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Perceived car dependence and multimodality in urban areas in Flanders (Belgium)

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In this study, we test the extent to which people who reside in hypothetically car-independent neighbourhoods travel multimodally and perceive themselves as car dependent. We used the Flemish region as our study case, and defined a car-independent neighbourhood as an area with a high node and a high place value. A cluster analysis with four constituent variables – car use frequency, bicycle use frequency, vehicle kilometers travelled (VKT) and the need for a car to carry out daily activities - led to defining four heterogeneous groups of car owners. We labelled the groups as car-dependent motorists - long distance, car-dependent motorists - short distance, car-independent cyclists and car-dependent cyclists. We found all clusters to be to some extent multimodal. For our selected study area, car ownership does not necessarily induce perceived car-dependence among people who can easily get around by bicycle. Nevertheless, even in an urban setting and when exhibiting multimodal travel patterns, people can perceive their car as indispensable. Perceived car dependence is not necessarily correlated with high VKT or high frequency of car use, neither can we conclude that multimodal behaviour necessarily leads to less VKT.

Keywords: *car dependence, cluster analysis, Flanders, multimodality, transport policy*

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1. Introduction

The private car remains the main mode of personal transport in the EU (Eurostat, 2021; Fountas et al., 2020) and despite the considerable benefits that come with reducing motorized traffic, car ownership in the EU increases. In 2019, the European Union car fleet grew by 1.8% compared to 2018, with the number of cars on the road reaching 242.7 million (ACEA, 2020). In addition, car ownership has increased from 2015 to 2019 from 553 to 569 cars per one thousand inhabitants (ACEA, 2020). It goes without saying that car owners are not a homogenous group, and as early as in 1995 Goodwin commented that there is no such thing as an 'average driver'. Indeed, the figures mentioned hide variations in travel patterns and mode use. Against this backdrop, multimodality is increasingly gaining attention. Multimodality is most commonly defined as the use of at least two modes during a specific time period (Kuhnimhof et al., 2006; Buehler and Hamre, 2015; Nobis, 2010; Kroesen and Van Cranenburgh, 2016). By using clustering techniques to profile respondents based on their mode choices within a given time, researchers illustrated the variability of behaviour not only between, but also within individuals. It is found that multimodality is more prevalent in areas with higher population densities (Nobis, 2007; Heinen, 2018; Heinen & Mattioli, 2019). Buehler and Hamre (2015) discuss the presence of a continuum of mobility types, ranging from monomodal car users to multimodal car users and people who only walk, cycle, or use public transport. In the same vein, Kroesen and van Cranenburgh (2016) identified, based on a German dataset, three mobility styles that can be placed on a scale from mono- to multimodal: habitual travellers, car (in)dependent choice travellers, and car users with an alternative mode preference. For The Netherlands, Molin et al. (2016) found that all identified groups were to some extent multimodal, due to the bicycle as a widely used mode of transport. Nobis (2007) drew a similar conclusion and reported a strong correlation between high car availability and monomodality, and thus very one-sided car-based travel patterns. Also, Heinen & Mattioli (2019) concluded that having fewer cars in the household is associated with higher levels of multimodality. These outcomes correspond with findings established by research that assesses the impact of car ownership on travel behaviour. According to Jones (2011), car ownership unlocks a 'ratchet effect': a process that builds up over time and makes households increasingly locked into travelling by car. Cullinane et al. (2003) found that, despite the presence of an excellent public transport offer, once people in Hong Kong have acquired a car, they consider it to be a necessary part of their lifestyle and become dependent on it for most trip purposes. Dargay (2001) yielded a similar result: in the UK, a rising income makes it easier for a household to acquire a car, but this leads to path dependence; once income levels drop, households are reluctant to relinquish the car. Moody et al. (2021) found that the total benefits of car ownership and use are estimated to be higher than effective car-related expenses. These benefits include flexibility, privacy and status. Also, Nolan (2010) and Van Acker and Witlox (2010) found evidence for the hypothesis that once people own a car, they tend to use it for a considerable number of journeys and evolve towards a car-dependent lifestyle. Moreover, Mattioli et al. (2020) stress that the presence of a hegemonic 'car culture' encourages people to drive even if there are other – cheaper or faster – modes available. In the same vein, Kent (2014:114) describes how, for many people, "*a shift away from the car is an imposition on notions of freedom and entitlement*".

