership is significantly stronger

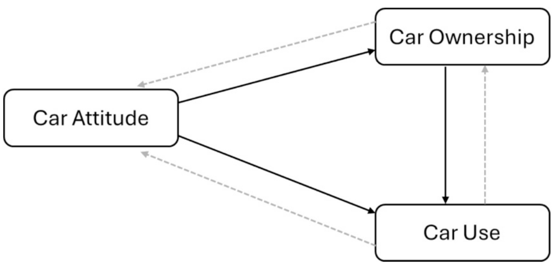

Fig. 1. The most tested and expected relationships between car attitude and car consumption based on the state of the art in the field. *Note: The solid black arrow shows the conventional link, while the gray dashed line represents the possible reverse effect.*

than the reverse influence. However, a year later, they found a different result using the same data after incorporating car use into the model. Moody and Zhao (2020) examined how three elements, car pride (attitude), car ownership, and car use (driving alone for commuting), interact with each other. Using the 2SLS method on the same cross-sectional data, they identified cyclical effects: (i) car use affects car pride (attitude), (ii) car pride influences car ownership, and (iii) car ownership impacts car use. Moody and Zhao (2020), however, suggested that future research should examine the dynamic, bidirectional relationship between car attitudes and car ownership, in addition to car use, using time-series structural equation modeling (SEM) approaches such as cross-lagged panel models.

1.3. Contributions of the current study

Our contributions to the literature are listed as follows. We test bidirectional effects over time instead of cross-sectional insights for the relationship between car-related attitudes and car consumption. This can give a better picture of (dynamic) effects between these elements. Another aspect of our study is that we also capture other elements such as utilitarian (e.g., reliability, safety, costs) and environmental considerations of car attributes during the car selection process in addition to car pride and hedonic values. Segmentation approaches show that, in terms of car ownership and use, the population can be divided into different attitudinal groups (Anable, 2005). It is, however, important to note that our study relies on secondary data, and the attitudinal items are not highly behavior-specific. They capture attitudes toward car-based attributes during the car selection process rather than directly reflecting car use or car ownership attitudes. In cross-sectional TPB-based studies, more behavior-specific attitudes often show stronger associations with behavior (Ajzen and Fishbein, 1977). However, by analyzing bidirectional effects over time, our study is less sensitive to this limitation.

Compared to past studies, our study also considers alternative travel mode (bus and bike) use in addition to car use in the modeling framework. These control variables give better insights into the findings that, for example, frequent public transport users or cyclists might show different car-related attitudes and car consumptions. Other exogenous variables including age, sex, number of children in household under 16, number of natural children in household,[1] employment status, disability or illness issues, household size are also used as covariates of the three elements (car-related attitude, the number of cars, car use) in both waves. The last but not least, we test a panel model using a large-scale national sample from the United Kingdom (n = 17,198), which enhances the reliability of the results compared to two similar past studies in the Netherlands (n = 1,376) and the United States (n = 1,236).

Fig. 2 illustrates the conceptual model. Within the framework of the Cross-Lagged Panel Model (CLPM), we examine the following relationships: (i) future number of cars at time point T2, predicted by past number of cars at T1, car use behavior at T1, and car-related attitudes at T1, (ii) future car use at T2, based on past car use at T1, past number of owned cars at T1, and past car-related attitudes at T1, and (iii) future car-related attitudes at T2, influenced by past car-related attitudes at T1, past number of cars at T1, and past car use at T1. The CLPM (Fig. 2) incorporates parameters S1, S2, and S3, representing stability coefficients, as well as L1a, L1b, L2a, L2b, L3a, and L3b, which capture the over-time (cross-)lagged effects among these three elements. Additionally, correlations C1 (three correlations at T1) and C2 (three correlations at T2) account for initial overlaps, considering potential prior causal influences in both directions or shared causes, while also controlling for stability (S1, S2, and S3) and cross-lagged effects (L1, L2, and L3). The significance and magnitude of the cross-lagged (standardized) coefficients (L) help determine whether the primary (causal) relationship flows from car-related attitudes to number of cars and car use, follows the reverse direction, or operates bidirectionally (Kroesen et al., 2017; Mehdizadeh & Kroesen, 2025). Furthermore, the model estimates the relationships (S1, S2, S3, L1, L2, L3) while controlling for various exogenous background/life event variables at both waves, such as age, gender, number of children in the household, disability, household size, job status, and use of other travel modes, as detailed in the Method section. Consequently, the number of cars, car use, and car-related attitude at both time points are treated as endogenous variables within the model. This approach ensures that relevant control factors are incorporated into the model estimation, enhancing the robustness of the analysis. Regarding car-related attitudes, before applying the CLPM, a factor analysis (including both exploratory and confirmatory analysis) is conducted, and its main components are considered in the CLPM.

2. Method

2.1. Sample and descriptive

We use panel data from the UK Household Longitudinal Study (UKHLS), also known as Understanding Society. This ongoing longitudinal survey tracks individuals, with data collection beginning from approximately 40,000 households across the UK in 2009–10 (University of Essex, Institute for Social and Economic Research., 2025). Participants from the initial wave are re-interviewed annually to monitor changes in their household composition and personal circumstances. Data is gathered either through face-to-face interviews conducted by trained professionals or via self-administered online surveys. The primary aim of Understanding Society is to deliver longitudinal data on various aspects of life, including health, employment, education, income, family dynamics, and social interactions. Certain waves of the study have also included transport-related variables, such as attitudes toward car-based attributes and travel mode use.

