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Who is ready to live a car-independent lifestyle? A latent class cluster analysis of attitudes towards car ownership and usage

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ABSTRACT

An excessive use of private cars for transportation has multiple negative effects on our society. It is therefore paramount to identify the underlying factors driving car usage among different segments of travellers. In this study, we aim to identify and characterise traveller segments in terms of their car-related attitudes and how different sociodemographic attributes, travel behaviour characteristics (such as using cars as the primary mode of transportation), and the accessibility of their place of residence vary amongst different population segments. Through Confirmatory Factor Analysis and Latent Profile Analysis we identify five different classes, namely *car-detractors*, *–hesitants*, *–positives*, *–friends*, and *–lovers*. More favourable car attitudes are associated with higher car ownership and access but, interestingly, there are no significant differences in terms of travel frequency and trip length distribution. This suggests that attitudinal differences relate mostly to modal preference rather than to the underlying travel demand patterns and the associated activities. We also see that car-less individuals are more likely to be *car detractors*, suggesting that the experiencing barriers for owning a car may contribute to developing more negative attitudes towards cars. Our results shed light on the different influencing factors and characteristics of individuals that consider, or not, a car-centred mobility.

1. Introduction

Car usage, ranging from day-to-day commuting to weekend gateways, is associated with negative externalities in terms of traffic and climate change mitigation. This problematic situation is expected to continue increasing as road motor vehicles possession has been steadily growing in the last decade in OECD countries (OECD, 2022), in contrast to the hypothesis that car usage had reached a saturation point a decade ago (Goodwin & van Dender, 2013). To address this problem, transport authorities improve and promote existing transportation alternatives such as public and active means of transportation while taking car drivers' preferences into consideration (Abenoza et al., 2017; de Oña, 2021; Jacob et al., 2010). The inherent idea behind this approach is that promoting better alternatives might make car users shift to more sustainable ways of mobility.

Taking the Netherlands as an example, a country with excellent public transport infrastructure and plenty of safe and well-connected bike paths, private cars still account for the majority (~42 %) of the modal share as the primary transport mode.

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Moreover, ~23 % of those trips are shorter than 2.5 km, and 40 % are shorter than 5 km (Hoogendoorn-Lanser et al., 2015). If we assume that 2.5 km is a distance where bikes (not to mention e-bikes) could easily become a competitive alternative, and considering the current share of trips performed by cars as the main mode, one could say that around 1 (~ 0.42 * 0.23) of 10 trips in the Netherlands that is currently performed by a car and could, at least theoretically, be done by bike.

One could argue then that there must be other reasons that explain part of the cars' additional attractiveness. In fact, different psychological theories have been applied to study car use. Among them, the Theory of Planned Behaviour (TPB) (Ajzen, 1991) has received a lot of attention in this domain, as it explains people's intention based on attitudes, social norms, and perceived behavioural control. Steg et al. (2001) studied these attitudes in depth and found that in addition to instrumental motives (e.g., availability, freedom, driving conditions) symbolic or affective characteristics also have an impact on car use. Importantly, symbolic and affective motives were found to explain most of the differences between different population segments (Soza-Parra & Cats, 2023; Steg, 2005). Empirically, it has been found that these motives derived from TPB have a significant effect on car use and intentions to drive (Gardner & Abraham, 2008). In general, it has been found that instrumental motives and autonomy have the largest effect on car ownership and more recently the effect of environmental motives have been addressed (Soza-Parra & Cats, 2023).

A promising, yet fairly uncommon, approach for studying the effect of these personal and unobservable variables on mobility, especially in car use, is to perform market segmentation by means of Latent Classification or Clustering Analysis. More simplistic approaches towards segmenting the population may lead to incorrect response prediction to certain policies as it has been shown that the same choices can arise from different motives (Anable, 2005). One of the benefits of this methodology is the possibility to define a set of relatively homogeneous and easy-to-understand groups, which can lead to more targeted public policies. For example, Magdolen et al. (2021) identified eight different segments, where the *"Environmentally oriented multimodals"* was found to be the one with the highest potential to transition to a more sustainable way of mobility.

Two notable recent examples have explored the differences in the use of different transportation modes through latent classes. Ton et al. (2020) identified five different classes, which were either uni-modal (e.g., exclusive car or bike users) or multi-modal based on a combination of mobility attitudes. They found a high level of travel mode consonance, meaning people tend to have a greater affinity towards the modes they use. Olde Kalter et al. (2020) explored how class membership evolves over time by analysing a panel of respondents around different car motives. They identified four latent classes, namely *cost-sensitive*, *car-minded*, *environmentally aware*, and *social-conscious travellers*. They found that attitudes towards car use are stable as most participants remain in the same class. They also found that the impact of attitudes towards the frequency of car use is limited, except for the case when moving to the *car-minded* class.

When aiming to discourage less sustainable travel behaviour, such as high car usage, it can be insightful to investigate the behaviour of individuals or households who do not possess a car. However, it is important to recognize that the decision to refrain from owning a car may stem from a variety of reasons. Two prominent groups, denominated car-free and car-less, have been examined in the literature. On the one hand, car-free individuals or households consciously choose not to purchase and use a car, even though they have the means to do so. On the other hand, car-less individuals or households are unable to use a car due to financial or physical constraints. (Brown, 2017; Paijmans & Pojani, 2021). Those living a car-free lifestyle are less associated with pro-car attitudes and more associated with pro-environmental attitudes, and tend to be more educated and of higher income (Brown, 2017; Heinonen et al., 2021; Magdolen et al., 2021; Olde Kalter et al., 2020). Research on this topic is limited, as car-free households constitute a relatively limited group in the population, with current efforts going in the direction of analysing car ownership intentions of children and adolescents in different contexts (Pojani et al., 2018; Sigurdardottir et al., 2013). Thus, understanding the similarities between these two groups and particularities in terms of their socio-demographic characteristics, mobility attitudes, and residential location is key for understanding the circumstances associated with a zero-car lifestyle.

None of the referenced studies had explored the spatial variations of these different car-mobility circumstances, namely car-attitudes, car-related classes, or the different zero-car categorizations. Thus, the present study aims at investigating three research questions related to car mobility, attitudes, and residential location. The first question is aimed at identifying and characterizing different segments of travellers based on their car-related attitudes, socio-demographic attributes, and behavioural characteristics, such as the primary mode of transportation used. The second question focuses on examining the spatial distribution of these segments and analysing related differences in accessibility. The third question specifically targets zero-car households and aims to analyse their attitudinal characteristics.

The remaining of this article is structured as follows: in Section 2, we describe our methodology, specifically focusing on data processing and the structure of different modelling stages. In Sections 3, 4, and 5, we present the results obtained from sample segmentation, socio-demographic characterization, and the spatial analysis, respectively. In Section 6, we characterize the differences between car-free and car-less households. Finally, in Section 7, we discuss the results obtained and propose further research directions.

2. Methodology

In this section, we first describe the data characteristics that make it suitable for studying the research questions previously described. We then present our methodological framework along with the different methods applied.

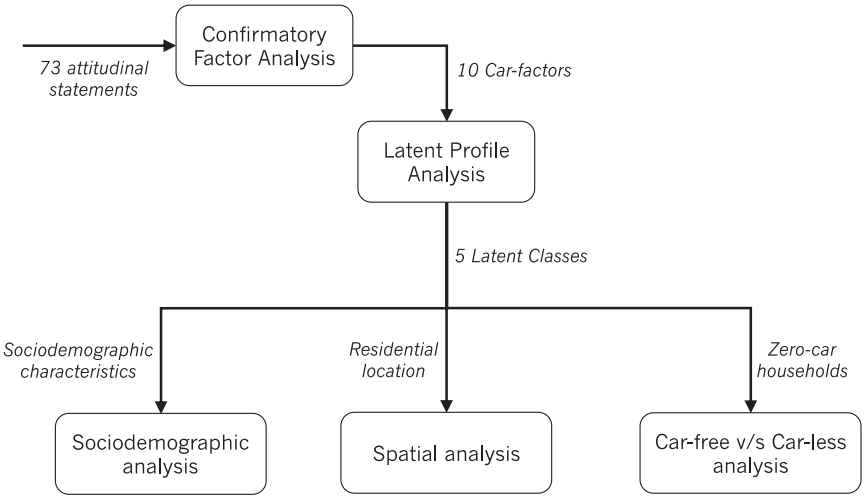


Fig. 1. Methodological framework diagram.