Car dependence of individuals may be composed by two elements: the absolute need for a car, and the perception of reliance on a car. As Farrington et al. (1998) argued, in the case of 'structural' car dependence there is absolutely no reasonable alternative for the car available. In the case of 'conscious' dependence, alternative transport modes are present but are not actively considered (Farrington et al., 1998). Lucas (2009) labelled this distinction as perceived versus actual car dependence. Also, Wiersma (2020) refers to the challenge of bridging the gap between potential and actual travel choices. He further distinguishes (based on Jeekel, 2013) between 'subjective dependence', 'occasional dependence' and 'hardcore car dependence'. Others referred to this distinction as objective and subjective car dependence (Zhao, 2011; von Behren et al., 2018). Despite this apparently straightforward classification, reality is less dichotomous. Lucas (2009:6) argues that we are dealing with "*a spectrum of behaviours and a huge degree of subtlety is needed to be employed in determining whether an individual or household is genuinely car reliant or merely wedded to their car because of habits, social norms and other non-physical factors*." Based on research in Tokyo, Ikezoe et al. (2021) conclude that the convenience and flexibility a car offers compared to other modes, cannot be underestimated, and that frequency of car use does not affect the willingness to own a car. For Germany, von Behren et al. (2018; 2021) equally identified this pragmatic stance towards car ownership as a fallback option to ensure mobility. Selzer (2021) concluded the presence of a persistent association of cars with flexibility and comfort, even if the car is not needed for daily mobility. This is in line with Johansson et al. (2019), who found that car-dependent mobility practices are maintained after relocating to a car-reduced neighbourhood.

2. Research goal

This study aims to test the extent to which people who reside in hypothetically car-independent neighbourhoods travel multimodal and perceive themselves as car dependent. Thus far, several attempts to study actual and perceived car dependence have been made. Handy et al. (2005) for instance explored people's own estimation of when they are driving by choice and when they drive out of necessity. Based on focus group research, Lucas (2009) concluded that most people are able to differentiate between car reliance for certain trips and the convenience of having a car. This illustrates that people themselves are well aware of the thin line between actual and perceived car dependence. Also, a range of quantitative geographical studies have been carried out, most of which identify and classify areas that force people into actual car dependence; defined as those areas where a car is the most feasible or fastest transport mode available, providing the best accessibility to most amenities. For instance, Wiersma et al. (2016) questioned how the spatial context shapes conditions for actual car dependence, thereby focusing on the accessibility of daily amenities and jobs. This type of mapping requires a definition of what trip length thresholds are considered acceptable for non-car travel as reasonable alternatives to a car trip. For daily amenities, Wiersma et al. (2016) fixed upper thresholds of 1 km for walking and 2.5 for cycling. With respect to access to jobs, the differences in level of accessibility to jobs within a travel time of 30 minutes between different travel modes were considered. Zhang (2006) measured actual car dependence as the probability that people have the car as the only mode in their choice travel set. In his study on London, Zhao (2011), highlighted car dependence as being characterized by three aspects: subjective car dependence, actual car use, and intent to reduce car use. The study used three indicators to quantify people's subjective car dependence: a self-reported estimation, whether or not other travel modes are considered in the choice set, and the possibility of mode switching. In their comparative study of Berlin, San Francisco and Shanghai, von Behren et al. (2018) explicitly address the dissonance between subjective and objective car dependence. The study considers the subjective dimension of car dependence as a combination of the 'affinity' (whether the respondent finds driving fun, and the respondent's assessment of public transport), and 'perceived need' of car use for daily travel. The objective dimension estimates the extent to which everyday life without a car is feasible.