In the current study, according to our research question, we focus on two waves (wave 6: 2014–2016 and wave 8: 2016–2018),

[1] The number of respondents' children is recorded in different forms in the dataset. The variable "number of natural children" refers only to biological mothers and fathers, while "number of children aged under 16" includes natural, adoptive, foster, or stepchildren.

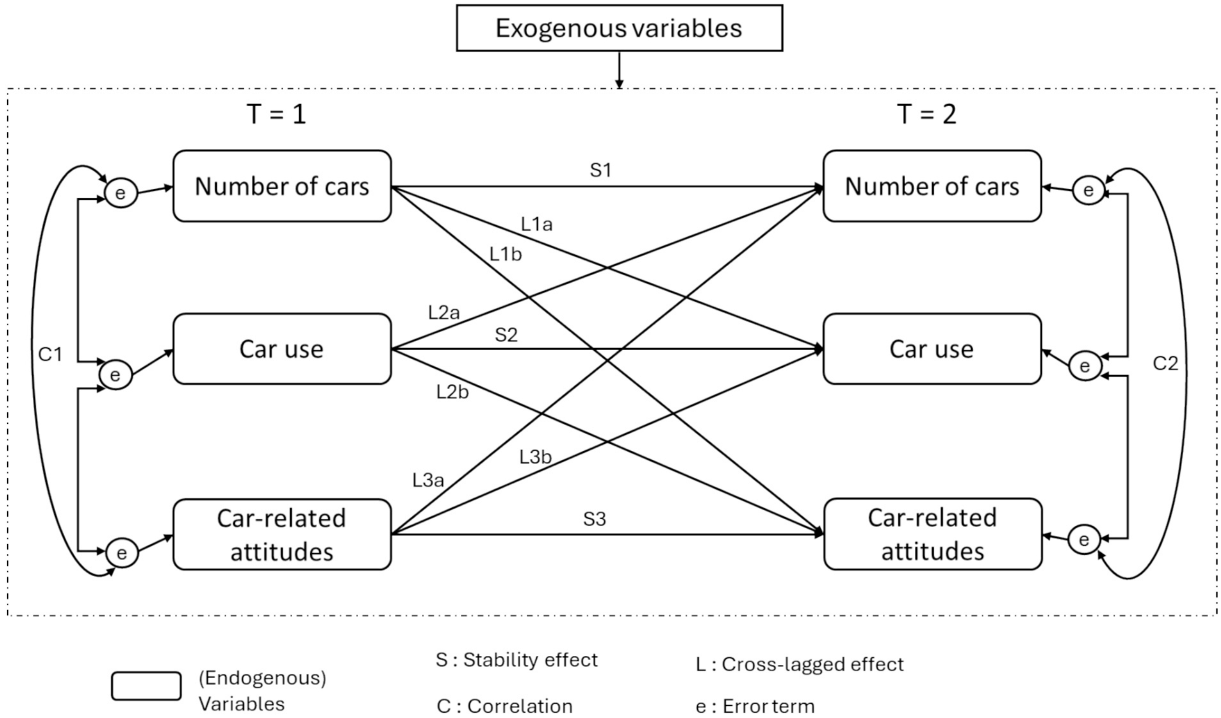

Fig. 2. The conceptual model testing bidirectional effects between car-related attitudes and car consumption over time.

which were before COVID-19. The reason for selecting these two waves is that some transport-related variables and attitudinal items were only available in a few waves of UKHLS and not in every wave. We also opted for pre-COVID-19 waves to avoid any potential effects of COVID-19 on the results. Another aspect of our study is that UKHLS evaluated car-based attitudes among individuals who had influence in owning a car in their household. Therefore, participants already had access to at least one car in their households. Individuals with this access can potentially use a household car (as a driver or passenger), and the mutual relationship between the number of cars and car use could make more sense. After matching individuals' identifiers for the two waves and cleaning missing and inapplicable respondents, 17,198 were selected for analysis. The data filtering was conditioned on the fact that attitudes towards car attributes in the UKHLS were asked from eligible individuals with a driving license and influence on purchasing a car for their household. Since in the UK, one can drive a car at the age of 16, the minimum age in the sample in the first wave is 16. Controlling variables such as age, gender, number of children in the household, disability, household size, job status, and use of other travel modes were extracted for both waves.

Table 1 presents the sample characteristics. The sample consists of 47.6% women, with an average age of approximately 52 years in the first wave. The average number of owned cars was 1.72 in the first wave and 1.74 in the second wave. In the first wave, 46.1% of individuals reported that their household owned one car, 40.6% owned two cars, and the remaining 13% owned three or more cars. In the second wave, 45.2% owned one car, 41.4% owned two cars, and 13.4% owned three or more cars. Car use frequency (to be discussed in the Measure section) was high in both waves, with an average of 7.58 and 7.49 on a scale of 1 to 8. In the first wave, 54% of individuals were in paid employment, which dropped by 2% in the second wave. Additionally, 34% reported having a long-term illness or disability[2] in the first wave. The average household size was approximately 2.75. As shown in Fig. 3, the percentages of participants who reported the importance of various car attributes are presented. Participants were asked to indicate whether each aspect was important to them during the car selection process. For instance, about 85% of participants cited reliability as important, while approximately 39% highlighted environmental friendliness.