2.1. Data

Our analysis is based on the Netherlands Mobility Panel (MPN) data, a representative panel of the adult Dutch population, which every year gathers information at a personal, household, and mobility level (Hoogendoorn-Lanser et al., 2015). The survey collects information by means of a three-day travel diary and also asks questions regarding how "common" those trips were and possible reasons for travel modifications. In addition, the survey contains questions at a household and individual level, also including a detailed characterisation of the different cars available. Finally, a set of additional personal attitudinal questions are asked on even and odd years regarding mobility and other matters, alternately. The dataset includes an additional set of attitudinal questions related to either mobility (on even years) or other topics (on odd years). Given the COVID-19 pandemic, we focused on the last even year before the start of the pandemic, i.e. 2018. This panel has been in operation since 2013 in yearly waves. In particular, the 2018 version collected information from 8,561 individuals and 4,468 households. Among these participants, 90 % of them have at least participated in one of the five previous waves.

In terms of the particular mobility attitudinal questions included in 2018, for each of the five modes analysed – car, train, bus/tram/metro (referred to as BTM, representing all urban public transport), bike, and walk – participants are asked about their overall opinion and about how they evaluate them in terms of being comfortable, relaxing, saving time, safe, flexible, pleasurable, and prestige. In addition, a set of 26 related to car usage and ownership experience were included in this specific wave in 2018. Thus, the total number of attitudinal statements available for analysis is 73. The number of respondents who answered all these questions is 6,502, which corresponds to the dataset used in our analysis. The distribution of sex, age, and household income is presented in Table 1, along with the national distributions thereof. As can be seen, there is only a slight over-representation of women and low-income households. This overrepresentation is corrected for by weighing each observation with the available weight factors in the

Table 1
Sample basic characteristics.

		Sample total	Sample %	National %
Sex	Men	3,048	46.9 %	49.7 %
(Individuals)	Women	3,454	53.1 %	50.3 %
Age (Individuals)	18—24 years	685	10.5 %	10.8 %
	25—39 years	1,584	24.4 %	23.1 %
	40 – 59 years	2,189	33.7 %	34.8 %
	> 60 years	2,044	31.4 %	31.3 %
Income (Households)	Minimum < € 13,700	221	6.7 %	5.4 %
	Low € 13,700 – € 28,600	747	22.5 %	25.2 %
	Benchmark € 28,600 – € 42,400	864	26.0 %	22.7 %
	<2x Benchmark € 42,400 – € 71,000	982	29.6 %	28.6 %
	2x Benchmark € 71,000 – € 84,700	222	6.7 %	7.8 %
	>2x Benchmark > € 84,700	284	8.6 %	10.4 %

sample. The rest of the analysis presented in this article considers this set of weights in order to provide results as representative as possible.

2.2. Methodological framework

To handle the large number of attitudinal questions present in our dataset, we first carry out an exploratory factor analysis (EFA) to determine potential factors structures which we then use as a first step in composing a confirmatory factor analysis (CFA). Different structures are compared to come up with a final set of latent factors to be included in our analysis.

Next, based on these selected factors, we aim at estimating models for a varying number of subpopulations in order to study how these different segments differ in their affinity with the car, their sociodemographic characteristics, and the built environment in which they live. Since these factors are continuous variables (and not ordinal as the initial set of 73 statements), we estimate these segments through Latent Profile Analysis (Spurk et al., 2020).

In general, an LPA model aims to explain the variance of a particular i continuous response variable by assuming it comes from the joint distribution of k latent profiles in which each variable is normally distributed. This is mathematically carried out by assuming the following equation (Spurk et al., 2020):

$$\sigma_i^2 = \sum_{k=1}^{K} \pi_k (\mu_{ik} - \mu_i)^2 + \sum_{k=1}^{K} \pi_k \sigma_{ik}^2$$

where μ_{ik} and σ_{ik}^2 correspond to the mean and variance of the variable i and latent profile k, and π_k represents the probability of belonging to such profile. Next, we can calculate individual posterior probabilities for each respondent by looking at the estimated mean and variances of each profile and the observed individual continuous variables used in the analysis (Oberski, 2016).

In the following, we use the term "classes" to refer to the different segments identified (not to be confused with a Latent Class Analysis). It is important to note that these methods estimate the probability of belonging to each class – a probabilistic assignment – rather than making a definite assignment as in clustering methods. As a result, all the analyses presented in this study are based on the calculations of such probabilities.

Considering the class membership probabilities, we continue our analysis targeting the three research questions presented above. First, we investigate sociodemographic profiles in order to characterise and compare the different classes. Second, based on the residential location of each individual, we compare the spatial characteristics of each class as well as differences in accessibility. Third, we focus on zero-car households to determine if they more likely correspond to a car-free or car-less situation and compare their class membership differences. The methodological framework is summarised in Fig. 1.

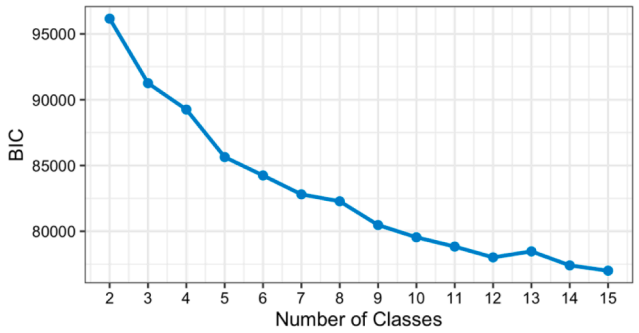
3. Confirmatory factor and latent Profile analyses results

The Confirmatory Factor analysis resulted in a structure consisting of ten factors. These factors are related to the (i) convenience of cars, (ii) experience of driving, (iii) social status of car owners, (iv) own-car ideas, (v-ix) opinions on each of the five modes and (x) attitude to modal prestige. In general, car convenience is associated with ideas such as freedom, safety and how cars facilitate daily and personal activities, while driving experience is associated with the sense of control and adrenaline during driving. The social status factors are related to how people feel about having a car and the image it conveys to others, and the own-car ideas factor bundles those statements that pertain specifically to the possession of a car. Finally, there are five factors with similar characteristics, in which each respondent evaluates a series of seven attributes for the five different modes included in this study (as explained in Section 2.1), while the prestige attributes are collected in the final factor. A complete list of statements that are loaded into each factor can be found in the appendix.

This Confirmatory Factor model used is a special case of an Exploratory Factor model. The latter suggested a structure of 13 factors. Among those, seven were exactly identical to those in our confirmatory model (the four car-related factors, the opinion of cars and bikes, and the prestige factor). The other six were splits of the three remaining in our model. For example, statements about the train and the bus time saving and flexibility formed one additional factor, and walking time saving constituted a factor by itself. We propose merging these factors into the structure described in the previous paragraph. As can be seen in Table 2, the measures of fitness are almost unchanged (differences of approximately 0.7 %) given the considerable reduction in the number of factors. Consequently, we choose to opt for this simplified structure, which will facilitate the next series of analyses.

Table 2
Statistical comparison between the exploratory and confirmatory factor model results.