In summary, the literature on multimodality postulates that people's travel patterns have to be depicted on a continuum. Where individuals situate on that continuum is, among other variables as socio-economics, determined by car availability in the household, the degree of urbanization and the extent to which people identify with the existing car culture. People's perception of car dependence can be treated in a similar respect. However, it is not clear if multimodal travel patterns lead to a lower perceived car dependence. Using cluster analysis, we aim to fill this gap and we explore if and in what way multimodality correlates with perceived car dependence. We hypothesise that the perceived car dependence of people will decrease when their travel pattern is more multimodal.

In the remaining part, the paper introduces the study area and describes the data and methodology. Then we move over to presenting the obtained clusters and their main characteristics. Finally, the discussion and conclusion is concerned with a summary of the outcomes, implications for policy, the limitations of the study and avenues for further research.

3. Study area

The geographical scope of the research are urbanized areas in the Flemish region in Belgium. Belgium is a federal state, divided into three regions: the Flemish Region (Flanders) in the north, the Walloon Region (Wallonia) in the south, and the Brussels-Capital Region in the centre (Figure 1). In 2019, the Flemish region had approximately 6.6 million inhabitants, and an average population density of 484 inhabitants/km^2 (Statistiek Vlaanderen, 2020). The two largest cities located in the Flemish region are Antwerp (500,000 inhabitants) and Ghent (250,000 inhabitants). Furthermore, the region includes ten regional cities (with a population of around 100,000 inhabitants) and a series of smaller urban centres and municipalities. The Brussels Capital Region, which is the largest agglomeration in Belgium with over one million inhabitants, is geographically situated in Flanders, although it is not administratively part of it. On average, 69.6% of the trips in the Flemish region are carried out by car (as a driver or as a passenger), although the car accounts for 82.3% of the Vehicle Kilometres Travelled (VKT) (Janssens et al., 2021). Overall, 12.4% and 11.4% of all trips are carried out respectively by bicycle and on foot. Only 4.5% of all trips are undertaken with public transport (Janssens et al., 2021).