2.2. Measures

Individuals were asked about the number of cars in their household in both waves. Car use (as a driver or passenger) was measured based on the frequency of use throughout the year, regardless of trip purpose.[3] Responses were recorded on an eight-point scale: (1) at

[2] The exact asked question: “Does NAME have any long-standing physical or mental impairment, illness or disability? By 'long-standing' I mean anything that has troubled NAME over a period of at least 12 months or that is likely to trouble NAME over a period of at least 12 months”.

[3] The exact question that was asked is: “How frequently do you travel by private car or van – whether as a driver or passenger? Please count a single trip as one journey and each return trip as two”.

Table 1
Sample characteristics.

Variable	First wave	Second wave	Change
Number of owned cars (1, 2, 3, 4, 5, etc)	1.72 (M)	1.74 (M)	+ 0.02
Car use (scale from 1 to 8)	7.58 (M)	7.49 (M)	− 0.09
Bus use (scale from 1 to 8)	2.46 (M)	2.41 (M)	− 0.05
Bike use (scale from 1 to 8)	1.99 (M)	1.90 (M)	− 0.09
Being woman	47.6%	47.6%	0
Age (from 16 to 95 at first wave)	52.15 (M)	54.15 (M)	+ 2
Individual is at paid employment (1/0)	54%	52%	− 2%
Individual is self-employed (1/0)	11%	11%	0
Individual is retired (1/0)	27%	30%	+ 3%
Individual has long-standing illness or disability (1/0)	34%	35%	+ 1%
Household size	2.75 (M)	2.73 (M)	− 0.02
Number of children under 16 at household	0.51 (M)	0.50 (M)	− 0.01
Number of biological children in the household	0.78 (M)	0.77 (M)	− 0.01

M = Mean.