Model	Number of factors	Loglikelihood	AIC	BIC
EFA	13	−134,159.6	268741.2	269917.7
CFA	10	−135,246.7	270851.5	271849.6



N. Classes	Smallest class	BIC decrease
3	17%	-5.1%
4	11%	-2.2%
5	13%	-4.1%
6	2%	-1.6%
7	2%	-1.7%
8	4%	-0.6%

Fig. 2. Share of the smallest class and BIC decrease for different number of classes.

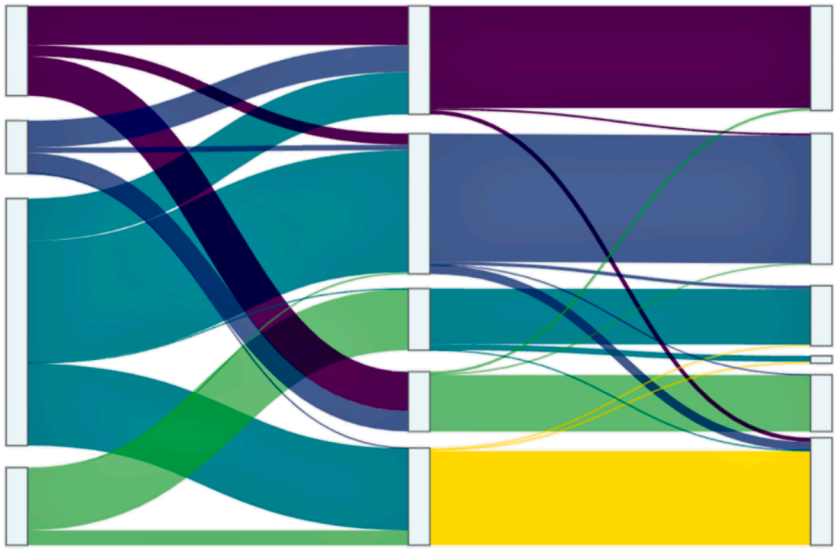


Fig. 3. Class assignment distribution when modifying the number of classes between four and six.

3.1. Number of classes

Taking these 10 factors, we estimate several classification models for different number of classes. We select a five classes model for three particular reasons: first, the marginal decrease in BIC goes under 2 % when increasing to six classes. Second, the share of the smallest class is considered reasonable (~13 %) compared to the model with six classes (~2%), as can be observed in Fig. 2.

Third, we investigate how individuals are assigned to different classes with an increasing number of classes. Fig. 3 shows the distribution of these assignments. We observe that a model with four classes appears unstable, with many segments splitting to form new segments when we increase the number of classes to five. However, when we increase the number to six, we only see minor changes, including a new class comprising of only 2 % of the sample formed as a split from class number three.

3.2. Five classes model results

Overall, the five different classes vary in the way they relate to cars. We arrange them so that the their attitudes towards cars become increasingly positive from left to right. We name these five classes "*car detractors*", "*car hesitants*", "*car positives*", "*car friends*", and "*car lovers*", respectively. These names are based on the distribution of the ten different factors, which can be seen as in the estimated mean and variances for each variable and class in Table 3. We impose a class-invariant parametrisation in which the estimated variances are equal across classes. Overall, we see how mean values for car-related attitudes move from more negative to more positive when moving from *car detractors* to *car lovers* in the case of "Car convenience", "Own car ideas", and "Car opinion". While observing that the highest estimates are associated with *car lovers*, the trend is however erratic for "Driving Experience" and "Car-owning social status. In addition, we see how the vast majority of factors means and variances are highly significant, with the only exceptions being "Bike opinion" for *car lovers* and "Own car ideas", "Car opinion", and "Train opinion" for *car positives*.

When we calculate the expected share of these five classes, we see a bell-shaped distribution centred around the third class, "*car*

Table 3
Estimated mean and variance for each variable and latent class and goodness of fit indicators of the Latent Profile Analysis.

	Detractors		*Hesitants*		*Positives*		*Friends*		*Lovers*	
Car Convenience	μ_{ik}	−1.037 (****)	μ_{ik}	−0.165 (****)	μ_{ik}	−0.105 (****)	μ_{ik}	0.538 (****)	μ_{ik}	0.612 (****)
	σ^2_{ik}	0.059 (****)	σ^2_{ik}	0.059 (****)	σ^2_{ik}	0.059 (****)	σ^2_{ik}	0.059 (****)	σ^2_{ik}	0.059 (****)
Driving Experience	μ_{ik}	−0.028 (***)	μ_{ik}	−0.293 (****)	μ_{ik}	0.102 (****)	μ_{ik}	−0.079 (****)	μ_{ik}	0.443 (****)
	σ^2_{ik}	0.047 (****)	σ^2_{ik}	0.047 (****)	σ^2_{ik}	0.047 (****)	σ^2_{ik}	0.047 (****)	σ^2_{ik}	0.047 (****)
Car-owning social status	μ_{ik}	0.074 (****)	μ_{ik}	−0.453 (****)	μ_{ik}	0.205 (****)	μ_{ik}	−0.253 (****)	μ_{ik}	0.699 (****)
	σ^2_{ik}	0.127 (****)	σ^2_{ik}	0.127 (****)	σ^2_{ik}	0.127 (****)	σ^2_{ik}	0.127 (****)	σ^2_{ik}	0.127 (****)
Own car ideas	μ_{ik}	−0.799 (****)	μ_{ik}	−0.337 (****)	μ_{ik}	−0.020 (ns)	μ_{ik}	0.352 (****)	μ_{ik}	0.809 (****)
	σ^2_{ik}	0.078 (****)	σ^2_{ik}	0.078 (****)	σ^2_{ik}	0.078 (****)	σ^2_{ik}	0.078 (****)	σ^2_{ik}	0.078 (****)
Car opinion	μ_{ik}	−0.569 (****)	μ_{ik}	−0.327 (****)	μ_{ik}	0.014 (ns)	μ_{ik}	0.310 (****)	μ_{ik}	0.545 (****)
	σ^2_{ik}	0.122 (****)	σ^2_{ik}	0.122 (****)	σ^2_{ik}	0.122 (****)	σ^2_{ik}	0.122 (****)	σ^2_{ik}	0.122 (****)
Train opinion	μ_{ik}	0.149 (****)	μ_{ik}	0.076 (***)	μ_{ik}	0.007 (ns)	μ_{ik}	−0.060 (*)	μ_{ik}	−0.191 (****)
	σ^2_{ik}	0.372 (****)	σ^2_{ik}	0.372 (****)	σ^2_{ik}	0.372 (****)	σ^2_{ik}	0.372 (****)	σ^2_{ik}	0.372 (****)
BTM opinion	μ_{ik}	0.226 (****)	μ_{ik}	−0.001 (ns)	μ_{ik}	0.063 (****)	μ_{ik}	−0.126 (****)	μ_{ik}	−0.146 (****)
	σ^2_{ik}	0.302 (****)	σ^2_{ik}	0.302 (****)	σ^2_{ik}	0.302 (****)	σ^2_{ik}	0.302 (****)	σ^2_{ik}	0.302 (****)
Bike opinion	μ_{ik}	−0.130 (****)	μ_{ik}	0.063 (***)	μ_{ik}	−0.048 (**)	μ_{ik}	0.071 (****)	μ_{ik}	0.007 (ns)
	σ^2_{ik}	0.264 (****)	σ^2_{ik}	0.264 (****)	σ^2_{ik}	0.264 (****)	σ^2_{ik}	0.264 (****)	σ^2_{ik}	0.264 (****)
Walk opinion	μ_{ik}	−0.139 (****)	μ_{ik}	0.039 (*)	μ_{ik}	−0.073 (****)	μ_{ik}	0.097 (****)	μ_{ik}	0.068 (*)
	σ^2_{ik}	0.269 (****)	σ^2_{ik}	0.269 (****)	σ^2_{ik}	0.269 (****)	σ^2_{ik}	0.269 (****)	σ^2_{ik}	0.269 (****)
Prestige	μ_{ik}	0.139 (****)	μ_{ik}	−0.364 (****)	μ_{ik}	0.256 (****)	μ_{ik}	−0.254 (****)	μ_{ik}	0.360 (****)
	σ^2_{ik}	0.314 (****)	σ^2_{ik}	0.314 (****)	σ^2_{ik}	0.314 (****)	σ^2_{ik}	0.314 (****)	σ^2_{ik}	0.314 (****)
Latent Profile Analysis Fit indicators										
Final Log Likelihood					−42512					
AIC					85,164					
BIC					85,638					
Entropy (Reverse coded)					0.848					