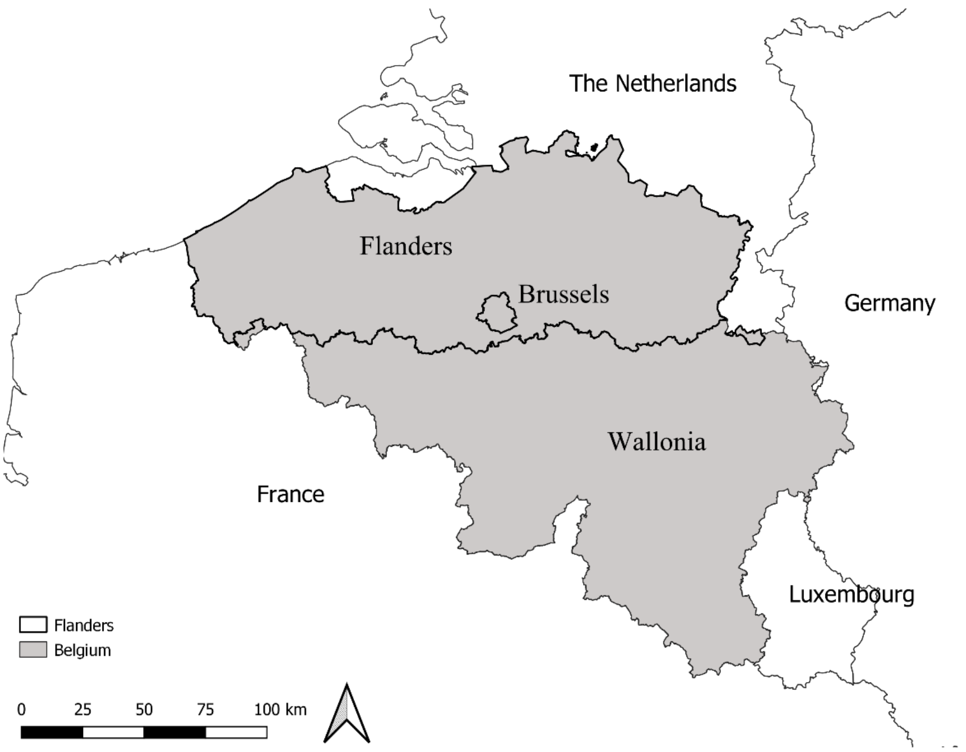

Figure 1: Flanders situated in Belgium

4. Data and methods

4.1 Defining actual car dependence

To define actual car dependence as clear as possible, we build on the work by Verachtert et al. (2016). Adopting the SNAMUTS methodology, created by Curtis & Scheurer (2010), Verachtert et al. mapped the node and place values for each hectare cell for the whole region of Flanders. The concept of node- and place value was developed by Bertolini (1996). An application for Flanders can be found in Caset et al. (2019). Node value refers to public transport accessibility: the provision of public transport (train, tram, metro and the backbone of the bus network), taking both the current provision and extensions of the network to be realised before 2025 into account. The place value concerns activities and amenities. For each hectare cell in the Flemish region, Verachtert et al. (2016) calculated to what extent it is located in the vicinity of basic, regional and metropolitan amenities. Basic amenities are needed to organise daily life (primary schools, food shop, medical doctor, park…). Regional amenities function on a larger scale and include for example secondary schools, offices, hospitals, cultural institutions, shopping centres. Metropolitan amenities have a much wider reach: universities, large cultural institutions or tourist hotspots. The obtained node and place values are then organised in a matrix, which results in a synthesis value (Figure 2).

The focus of our study is limited to areas with a high node and high place value, and thus a high synthesis value. Consequently, these are exclusively urbanized areas, which we can consider as theoretically actual car-independent, due to the presence of a high concentration of amenities, services and public transport. This makes multimodality more likely and car-free living conceivable, at least in principle.

4.2 Data collection

In the selected areas, we carried out an online survey between October 2019 and February 2020, specifically targeting individuals with at least one car in the household and in the possession of a driving licence. In order to obtain a well-balanced sample, we supplemented the online survey with paper questionnaires in order to reach groups who are digitally less skilled and distributed these in community centres and centres for seniors. The self-completion questionnaire inquired on travel behaviour and socio-economic background. Furthermore, respondents were asked to indicate to what extent they agreed with various statements relating to feelings of car dependence. After data cleaning, our sample consisted of 898 respondents (Figure 2). Due to the fact that we pre-selected our sample on car ownership, drivers' license and place of residence, it is hard to estimate to what extent we succeeded in obtaining a representative sample[4]. Despite the bias, we consider our sample to be satisfactory and suitable for our main goals: uncovering car use patterns and assessing if and how perceived car dependence is correlated with multimodality. We return to the issue of representativeness and the extent to which we can extrapolate our results to the population in the discussion and conclusion.

[4] We compared our sample with the sample of the group aged 18+ from Travel Behaviour Survey (TBS) for Flanders. We selected the sample on the same variables: car ownership, driver's licence, synthesis value (n=1230). This comparison revealed that a higher share of the respondents in our sample only have one car in the household (80.8% versus 61.3%). Singles are slightly overrepresented while adults who live with their parents are underrepresented. On average, respondents of our sample have a higher income than those of the TBS and a higher proportion has a paid employment (64.9% versus 55%). Our sample is composed of on average older respondents and a higher share of men (57.9% versus 49.5%).