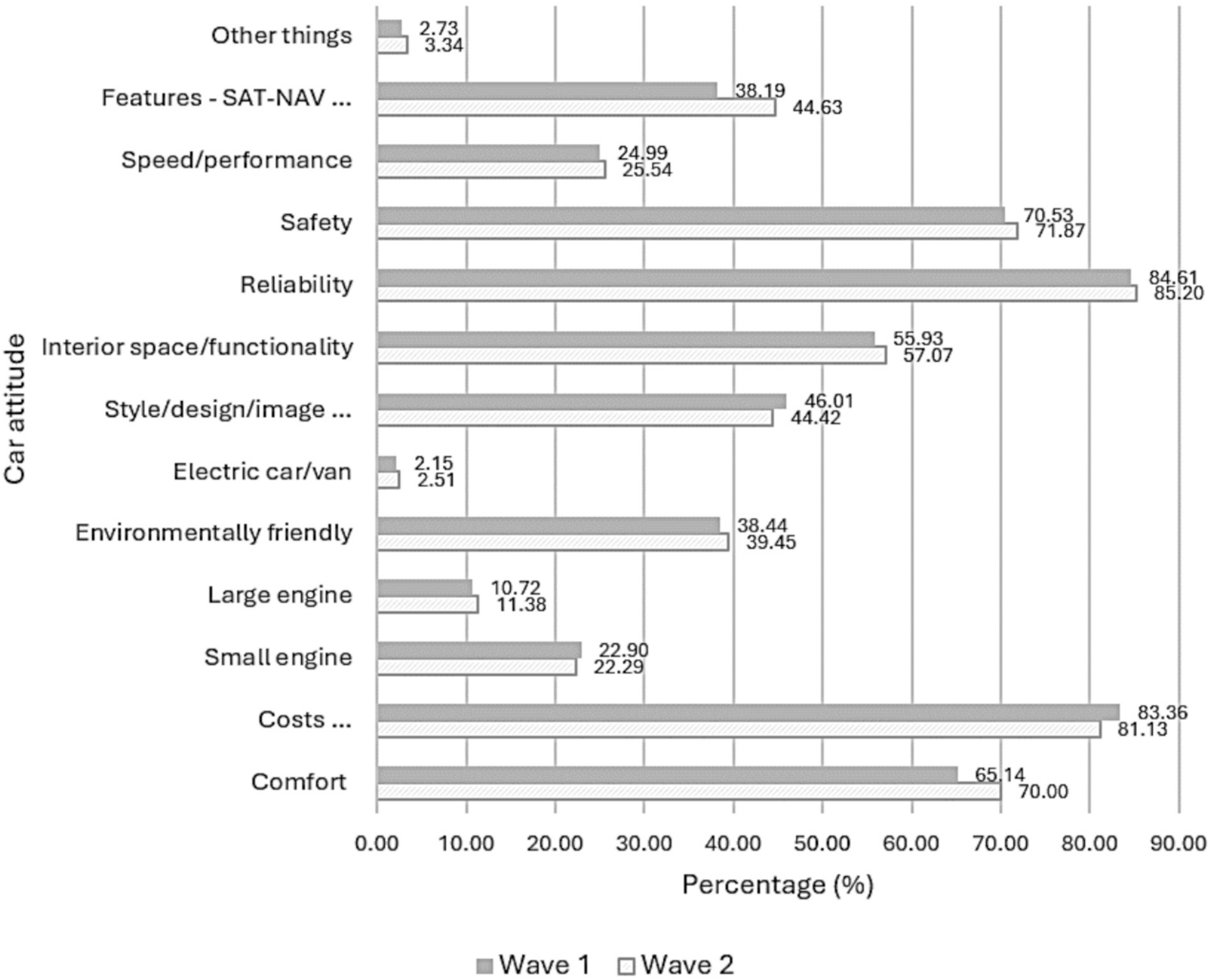

Fig. 3. Share (%) of reported importance of car characteristics when purchasing a car.

least once a day, (2) less than once a day but at least three times a week, (3) once or twice a week, (4) less than that but more than twice a month, (5) once or twice a month, (6) less than that but more than twice a year, (7) once or twice a year, and (8) less than that or never. The same scale was used to measure bus and bike use. However, for analysis purposes, this scale was reverse-coded so that lower values represent infrequent use and higher values indicate more frequent use. In the UKHLS dataset, the transport module includes a question for respondents with at least one car in their household who were involved in car or van purchase decisions (Chng et al., 2019). They were asked, which of these things are important to you when it comes to buying a car or van? The items were measured using a binary response format, where participants were presented with 13 attitudinal aspects/statements related to their decision-making process when considering purchasing a car. Respondents were asked to select which of the 13 aspects (e.g., comfort, costs, environmental friendliness, style/image of car, reliability, travel speed/performance, safety) were important to them. Another answer option named "I do not know" was also provided for respondents in case they had no knowledge or opinion about the question. Each statement functioned as an independent variable, and participants could select one, multiple, or none of the given options. The responses were recorded in a dichotomous (1/0) format, where "1" indicated that the participant considered the aspect important, and "0" indicated that they did not. The dimensionality of this instrument has been tested and validated through factor analyses in previous research (e.g., Chng et al., 2019).

2.3. Analysis method

To understand the underlying structure of attitudes toward car-based attributes, we employed a two-step factor analysis (Kline, 2023). First, we conducted an exploratory factor analysis using principal axis factoring (PAF) to identify the constructs with common variance. The number of factors was determined based on the eigenvalue criterion (eigenvalues greater than 1) and a factor loading above 0.4 (Abdi and Williams, 2010). Prior to conducting PAF, we assessed the internal consistency of the instrument using Cronbach's alpha to ensure the reliability of the scale. A principal component analysis (PCA) was previously applied to the same UKHLS attitude instrument in a past study, though with a different research focus and sample size (Chng et al., 2019). Next, we performed confirmatory factor analysis (CFA) to validate the factor structure suggested by PAF. Since the attitude indicators were dichotomous (categorical), we used a generalized structural equation model (GSEM) with a binomial logit function to perform CFA, ensuring an appropriate estimation method for categorical data. After confirming the factor structure, the factor scores used as attitudinal variables in the subsequent cross-lagged panel model (CLPM). This approach ensured that the model remained linear, preventing excessive complexity due to variables with different functional forms. Keeping a linear functional form allowed us to obtain standardized effects, making bidirectional (effects) comparisons more interpretable and enabling the inclusion of covariances between error terms of endogenous variables.

As shown in Fig. 1, a CLPM based on structural equation modeling (SEM) was developed to examine bidirectional effects between car-related attitudes, the number of cars, and car use. Both car-related attitudes and car use were modeled as continuous variables, while the number of cars (a count variable) was tested in two forms: categorical (unordered) and count/ratio. However, defining the number of cars as an unordered categorical variable results in a CLPM with different functional forms that prevented the control of error term covariances across the three elements with different functional forms. To address this, we treated the number of cars (1, 2, 3, 4, etc.) as a ratio measurement level/count variable in the model. To ensure robust estimation, we applied Asymptotically Distribution-Free (ADF) estimation alongside Maximum Likelihood (ML) and Robust Maximum Likelihood (ML Robust). ADF is better suited for handling non-normal, ordinal/ratio, and count data, whereas ML is more commonly used when normality assumptions hold. ML Robust adjusts for potential violations of normality in the data while maintaining the ML framework. The results from all three estimation methods were largely similar, with only minor differences observed. This similarity is likely due to the large sample size ($N \approx 17{,}000$), which supports the asymptotic properties of all three estimators.

In the CLPM, covariances between the error terms of endogenous variables in both waves were included to prevent biased estimation. Various exogenous covariates were also incorporated for all three elements in both waves. Given that the time gap between the two waves was two years, most covariates (except sex) were allowed to change over time. Thus, we used wave-specific covariates in the model. To assess the model fit, we used standard SEM fit indices with the following recommended thresholds for a good-fitting model (Kline, 2023). The Root Mean Square Error of Approximation (RMSEA) should be below 0.05 for a good fit, while values between 0.05 and 0.08 indicate an acceptable fit. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) should be above 0.95 for a good fit and above 0.90 for an acceptable fit. The Standardized Root Mean Square Residual (SRMR) should be below 0.08 to indicate a good fit. The Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) are also used mainly for comparing alternative models, where lower values suggest a better-fitting model. The analyses were conducted by Stata.