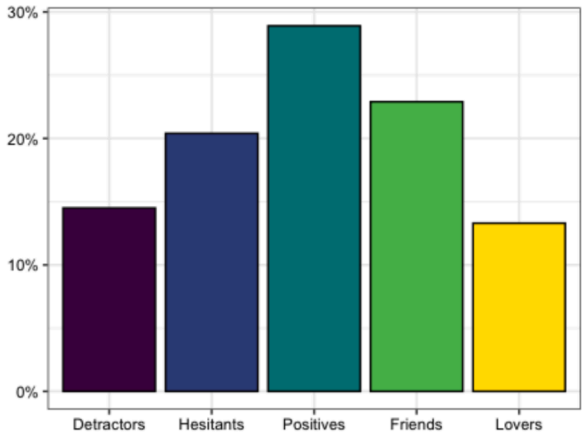


Fig. 4. Classes' shares of sample respondents.

positives", as presented in Fig. 4. However, if we consider that each individual is assigned to the class with the highest probability, we see that the vast majority – 83 % and 70 % – of individuals that are, respectively, labelled as *car detractors* or *car lovers* have a membership probability in the excess of 95 %. This is significantly higher than the case for the other classes where probabilities that high only account for about 50 % of their members. This result suggests that even though *car detractors* and *car lovers* are the classes with the smallest shares, their composition fundamentally differs from that of the remaining classes.

In Fig. 5, we present the 10th to 90th quantile range (grey line), the 25th and 75th quantile range (blue line), and the average (bullet) for each attribute and each class. The ten different factors obtained through the Confirmatory Factor analysis have the property that their respective average over the entire sample is fixed and equal to zero, denoted through a red dotted line in the figure. This property eases the comparison and allows us to identify differences among the latent classes. We also calculate and display the z-value for each attribute and class, assuming the null hypothesis of the mean being zero. We highlight in bold the z-values which imply significant differences from the sample average at the 95 % confidence level. It is important to highlight that these z-values are intended to aid the visual analysis, as the mean and variance values for each Latent Profile were already presented in Table 3.

In general, we find that car convenience and attitudes towards both private cars and cars in general become more positive as we move from *car detractors* to *car lovers*. *Car detractors* report a particularly low value for car convenience and both general car opinions as well as opinions towards their own car. These attributes are observed to be significantly higher amongst the other four classes.

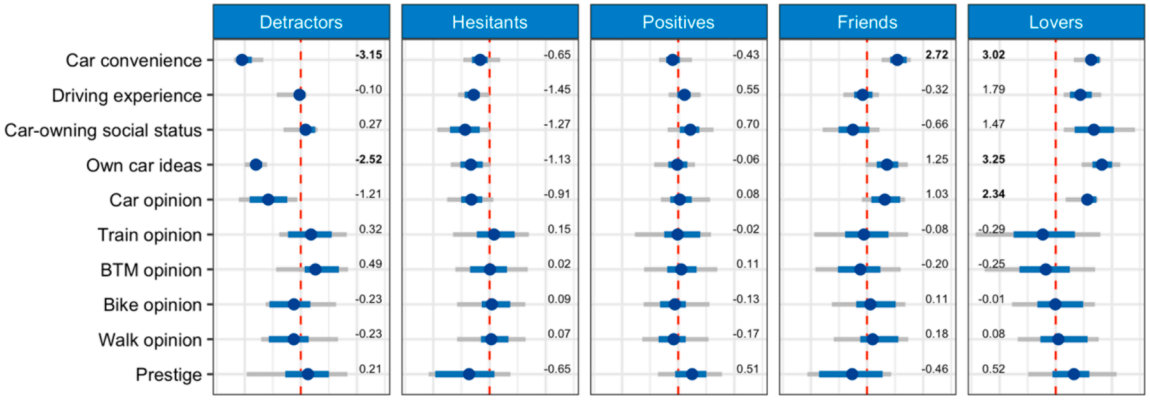


Fig. 5. Factors distribution and share for each class.

However, there are no significant differences between *car detractors* and the overall sample with respect to driving experience and social status. Although not significantly different from the sample average, we observe that this class exhibits the highest appreciation for both trains and BTM among the different classes. *Car hesitants* exhibit negative attitudes toward cars, but to a lesser degree than *car detractors*. However, they have more negative attitudes towards the driving experience, social status, and the relevance of prestige factors. Together, these two classes make up 35 % of the sample.

In addition, the distribution of these five classes is centred around what we denoted as *car positives*, as these individuals hold slightly positive attitudes towards driving experience, car-owning social status, and also towards modal prestige. This fact suggests that this class of users have a positive impression of what owning and using a car means. Interestingly, we found no significant differences between this class and the sample for any of the attributes.

The *car friends* segment exhibits significantly more positive attitudes towards car convenience and car opinions compared to the other three classes already described and the sample as a whole. However, they do not share this positive attitude towards driving and social status, suggesting a potential willingness to consider alternative modes if they are similarly convenient. Conversely, *car lovers* display very positive attitudes towards cars across all variables and report more negative impressions of other modes, particularly trains and buses. These two classes together make up for just over 36 % of the sample, and when including the more neutral but still pro-car *car positives* class, they account for 65 % of the sample.

4. Sociodemographic analysis

In this section we analyse the socio-demographic composition of each identified latent class. To aid our analysis, we use Fig. 6 to present the distribution of 13 attributes for each class, with a colour code indicating the percentage-wise difference from the sample average. This visualization facilitates the identification of those attributes' levels that are either under- or over-represented in each class. Looking at Fig. 6a and 6b, which show *car detractors* and *car hesitants*, respectively, we see that there are no gender differences for *car detractors*, but women are overrepresented amongst *car hesitants*. The share of people older than 60 years old in both classes and younger people in the case of *car detractors* is higher than in the sample as a whole. Both classes have a higher proportion of people who own a public transport card and fewer who never use bike as a means of transportation. Most *car detractors* do not own a car, whereas households who have only one car are overrepresented in the *car hesitants* class. In terms of car access, *car detractors* tend not to have a driving license, while households who have a car available but not freely accessible are overrepresented amongst *car hesitants*. Both *car detractors* and *car hesitants* are characterized by a higher proportion of smaller households: with one and two persons per household, respectively. Regarding the central class, *car positives*, there is no evident difference between their socio-demographical distribution and the sample's average (Fig. 6c).

Fig. 6d and 6e present the socio-demographic characteristics of *car friends* and *car lovers*, respectively. *Car lovers* are predominantly male, while there is no gender difference for *car friends*. Both segments have a higher proportion of working-age people and households with at least two cars, and they also have greater car access than the overall sample. They are also less likely to own a personal public transport card and have a higher percentage of individuals who never bike. *Car lovers* also have a higher share of people who never use the train. There are no significant differences between these classes and the overall sample in terms of their travel distance and travel frequency.

Finally, special attention should be given to the analysis of the relationship between car-use levels and different attitudinal profiles, as it is not clear if attitudes cause behaviour, if it is the other way around, or even if the two relationships coexist (Kroesen et al., 2017). While this is true for any mode of travel, this concern is particularly pronounced in the context of cars, where not only usage but also ownership intertwines with associated motives and attitudes (Moody & Zhao, 2019; Soza-Parra & Cats, 2023). If these variables are incorporated as covariates, there is a risk of endogeneity and related estimation issues. In our study, individuals are classified solely based on their attitudinal responses. Therefore, the analysis presented serves as a depiction of the sample situation and offers insights into potential causal relationships rather than a conclusive proof.