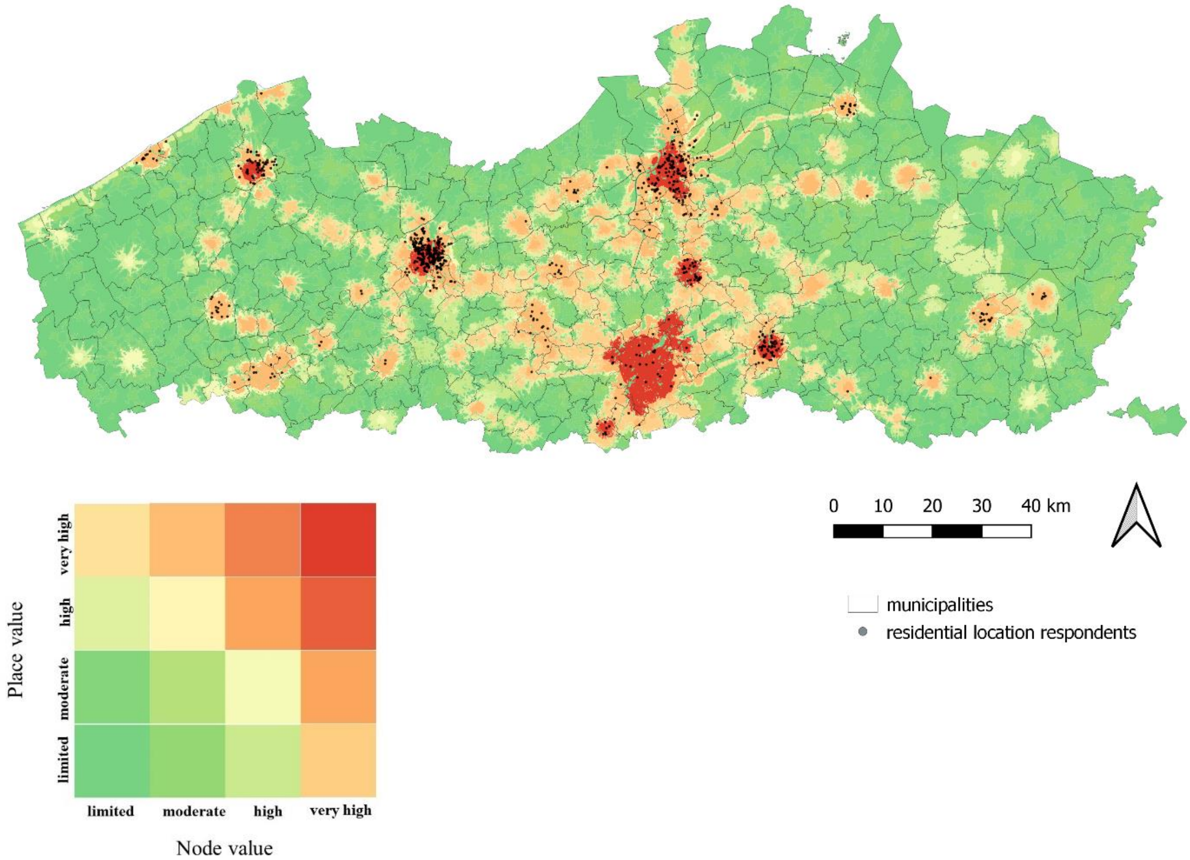

Figure 2: Residential location of survey respondents. Background: synthesis of node-place value (Verachtert et al. 2016).

4.3 Selection of cluster technique and constituent variables

To define different profiles, we use segmentation and clustering techniques. These techniques are often applied in transport research, mainly to obtain relatively homogenous and meaningful groups to prescribe tailor-made car reducing strategies (see for instance Anable, 2005; Hunecke & Haustein, 2010; Prillwitz & Barr, 2011; Haustein & Hunecke, 2013; Molin et a., 2016; Mattioli & Anable, 2017; McCarthy et al., 2019; Brand et al. (2020); von Behren et al., 2021). Before we set out our methodological approach, we think it is important to stress pitfalls regarding determinism in cluster analysis. It is clear that reality is fuzzier than what statistical clustering suggests, but the main goal of cluster analysis is to uncover patterns in data that otherwise would remain visible (Browne et al., 2013). Assigning people to a specific group is a means to do so, and our respondents are assisting in identifying these patterns. As Diana & Moktharian (2009) emphasize, cluster analyses are inherently of exploratory nature and the results of each cluster analysis are very context-dependent. As such, the identified patterns are only relevant in a given context and hence should be interpreted in that specific context.