One might ask why we do not employ a measurement model with a latent variable structure in the CLPM. As mentioned earlier, since the indicators for the attitudinal items are measured in a dichotomous format (0/1) in the UK Understanding Society survey, we estimated the CLPM using a GSEM framework, which allows the combination of variables with linear and logistic functional forms. Given that the model includes six (endogenous) latent variables (three in each wave), the estimation becomes highly complex, resulting in non-convergent Hessian matrices due to the large number of parameters and the presence of mixed functional forms. If the car-related attitudinal statements had been measured using Likert scales, it would have been straightforward to incorporate them as latent constructs within a standard longitudinal SEM (or CLPM) framework.

3. Results

The PAF results show a three-factor solution for car-related attitudes, indicating three themes of factors named image (pride)/hedonic, utilitarian and environmental considerations for both waves (Table 2). This solution is in line with PCA solutions reported in past research using the same instrument of UKHLS data (Chng et al., 2019). The reliability of the scale was also acceptable ($\alpha > 0.65$). Another item named "other things" failed to load consistently in any factors, so it was removed from the analysis. The first dimension was represented by image (pride)/hedonic aspects in both waves. Image/hedonic aspect contains comfort, large engine, style, interior space, speed/performance, and features such as sat-nav. The second factor encompasses utilitarian aspects, including cost, reliability, and safety. The third factor represents environmental considerations, incorporating elements such as a small engine, lower CO_2 emissions, and preferences for electric vehicles. In addition to PAF, a CFA considering binomial logit function for indicators was conducted to evaluate the PAF solution. As shown in the *supplementary material file*, the results of the CFA were satisfactory showing that the identified indicators for each of the factors have a significant factor loading and they can represent the factors in line with the PAF solution for both waves.

The standardized effects from the CLPM, testing the relationships between the number of cars, car use and car-related attitudes are shown in Fig. 4.[4] The model shows excellent fit to the data (*Chi-square = 1211.69, RMSEA = 0.025, CFI = 0.97, TLI = 0.93, SRMR = 0.005*). When assessing the model's fit at the equation level, it becomes clear that the variance explained for the number of cars is higher compared to car use and car-related attitude. For example, in the second wave, the R-squared value for the number of cars is 0.60, while for car use, it is only 0.13. Similarly, the R-squared values for the three attitudinal elements, including image/hedonic, utilitarian, and environmental concerns, are 0.35, 0.15, and 0.11, respectively, in the same wave. All stability effects within this set of relationships, such as the link between previous and current number of cars owned, were statistically significant at the 5 percent level ($p < 0.05$). The stability coefficients indicate that the number of cars owned remains highly consistent over time, with standardized estimates around 0.64, surpassing the stability effects observed for car use and car-related attitudinal factors. Specifically, the stability effects for image/hedonic, utilitarian, and environmental factors are 0.52, 0.36, and 0.31, respectively, while the stability effect for car use is 0.31. Overall, stability effects tend to show a stronger effect than cross-lagged effects, highlighting the role of past behavior in impacting future actions and relatively persistence of attitudes over time.

In analyzing cross-lagged effects among the number of cars, car use, and car-related attitudes (comprising three dimensions: image/hedonic, utilitarian, and environmental considerations) across waves, six primary cross-lagged effects emerge. The findings indicate statistically significant cross-lagged effects between these elements, confirming the existence of bidirectional effects among number of cars, car use, and car-related attitudes. However, the effect of number of cars on car-related attitudes is consistently stronger than the reverse effect. The total absolute value of standardized cross-lagged effects from number of cars to car-related attitudes is 0.1 (0.044 + 0.031 + 0.025), which is twice as large as the reverse effect of 0.05 (0.014 + 0.035). Similarly, the influence of car use on car-related attitudes is 0.042 (0.019 + 0.023), exceeding the reverse effect of 0.014. Image/hedonic aspect and the number of cars positively affect each other, with number of cars owned strengthening greatly one's image/hedonic values over time that the reverse. The relationship between environmental considerations and the number of cars is also bidirectional, though ownership shows a stronger effect. This suggests that as people acquire more cars, their environmental concerns diminish rather than environmental considerations prompting them to give up a car. Interestingly, the relationship between practical considerations and the number of cars is unidirectional, with higher number of cars owned leading to a weaker emphasis on utilitarian factors. This may reflect that households with more cars tend to have higher incomes or greater financial flexibility and therefore place less importance on cost-related considerations. Additionally, the number of cars owned has a greater impact on car use than the other way around.