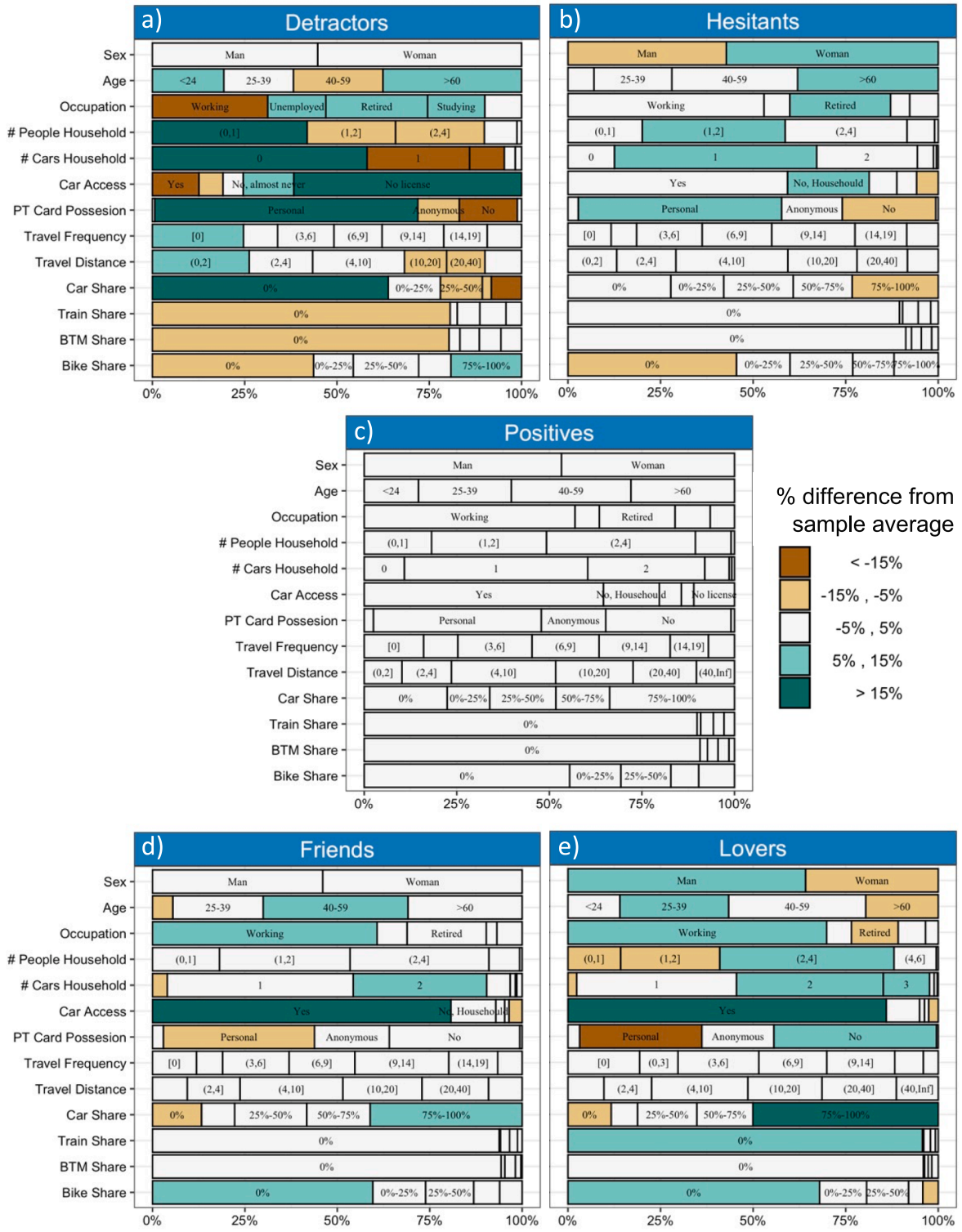


Fig. 6. Socio-demographic characterisation of a) *car detractors*, b) *car hesitants*, c) *car positives*, d) *car friends*, and e) *car lovers*.

5. Spatial analysis

The previous analysis does not take into account where each individual lives. Therefore, we next examine the spatial distribution of the five latent classes across the Netherlands and how various urban environment variables vary across classes. This analysis is

Table 4
Average and 10th to 90th quantile range of the distance to different locations for each the classes.

Distance to	Detractors	Hesitants	Positives	Friends	Lovers
Urban area [km]	15.06	15.35	17.07	16.39	18.56
	(1.7–35.1)	(2.2–35.0)	(2.5–37.1)	(2.8–35.4)	(3.3–38.3)
Train station [km]	3.07	3.55	3.87	3.79	4.09
	(0.5–7.8)	(0.6–8.9)	(0.7–9.5)	(0.7–8.8)	(0.7–9.6)
Metro, express tram stop [km]	50.10	48.36	53.62	51.25	58.83
	(0.9–132.4)	(1.6–122.8)	(2.0–128.0)	(2.0–125.4)	(2.3–133.4)
Tram stop [km]	54.37	53.857	59.09	57.36	64.50
	(0.4–134.7)	(2.1–128.4)	(2.6–130.6)	(3.3–129.8)	(4.6–138.9)
Bus stop > 4/hr [km]	1.07	1.26	1.48	1.48	1.71
	(0.1–2.7)	(0.1–3.3)	(0.2–4.2)	(0.2–4.4)	(0.2–5.4)
Bus stop > 2/hr [km]	0.46	0.55	0.61	0.61	0.66
	(0.10–0.83)	(0.11–1.58)	(0.11–1.31)	(0.11–1.35)	(0.11–1.38)
Bus stop > 1/hr [km]	0.30	0.35	0.35	0.36	0.35
	(0.09–0.52)	(0.10–0.59)	(0.10–0.60)	(0.10–0.61)	(0.10–0.66)
Bus stop [km]	0.28	0.31	0.31	0.31	0.31
	(0.09–0.48)	(0.10–0.52)	(0.10–0.54)	(0.10–0.55)	(0.10–0.58)

important as we expect that the factors that influence car usage affinity will vary depending on the built environment conditions. We calculate the distance between all households and the nearest urban area, train station, metro or express tram stop, tram stop, and bus stop (based on different frequency thresholds) and then average those based on class membership rates. The results of this analysis are presented in Table 4.

The proximity of households to urban areas and public transport facilities varies depending on the degree of affinity with cars. Even though the intervals are not significantly different, *car detractors* and *car hesitants* tend to be closest to urban areas, followed by *car positives* and *car friends*, while *car lovers* tend to reside farther away. In terms of distance to the closest train station, *car lovers* are, on average, one kilometre (+33 %) farther away than *car detractors*. The situation is different for metro and tram stops, as *car lovers* are significantly farther away from these facilities, while the other classes are comparatively closer to each other. Regarding bus stops, the frequency threshold is an important factor. Although there are no major differences between the classes for any bus stop, *car detractors* are significantly closer to high-frequency bus stops. This distance increases, as expected, for the other classes, particularly for *car lovers*. In addition, it is important to highlight that these differences between class averages are fairly limited. Examining the range between the 10th and 90th provides a more complete impression of the differences between classes. As an example, individuals in the 90th

Table 5
Responses distribution for different urban variables for each of the classes.