Most common cluster techniques applied are latent class cluster analysis (LCA) and (a combination of) hierarchical and non-hierarchical cluster analyses. LCA is a subset of structural equation modelling and probabilistically assigns individuals to classes or groups. Each respondent possesses a probability to be in each class, whereas hierarchical and non-hierarchical analyses do not offer this nuance and assign each respondent to a class (McCarthy et al. 2019, Molin et al. 2016). However, the hierarchical and non-hierarchical techniques are widely applied and easy to interpret, therefore we decided to proceed with the latter. All analyses were carried out using SPSS version 27.

A cardinal step in cluster analysis is selecting the constituent variables. These should resonate with research purposes and the questions at hand (Anable, 2002). We used four categorical variables to determine cluster membership (Table 1). As we want to detect car use patterns we included the variable 'frequency of car use' and 'vehicle kilometres travelled' (VKT). Since we are looking for multimodality, we also added 'frequency of bicycle use'. We excluded the variable 'frequency of bus/tram use' and 'frequency of 'train use', because the descriptive statistics pointed out that these percentages are overall very low (Table 4). As such, public transport use would have dominated the cluster solution. The questionnaire includes a statement on the need of having access to a private car to carry out daily activities. We considered this variable as a proxy for perceived car dependence. All variables used are categorical. For the coding, we refer to Table 1. We conducted a two-stage analysis. We firstly ran a hierarchical cluster analysis in order to uncover patterns in the data and to assist in obtaining the optimal number of clusters, and subsequently a k-means analysis to classify the data into a final cluster solution.

As explained earlier, cluster analyses depend much on the goal of the researcher. The number of clusters is to a certain extent a subjective estimation (Haustein, 2012). If too few clusters are used, we risk overlooking relevant patterns, if there are too many clusters, they may be too small to be meaningful (Anable, 2002). To assess patterns in the data, we employed a hierarchical analysis using ward's distance and visually inspected the plotted dendrogram (Appendix 1). The dendrogram clearly identifies two main clusters. These two clusters can subsequently be divided into respectively two clusters each, which leads to a possible four-cluster solution. Next, we conducted a k-means cluster analysis for two to five clusters. Looking at the iteration history of the k-means cluster analysis, both a two and four cluster solution provided the most stable results. In both cases, convergence in the clusters was achieved after seven iterations of searching for cluster centres. As we considered two clusters not offering sufficient variation and thus too limited for our purposes, we selected the four cluster solutions. However, as an additional check, we analysed the stability of the cluster. For this purpose, we split the sample randomly into two equal parts, and ran the k-means analysis for each subsample. The subsample and the total sample lead to the same output, which provided support to retain the four segments. By means of ANOVA and post-hoc tests, we compared the cluster characteristics in order to highlight the main differences between the clusters and to estimate the interpretability of the solution.

Firstly, we present the results of the cluster analysis. Subsequently, in order to profile the clusters in more detail, we shed light on the relation between the clusters and a range of relevant variables: the use of public transport (Table 4), sociodemographic features (Table 5), expected adaption towards increasing car use costs (Table 6), and finally car trip purposes (Table 7).

5. Results

5.1 Cluster analysis results

We begin by presenting a descriptive overview of the distribution of the constituent variables used for the cluster analysis (Table 1).

Table 1: Constituent variables overall sample (n=898)

	n	%
Car use frequency		
Daily	290	32.3%
Weekly	456	50.8%
Monthly	142	15.8%
Yearly	10	1.1%
Bicycle use frequency		
Daily	385	42.9%
Weekly	206	22.9%
Monthly	94	10.5%
Yearly	213	23.7%
Vehicle Kilometres Travelled		
<5000	218	24.3%
5000-10,000	265	29.5%
10,001-20,000	272	30.3%
> 20,000	143	16.0%
Car needed in daily life		
Strongly agree	258	28.7%
Rather agree	307	34.2%
Neither agree/disagree	145	16.1%
Rather disagree	148	16.5%
Strongly disagree	40	4.5%

Table 2 shows the size of each cluster and the respective final cluster centres of each constituent variable: car use frequency, bicycle use frequency, VKT, and car needed in daily life. For reasons of transparency, we mention the size and percentage of each cluster, but because of the bias in our sample, these shares cannot be extrapolated to the urban residents of the Flemish region as a whole.