The estimated correlation results indicate that while the relationships between the number of cars, car use, and attitudes are relatively weak, they remain statistically significant. The strongest correlations are observed between image and number of cars in the first wave ($r = 0.10$) and between number of cars and car use in the first wave ($r = 0.11$). Table 3 presents the influence of 11 exogenous variables on 10 endogenous variables, with five for each wave. While we do not focus on these results in detail, as they are not the focus of this study, the general direction of the effects appears reasonable. For instance, women tend to place less emphasis on car image (pride) and hedonic aspects compared to men but are more likely to consider environmental factors when deciding whether to reduce or increase the number of cars they own. Older individuals also show lower car pride while placing greater importance on environmental concerns. Employment status is associated with higher number of cars and use in both waves. Larger household size corresponds to increased number of cars and higher car use. Those who frequently use buses are less likely to increase the number of cars and their car use, whereas bicycle use shows a positive relationship with number of cars owned but a negative association with car use.

4. Discussion

One of the key findings is the existence of bidirectional effects between the number of cars owned, car use, and car-related attitudes (i.e., the importance of car characteristics when purchasing a car). To give a better picture of these effects, as shown in Fig. 5, the magnitude (thickness of the arrows) of the directional links between car-related attitudes and car consumption is scaled and ranked according to the absolute (standardized) effects. These findings suggest that the effect of the number of cars owned on car-related attitudes is consistently stronger than the reverse effect. This asymmetry indicates that once households acquire more cars, the importance people place on different car characteristics during the car selection process tend to align with their ownership status rather than pre-existing attitudes strongly driving the acquisition of additional cars. This might imply that the number of cars owned itself reinforces certain beliefs over time, suggesting a self-reinforcing cycle where car ownership shapes perceptions rather than merely reflecting them. In particular, the findings suggest that, over time, a higher number of cars and higher levels of car use more strongly affect subsequent reductions in the weight individuals place on environmental considerations when purchasing a car (e.g., engine size, CO_2 emissions, or electric propulsion). This effect is stronger than the extent to which environmental considerations lead individuals to shed cars or reduce car use. This finding aligns with panel studies in travel behavior research, suggesting that attitudes are more influenced by behaviors rather than the other way around (Kroesen et al., 2017; Mehdizadeh and Kroesen, 2025). This

[4] The full model result is presented in the supplementary material file.

Table 2
The result of principal axis factoring (PAF) for car-related attitudes for both waves.

Item	Factor 1		Factor 2		Factor 3	
	W1	W2	W1	W2	W1	W2
Comfort	0.44	0.46				
Large engine	0.56	0.61				
Style/design/image of brand/model	0.64	0.65				
Interior space/functionality/boot size	0.42	0.46				
Speed/performance	0.69	0.72				
Features – SAT-NAV, CD player, music system, power steer	0.65	0.62				
Costs – purchase/running/resale value/tax/insurance			0.46	0.45		
Reliability			0.67	0.67		
Safety			0.68	0.68		
Small engine					0.57	0.44
Environmentally friendly/low CO_2 emissions					0.52	0.57
Electric car/van – one that's plugged directly …					0.72	0.80
Label	Image/hedonic aspects		Utilitarian		Environmental considerations	

Another item named “Other things” could not get a decent loading in any factors, so it was removed from the analysis.