Urban variable		Detractors	Hesitants	Positives	Friends	Lovers
UrbanizationLevel	Non urbanized	6.5%	7.3%	8.5%	9.2%	11.5%
	Low	15.9%	20.7%	23.2%	22.1%	24.4%
	Moderate	15.2%	17.3%	19.2%	18.3%	17.6%
	High	33.7%	31.0%	30.1%	32.0%	31.7%
	Very High	28.8%	23.7%	19.0%	18.4%	14.9%
My neighbourhood has a sufficient number of parking places	Strongly Disagree	5.7%	4.5%	3.8%	5.5%	5.5%
	Disagree	15.0%	15.4%	14.1%	14.9%	16.1%
	Neutral	18.1%	13.2%	13.4%	13.1%	11.7%
	Agree	32.6%	36.8%	39.2%	29.0%	23.6%
	Strongly Agree	24.0%	30.0%	29.0%	37.4%	42.6%
	Unknown	4.6%	0.1%	0.5%	0.1%	0.5%
My neighbourhood is easily accessible by car	Strongly Disagree	1.6%	1.1%	0.9%	1.1%	1.1%
	Disagree	4.1%	2.0%	1.9%	1.4%	2.1%
	Neutral	12.9%	4.0%	3.4%	2.3%	2.1%
	Agree	39.7%	38.9%	41.0%	20.8%	19.7%
	Strongly Agree	37.8%	54.0%	52.5%	74.4%	74.7%
	Unknown	4.0%	0.0%	0.2%	0.0%	0.4%
My neighbourhood is easily accessible by bicycle	Strongly Disagree	1.3%	0.9%	0.6%	0.5%	0.7%
	Disagree	2.0%	1.0%	1.6%	0.8%	1.4%
	Neutral	8.4%	0.9%	1.4%	0.8%	1.6%
	Agree	34.2%	31.5%	37.9%	16.9%	17.7%
	Strongly Agree	52.9%	65.5%	58.1%	80.7%	78.2%
	Unknown	1.2%	0.1%	0.4%	0.3%	0.4%
My neighbourhood is easily accessible by Public Transport	Strongly Disagree	5.6%	7.2%	5.3%	8.9%	7.9%
	Disagree	9.3%	13.1%	14.6%	14.2%	10.8%
	Neutral	16.8%	15.0%	16.7%	15.3%	17.4%
	Agree	37.8%	37.4%	38.4%	27.9%	27.1%
	Strongly Agree	29.1%	26.7%	23.4%	32.2%	35.0%
	Unknown	1.5%	0.6%	1.6%	1.5%	1.8%

percentile of *car lovers* tend to reside approximately 2 km farther from train stations and about 3 km farther from high-frequency bus stops compared to those in the 90th percentile of *car detractors*. In summary, we observe that the farther away households tend to be located from urban areas and public transport facilities the greater the affinity with cars, and vice-versa.

We are also interested in the urbanization level characterizing households place of residence and also the respondents' perceptions about parking and accessibility in their neighbourhoods. These results are presented in Table 5. The urbanization level varies from non-urbanized to very highly urbanized, while the scale used by respondents to indicate their opinions varies from strongly disagree to strongly agree.

It can be observed that *car detractors* and *car hesitants* are more likely to live in highly- and very highly-urbanized areas, while *car friends* and *car lovers* are more likely to live in non– or low-urbanization areas. It is important to make this type of relative comparison between classes because most people live in urbanized areas, which also applies to those with greater levels of affinity towards cars. In addition, we see that the differences between classes arise from the difference in how they strongly agree or disagree with the different statements rather than from those (moderately) agreeing or disagreeing in general. Once one sums up the agree and disagree groups, the joint shares do not vary much across different classes. In the case of parking facilities, respondents' answers are generally similar, except for *car friends* and *car* lovers who strongly agree more frequently with the statement that there are enough parking spaces in their neighbourhoods. When asked about accessibility by car, a considerable gap can be observed between car lovers and other classes. About 75 % of *car lovers* or *car friends* strongly agree that their neighbourhood is easily accessible by car, while this figure drops to under 40 % for *car detractors*. A similar trend is observed for bike accessibility, where approximately 80 % of *car friends* and *car lovers* strongly agree that their neighbourhood has good bike accessibility, whereas only 53 % of *car detractors* do. As for public transport, the only notable difference is that *car detractors* are more likely to agree that their neighbourhood should be easily accessible.

Following our previous analysis of urban environment areas, we now turn to investigate the extent of spatial disparities in relation to our classes, i.e. if it is possible to identify regions where certain classes are more likely to reside. Fig. 7 shows the classes composition in each of the 12 Dutch provinces.

The results indicate that the proportion of *car detractors* and *car lovers* differs significantly between the provinces, with the share of *car lovers* being lowest in the western and more urbanized provinces of Noord and Zuid Holland and Utrecht. Notably, the province of

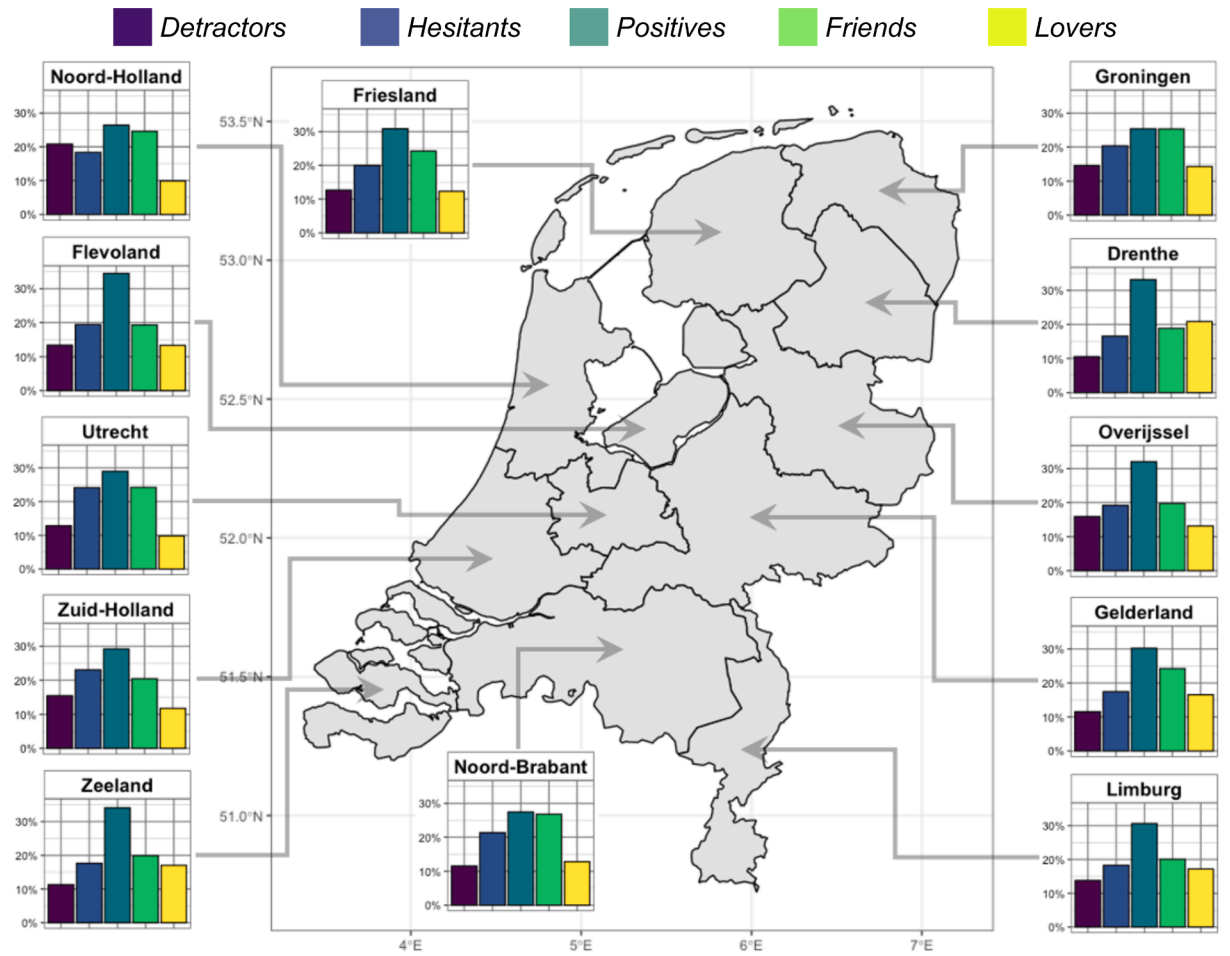


Fig. 7. Latent classes distribution across the 12 provinces of the Netherlands.