Table 2: Final cluster centres of constituent variables (subscript indicates which cluster centres are significantly different from the other values in the same row of the table, p<0.01)

	Cluster 1 (n=228, 25.3%)	Cluster 2 (n=180, 20.0%)	Cluster 3 (n=235, 26.2%)	Cluster 4 (n=255, 28.4%)
Car use frequency	$1{,}13_a$	$0{,}07_b$	-0.87_c	$-0{,}34_d$
Bicycle use frequency	$-0{,}62_a$	$-1{,}23_b$	0.74_c	0.75_c
VKT	1.04_a	-0.55_b	$-0{,}57_b$	0.01_c
Car needed in daily life	$-0{,}65_a$	-0.35_b	1.30_c	$-0{,}37_b$

To assess the difference in the variables used to distinguish between the clusters, we employed an ANOVA (Table 2) and post hoc Bonferroni test to search for differences among all combinations of groups. Figure 3 graphically represents these differences. The Bonferroni test indicates that, regarding car use frequency, all four clusters significantly differ from each other. For the variable bicycle use frequency, significant differences between the first and the second cluster emerge. Bicycle use frequency is equal between clusters 3 and 4, but significantly different from respectively cluster 1 and 2. With respect to VKT, cluster 2 and 3 are similar, but differ significantly from cluster 1 and 4, which in their turn differ significantly from each other. Regarding the variable car needed in daily life, results suggest that perceived car dependence is equal for clusters 2 and 4, but the cluster centres differ significantly from those of cluster 1 and 3, and these also differ significantly from each other.

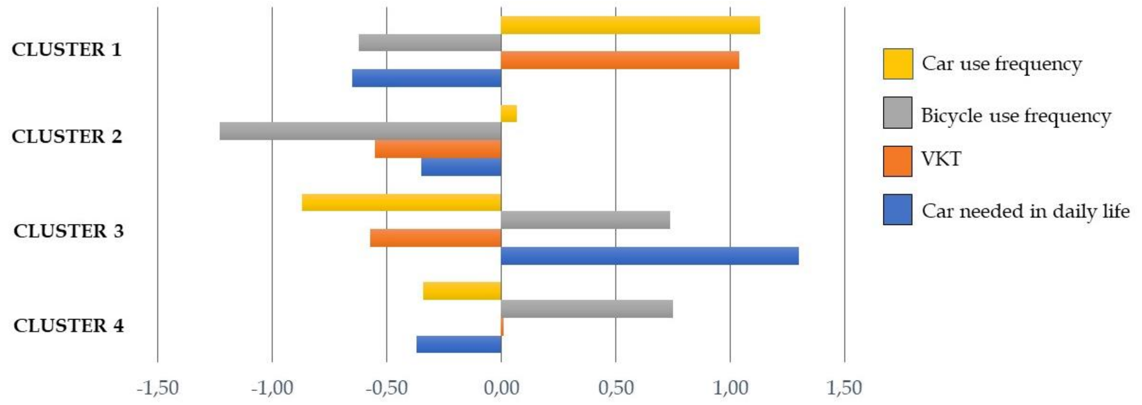

Figure 3: Graphical representation of cluster centres for each constituent variable.

Table 3 provides a more detailed overview of the share of respondents within each cluster for each constituent variable. Based on this closer inspection, we labelled the clusters as follows: (1) car-dependent motorists - long distance (CDML), (2) car-dependent motorists - short distance (CDMS), (3) car-independent cyclists (CIC), (4) car-dependent cyclists (CDC).

Table 3: Share of respondents per cluster (%), for each constituent variable.