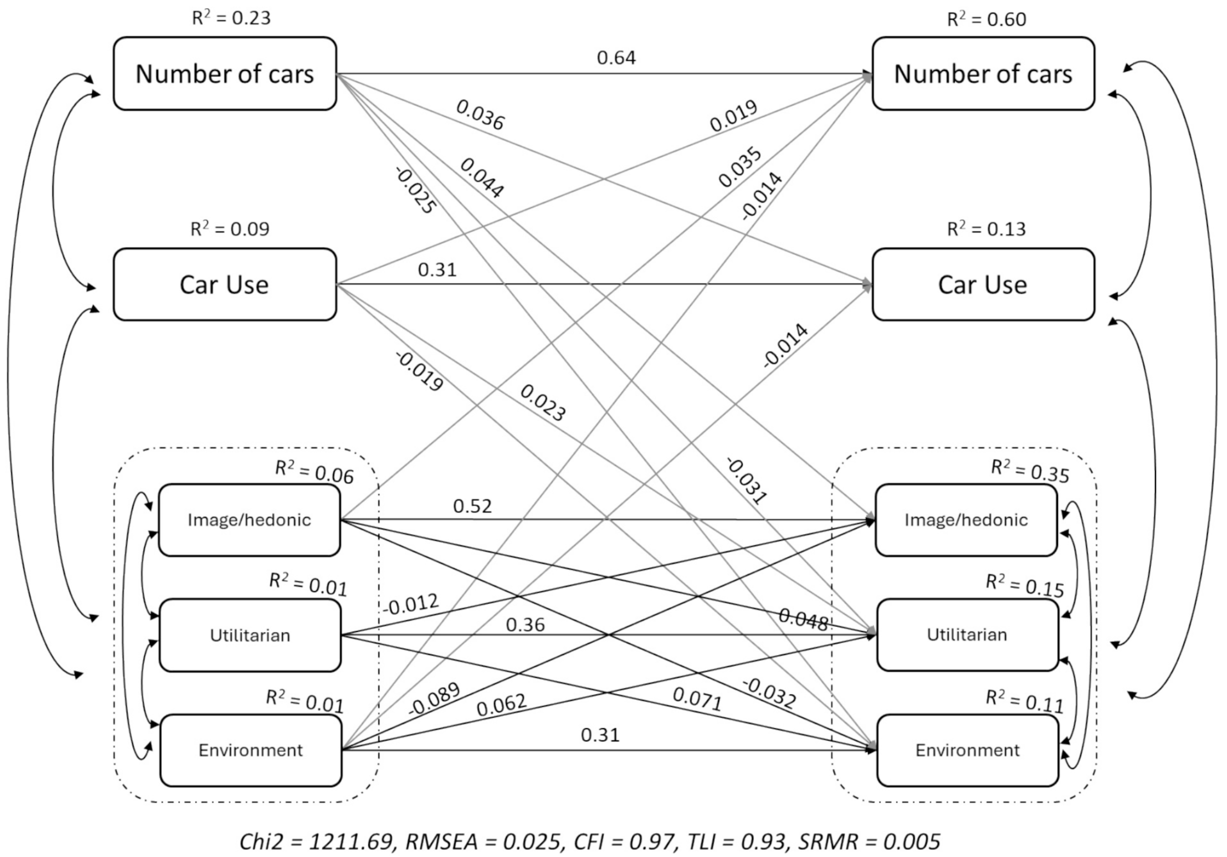

Fig. 4. Standardized effects from the cross-lagged panel model for the relationships between car-related attitudes, the number of cars owned and car use (n = 17,198). *Covariances and covariates (from exogenous variables) are not shown in this figure, and they can be found in table results.*

asymmetry may be interpreted through the lens of cognitive dissonance theory (Festinger, 1957), which argues that individuals experience psychological discomfort when their actions conflict with their beliefs or attitudes. To reduce this discomfort, they often adjust their attitudes to align with their behaviors. In the context of car ownership, once individuals acquire a new car, especially in environments where ownership may conflict with environmental values, they may subconsciously shift their attitudes to justify the number of owned cars.

Our findings indicate that the impact of car use on car-related attitudes is weaker than that of the number of cars owned, but still significant. This suggests that while using a car regularly does influence car-related attitude, it does not reshape attitudes as strongly as simply owning cars. This distinction can have implications for transport policy: reducing car use alone may not be sufficient to shift

Table 3
Impact (standardized effects) of exogenous variables on key endogenous variables.

	T = 1					T = 2				
	Car …		Attitude …			Car …		Attitude …		
	Number	Use	Image	Utilitarian	Environment	Number	Use	Image	Utilitarian	Environment
Sex (man = 1, woman = 2)	0.03		−0.15	0.09	0.06	0.01		−0.08	0.06	0.01
Age			−0.18		0.05		0.05	−0.13		0.05
Number of kids under 16	−0.40			0.05	−0.03	−0.19			0.03	
Number of biological children	−0.06		−0.09	0.04	0.08					
Paid employment	0.14	0.22	0.07	0.06		0.05	0.09	0.04		
Self-employed	0.15	0.11	0.05			0.04	0.05	0.03		
Retired	0.05	0.04	0.08	0.05		0.02		0.05	0.05	
Illness or disability	−0.04	−0.03	−0.02			−0.01				
Household size	0.58	0.02	0.05	−0.05	−0.05	0.28				
Bus use	−0.15	−0.20	−0.06	0.03	0.06	−0.05	−0.07	−0.03		0.04
Bike use	0.04	−0.08		0.03		0.03	−0.03			0.02
_Cons*	0.99	9.44	0.96	−0.43	−0.31	0.04	4.21	0.64	−0.45	

Only significant effects at $p < 0.05$ are shown.
* The standardized value for_cons is automatically reported by the software and represents the intercept divided by the standard deviation of the dependent variable. It does not represent a standardized regression coefficient and should not be interpreted as such.

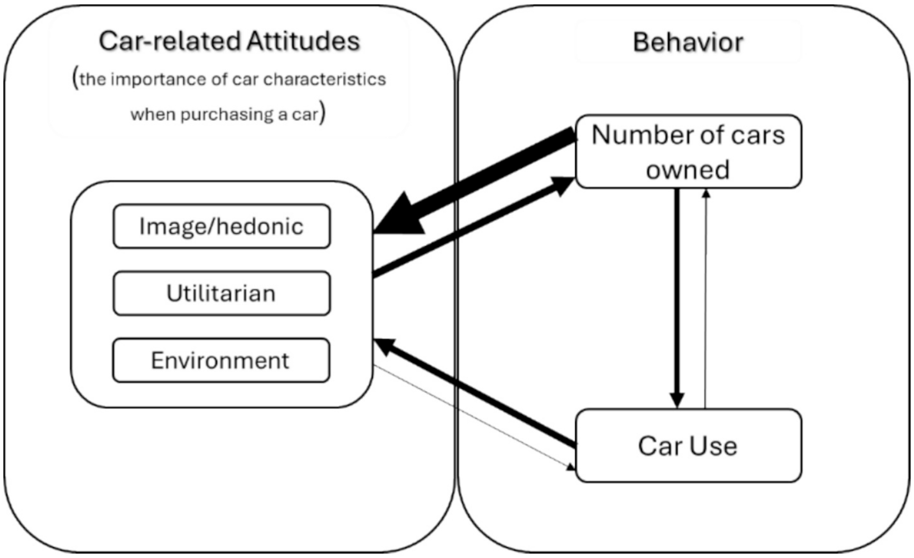

Fig. 5. The effects between car-related attitudes and car consumption derived from the panel model.

long-term attitudes toward car dependency. Instead, radical measures aimed at reducing car ownership itself, such as strict residential parking restrictions and progressive taxation based on the number of cars, may have better impact on car ownership reduction.