Noord Holland, which includes the city of Amsterdam, stands out as having the highest share of *car detractors*. Amsterdam accounts for around one-half of the province's population and *car detractors* take up in Amsterdam a share of 27.5 % (compared to 14.5 % for the sample as a whole). In the eastern part of the country, we find a higher percentage of *car friends* and *car lovers*, especially in the provinces of Drenthe, Limburg, and Gelderland. This is not surprising because these provinces are more rural and have a smaller proportion of large urban areas.

In order to deepen such analysis, we now focus exclusively on the share of *car detractors* and *car lovers* in different areas of the country. To do so, we overlay a hexagonal grid of ~ 16 km of width over the study area and calculated for each hexagon the likelihood of belonging to each of these two classes. The results are presented in Fig. 8, in which we present the likelihood difference between *lovers* (positive difference) and *detractors* (negative difference). Hexagons with fewer than 30 respondents are excluded, and we also plot in red those cities with at least 95,000 inhabitants, whose population is represented by the size of each circle. The general trend that can be observed is that areas with a higher proportion of *car detractors* are indeed located closer to cities, while the opposite happens for *car lovers*, who are more likely to be farther away. Still, there are exceptions to these overall trends, as well as areas with low shares of both, suggesting a higher presence of the three central classes, i.e., *car hesitants, car positives, and car friends.* A more careful and granular analysis could potentially find reasons for these geographical differences but may require more representative data in small areas and associated methodologies.

As a final spatial analysis, we are interested in looking at whether residential locations for the two previously analysed classes – *car detractors* and *car lovers* – vary within a given region. As discussed when looking at Fig. 7, Nord-holland is the region with the highest share of *car detractors,* heavily influenced by the presence of Amsterdam. Thus, we zoom-in on the Amsterdam Metropolitan Region to study the likelihood of each respondent being a *car detractor* or a *car lover*. Fig. 9 shows the probability of being a *car detractor* (left) or a *car lover* (right) associated with the size and opacity of each circle; larger and darker circles represent a higher likelihood. The maps are centred around Amsterdam, which has a high concentration of *car detractors*, but we also observe that some respondents with a high likelihood of being *car lovers* live within the metropolitan area and even the city boundaries, albeit primarily in less central areas. The same trend is observed in other cities within the region, where highly likely *car lovers* tend to live further away from Amsterdam. In particular, to the east of Amsterdam lies the city of Almere, which is located in the province of Flevoland and was planned in the 1970 s as a family-oriented satellite suburb of Amsterdam. Since then, the population started to grow and is now in the excess of 200,000 inhabitants. These characteristics, together with the predominantly car-oriented planning practices which characterise its development might be the reason for observing a higher likelihood of *car lovers* in the area. This is in line with the bi-directional relation between attitudes and behaviour (Kroesen et al., 2017), which also applies to residential location (Ettema & Nieuwenhuis, 2017), which makes it hard to disentangle if their attitudes were developed because of their residential (re-)location or if they decided to relocate because of their attitudes.

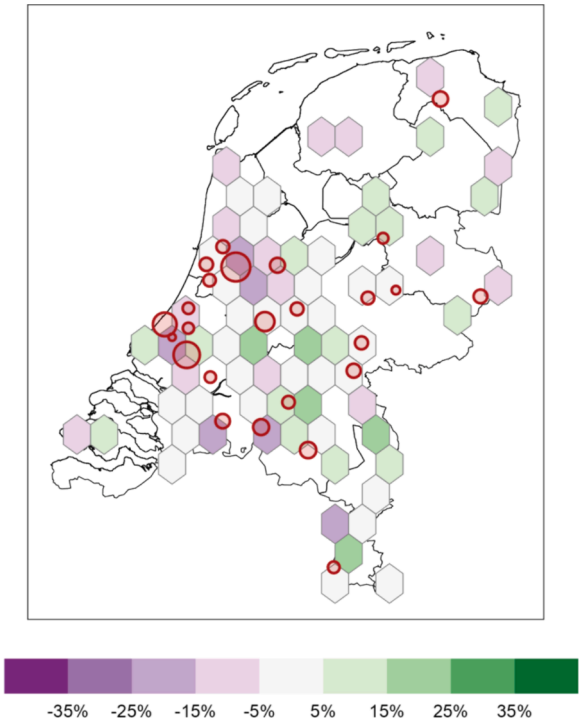


Fig. 8. Share difference of *car lovers* and *car detractors* over a hexagonal grid across the Netherlands.

Fig. 9. Likelihood and location of *car detractors* (left) and *car lovers* (right) around the Amsterdam Metropolitan Area.

6. Car-free v/s car-less

In this section, we investigate the characteristics of zero-car households. In particular, we are interested in identifying the differences between car-free and car-less, where the former represents those households who do not have either monetary or physical barriers to using a car but nevertheless decide not to own one, whereas the latter represents those that do not own a car because they cannot afford it or have some personal restrictions that inhibit them from using it. We make this distinction using three different questions: (i) the number of cars in the household, (ii) if health is or is not an issue to drive, and (iii) the household income. A household is considered car-free if it has zero cars, health is not a barrier, and their household income is equal to or larger than € 28,600, which is defined as the benchmark income in the Netherlands by the Central Bureau of Statistics (CBS). Conversely, a household is denominated car-less if it has zero cars and if either its members are unable to drive due to health reasons or its income is lower than the benchmark. When one of these questions is not answered, the household is assigned into the unknown category. In our sample, this categorization leads to 20 % of the households that do not own a car being identified as car-free (3 % of all households) and 61 % of those being car-less households (9 % of all households). In other words, for every car-free household there are about three car-less household in our sample. We note however that our classification is likely to overestimate the share of car-less household relative to the share of car-free households for two reasons: first, in case of missing information, the households are categorized as unknown even when one of the dimensions satisfies the car-free criteria, and second, there is no information regarding actual intentions regarding car use, which means that households that are currently labelled as car-less may not desire to own a car, and thus they should be considered car-free. In Fig. 10 we present how these two groups are distributed over the five latent classes as well as how the respective distributions of the 10 attitudinal factors.

When examining the latent class distribution, we see how both car-free and car-less have low shares of being *car friends* or *car lovers*. However, there is a clear difference with respect to the *car detractors* class, where car-less are much more prone to fall into this category. This is an interesting result as one could argue that car-free are those with more of a choice to make, which is not reflected in the respective share of *the car detractors* class. Nevertheless, the share of those being either *car detractors* or *car hesitants* is significantly higher when compared to the full sample for the case of car-free respondents. Regarding the high proportion of car-less *detractors*, one possible hypothesis could be that the inability to afford or use a car is what makes them more like *car detractors* in the same way a particular context develops attitudes and vice-versa, which is still something that needs to be better understood (Kühne et al., 2018).

In terms of attitudes distribution, we observe no noticeable difference in the distribution of attitudes among the car-free and car-less groups. We then carry out a two-sample *t*-test to determine if the distributions of each attitude are significantly distinct from one another. Among the different attitudes, only the social status factor and the opinion about walking are not significantly different. Still, all the attitudes average values are of a similar magnitude, suggesting attitudes relate more with not owning a car than to the reasons for not owning one. Interestingly, the driving experience attitude is more positive for car-less and even resembles the one observed for *car lovers*. This suggests a conscious decision to abstain from car ownership despite acknowledging the enjoyment of driving.