Although the importance people place on different car characteristics when purchasing a car play a role in the number of cars owned and car use, their impact is relatively modest. Our findings suggest that these car-related attitudes, particularly those related to environmental aspects, have a weaker influence on car consumption than expected. This finding is particularly relevant in light of previous research (cited papers in Soza-Parra and Cats, 2024), which suggested that individuals with strong environmental values tend to consume car less. However, our findings suggest that environmental considerations alone may not be a strong enough driver of behavioral change. As people acquire more cars, their environmental concerns tend to fade rather than motivating them to reduce the number of cars owned. This may also reflect a cognitive dissonance reduction process, where individuals reconcile the conflict between their environmental values and ownership behavior by moderating the importance of those values. When it comes to practical considerations, those with higher levels of car ownership gradually place less importance on factors like reliability, purchase price, running costs, resale value, taxes, and insurance. Instead, they become increasingly focused on the image their cars project, reinforcing the social and symbolic characteristics when purchasing a car over time.

Our findings reveal high stability effects for the number of cars owned, exceeding those observed for car use and car-related attitudes. This underscores the habitual nature of behavior, reinforcing previous research (Thøgersen, 2006) suggesting that once individuals acquire a new car, they are unlikely to relinquish it unless external circumstances force them to do so. While car use shows some degree of variability, the number of cars owned appears to be deeply established in household mobility decisions. These results emphasize the challenges of reducing car dependency, as ownership decisions are not easily reversed. Policies aimed at promoting car shedding should consider targeted interventions that disrupt habitual ownership patterns, such as financial disincentives for second-car ownership. Another insight from our study is the contrasting effects of public transport and bicycle use on car consumption. As expected, frequent public transport users are less likely to purchase a new car or increase their car use, reinforcing the importance of transit accessibility in reducing car dependency. However, bicycle use shows a different pattern: while cyclists are less likely to use cars frequently, they are more likely to own more cars in households. This finding might suggest that in certain contexts, cycling and car ownership may not be mutually exclusive but rather complementary. This may challenge the common assumption that promoting cycling automatically reduces car ownership. Instead, it suggests that individuals may use bicycles for certain trips while still relying on a car for others, particularly in suburban or *peri*-urban areas where public transport options are limited. Future research should explore whether this pattern reflects practical necessity or a cultural preference for multimodal flexibility.

5. Conclusion

The present study provides new insights into the dynamic relationships between car-related attitudes (the importance of car characteristics when purchasing a car) and car consumption. We find that, although the importance people place on car characteristics when purchasing a car influences decisions to increase the number of cars owned or the frequency of car use, car consumption over time (in particular, the number of cars owned) has a greater effect on these attitudes towards car characteristics. The findings have implications for transport policies aimed at reducing car dependency. First, interventions targeting car ownership itself may be more effective in shifting long-term behavior than policies that solely target car use. Second, policymakers should recognize that attitudes alone are not strong enough to drive change; instead, radical policies and financial disincentives could be developed to reduce car ownership. Furthermore, this study highlights the importance of considering alternative travel modes beyond just car use. While public transport remains a key lever in reducing car dependency, the role of cycling and other emerging mobility options should not be overlooked.

In this study, which is based on secondary data (the UK Understanding Society), attitudes toward car-based attributes have been measured, which might not directly reflect car use, or the number of cars owned. Identifying and measuring attitudinal variables that satisfy the two necessary criteria for causal inference, namely empirical association and exogeneity, is however challenging (Kroesen and Chorus, 2018). Regarding the inclusion of public transport use and cycling as covariates in the model, we tested their one-way effects on car consumption. However, the reverse effects are also plausible. Due to the complexity of the model, we opted to test only the one-way effects. Future research could specifically examine the directionality of effects between travel modes. We also used two waves of data with a two-year gap between waves. Future research could explore how different time lags may change the mutual effects between attitudinal elements and behaviors. According to cognitive dissonance theory, the dissonance between attitude/preference and behavior might reduce over time. However, how long it takes for this consonance to occur remains an unaddressed question in transport research. Many longitudinal studies use one- or two-year gaps, but we do not yet know how long it actually takes for transport behavior to be affected by attitude and vice versa. Life events are also important elements in changing car ownership status. Examining how the attitude–behavior relationship functions during such events can provide new insights. Finally, further research is needed to explore whether these patterns hold across different cultural and policy contexts. Comparing these dynamics in countries with varying levels of car dependency and alternative mobility infrastructure could provide better insights into the generalizability of our findings.

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CRediT authorship contribution statement

Milad Mehdizadeh: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jillian Anable:** Writing – review & editing, Validation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tra.2026.104892.

Data availability

The authors do not have permission to share data.

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