7. Conclusions, policy Implications, and further research

Based on the analysis of the distribution of ten latent attitudinal factors, we identify five different sub-population classes which vary in terms of car ownership and usage ideas. These classes differ not only in their attitudes' distribution but also in their sociodemographic characteristics. As expected, more positive car attitudes are associated with higher car ownership and access and reduced use of public transport modes. Noticeably, there are no significant differences in terms of travel frequency and trip length distribution, which suggests that the differences stem mostly from modal preference and not from the underlying travel demand patterns and the associated activities. In general, we observe that men are more likely to be more attached to cars than women, everything else being equal. From a policy point of view, it is important to recognise and address the existing diversity in attitudes towards car ownership and use. Developing targeted strategies could potentially, for example, focus on those more prone to a shift to sustainable behaviour (*car positives* or *friends*) and thereby yield a more efficient use of resources.

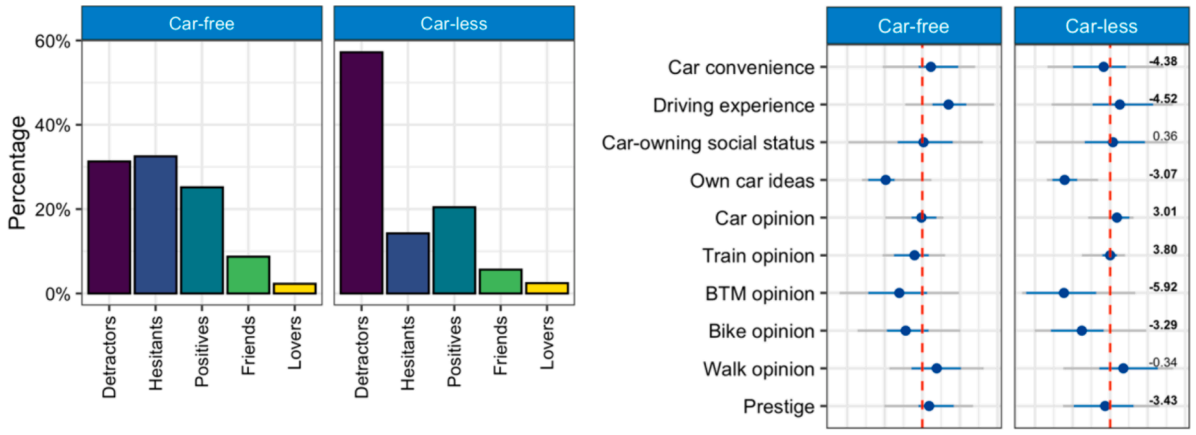


Fig. 10. Class and attitudinal factors distribution for car-free and car-less respondents.

The place where people live and their personal circumstances are also relevant variables when studying car ownership and usage. In summary, we observe that the farther away households tend to be located from urban areas and public transport facilities, the greater their affinity with cars is, and vice-versa. The fact that the classes are easy to describe and characterise is helpful when communicating the implications of different strategies to policy makers. This type of classification could be used to design policies in a more targeted way by focusing, for example, on *car positives* and how to promote a shift to different mobility options as they are more likely to be persuaded. Policies that either aim to restrict or reduce car use should thus acknowledge that not every car user behaves the same: behavioural responses will vary depending on their attitudinal characteristics. It is therefore crucial to recognise the influence of spatial location on car affinity. Policies then could promote alternative transportation and enhance the accessibility to more sustainable ways of transportation particularly in areas distant from urban centres.

The observed classes are such that when moving from one to the other, the changes in attitudes, socio-demographics, and spatial location and accessibility evolve in consistent direction. This suggests that one could incorporate a unique and simplified latent construct, namely a "car value", into different models to help explain car ownership and use but also residential location or other related topics. This idea has been studied in different urban settings (Zhao & Zhao, 2020), and findings suggest that about 50 % of the perceived added value of cars corresponds to attributes not related to the use of the car per se (Moody et al., 2021). Based on our results on classes' attitude distribution, this variable is correlated exclusively with car-related dimensions and not with the opinion towards other modes of transportation. Incorporating latent constructs into projects and policies evaluation still remains however challenging. More research on potential means and the added value of doing so is needed. A potential first step could be to develop a way to measure a simplified construct, such as the mentioned "car value", which could be measured and geographically located. Looking at its evolution and incorporating it into car ownership, modal choice, and residential location models could lead to better policy planning.

Regarding zero-car households, our analysis yields intriguing results. Car-free and car-less characterisation has gained some attention in recent years. Nevertheless, the identification of these groups based exclusively on questionnaire questions is challenging, especially when the car accounts for the majority of trips and is the preponderant mode of transportation in society. The fact that most car-less individuals in our sample are *car detractors* suggests that the absence of a transportation alternative can also develop more negative attitudes towards that mode. One could generalise this result to other contexts where public transport, for example, has poor coverage. In addition, we observe that car-free individuals tend to be associated with the *car detractors* and *car hesitants* classes, as expected, but also with *car positives* (~20 %) and *car friends* (~10 %). It is paramount that policies continue to provide good-quality alternatives for this type of users because otherwise there is a risk of them switching to car-based mobility. Furthermore, policies should also focus on developing positive attitudes to other transportation modes (i.e., public transport), particularly in the case of car-less households. Otherwise, these households could potentially shift straight to the car if their limiting barriers cease and there is no strong bond with their initial mobility choice.

While our study provides valuable insights about attitudinal classes affecting car ownership and use, several limitations should be pointed out. Self-reported survey data might introduce potential respondent bias, particularly in terms of social desirability, and its cross-sectional nature limits our ability to establish causal relationships. In addition, the results might be heavily influenced by the local context and culture, and thus it is hard to generalise our findings to different regions. Furthermore, the latent attitudinal profiles, while useful, may not fully capture the complexities of transportation choices nor the dynamic interplay between urban development policies and transportation behaviour. A qualitative approach could prove complementary in understanding the aforementioned phenomena in greater detail.

Future research may also explore the use (or combination with) qualitative methods to understand better the nuances of car ownership and car use. For example, focusing on groups of people who hold negative attitudes towards cars but don't have sufficient access to alternative modes of transportation could be interesting as these individuals may feel that they have no other choice but to rely on cars, even though they would prefer not to. Understanding their reasons for preferring different mobility options, their residential location, barriers, and possible dissonance exclusively through questionnaires or stated preferences is difficult. By conducting

interviews and focus groups, we believe one can get valuable insights regarding how to identify and address the barriers that prevent people from choosing more sustainable transportation options.

CRediT authorship contribution statement

Jaime Soza-Parra: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Oded Cats:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, 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

Confirmatory Factor Analysis statements in each factor

Car convenience	Own car ideas
The car gives me a feeling of freedom	I love my car
The car makes my life easier	I feel safe in my car
The car offers me protection against bad weather	My car suits me
The car offers privacy	My car is always available
By car I can easily visit friends and family	Thanks to my car, I am not dependent on others
I use the car for outings and holidays	I regularly use my car to pick up or drop others off
The car makes it easy to take stuff with you	
The car gives me the freedom to go wherever I want	**Mode X opinion (for each of the five modes)**
By car I can plan my own route	Personal impression of the Mode X
	I find Mode X to be comfortable
Driving experience	I find Mode X to be relaxing
When I'm behind the wheel, I have a sense of control	Mode X saves me time
I like to drive fast	Mode X is safe
Driving a car is my hobby	I find Mode X to be flexible
Driving a car gives me a kick	Mode X is pleasurable
Driving a car is sporty and adventurous	I only use the car when it is really necessary (only for bikes)
Car-owning social status	**Prestige attitude**
A car says a lot about someone's status in society	Travelling must give me prestige
I like driving a nice car	Travelling by car gives me prestige
I like the engine sound of my car	Travelling by train gives me prestige
With my car I can distinguish myself from others	Travelling by bus, tram or metro gives me prestige
My car is a means to express myself to others	Cycling gives me prestige
	Walking gives me prestige

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