	CDML	CDMS	CIC	CDC	Sample average
Frequency of car use					
Daily	89.5%	28.9%	4.3%	9.4%	32.3%
Weekly	10.5%	62.2%	52.8%	76.8%	50.8%
Monthly	0.0%	8.9%	39.1%	13.3%	15.8%
Yearly or less	0.0%	0.0%	3.8%	0.4%	1.1%
Frequency of bicycle use					
Daily	5.7%	0.0%	78.3%	73.7%	42.9%
Weekly	35.5%	9.5%	17.5%	23.1%	22.9%
Monthly	23.2%	20.0%	2.1%	3.1%	10.5%
Yearly or less	35.6%	70.5%	2.2%	0.0%	23.7%
VKT					
< 5,000	0.0%	37.2%	43.4%	19.3%	24.3%
5,001-10,000	6.1%	47.8%	35.7%	31.8%	29.5%
10,001-20,000	40.8%	15.0%	19.0%	42.0%	30.3%
> 20,000	53.0%	0.0%	1.8%	7.1%	16.0%
Car needed in daily life					
Strongly agree	53.1%	39.5%	0.0%	25.9%	28.7%
Rather agree	39.5%	35.6%	2.1%	58.0%	34.2%
Neither agree/disagree	4.4%	18.3%	26.0%	16.1%	16.1%
Rather disagree	3.1%	6.7%	54.9%	0.0%	16.5%
Strongly disagree	0.0%	0.0%	17.0%	0.0%	4.5%

5.2 Use of public transport

We distinguish between train and bus/tram as the train is mainly used for longer journeys from one municipality to another, while tram/bus primary serves for journeys within the city. A Pearson Chi-square indicated significant differences of use of public transport among the clusters ($p<0.01$).

Table 4: Use of public transport (%) (Assympt. significance Pearson Chi-square p<0.01).

	CDML	CDMS	CIC	CDC	Sample average
Frequency use train					
Daily	1.7%	1.7%	7.2%	4.8%	4.0%
Weekly	2.7%	5.0%	12.7%	9.0%	7.5%
Monthly	6.1%	9.4%	16.6%	17.6%	12.8%
Yearly or less	89.4%	83.9%	63.4%	68.7%	75.6%
Frequency use bus/tram					
Daily	3.1%	10.0%	3.4%	1.6%	4.1%
Weekly	3.1%	19.5%	14.9%	10.2%	11.4%
Monthly	20.2%	18.9%	27.2%	20.4%	21.8%
Yearly or less	73.6%	51.6%	54.5%	67.8%	62.5%

5.3 Socio-economic characteristics

As research clearly established a link between travel behaviour and socio-economic characteristics (Boussauw et al., 2011; Naess, 2012; Naess, 2014; Ewing & Cervero, 2017; Fransen & Farber, 2019; Van Eenoo et al., 2022), we ran a multinominal logistic regression with the cluster as dependent variable and socio-economic characteristics as independent variables (Table 5). All used variables are categorical. In the regression, we omitted the variable 'paid employment' as this variable was strongly correlated with age, education and income. We obtained statistically significant results for all variables: gender ($p<0.00$), net personal income ($p<0.00$), education ($p<0.00$), household composition ($p<0.00$), age (<0.05), car ownership, and the presence of a company car ($p<0.00$). A company car is defined here as a car made available to an employee by his/her company that may also be used for private purposes. Besides the company car, employees often receive a fuel card from their employer, a fringe benefit enabling them to fill up at lower or no cost. In Belgium, company cars are used by employers as a partly tax-exempt component of the remuneration package they offer to their staff, and are therefore often called 'salary car' (Macharis & De Witte, 2012; May et al., 2019). On average, the Belgian company cars annually cover much longer distances than private cars (Van Eenoo et al, 2022). Furthermore, it is estimated that the commuting distance for employees with a company car is twice the distance of employees without one (May et al., 2019).

Table 5: Contingency table of socioeconomic variables and significance based on multinominal logistic regression (Nagelkerke pseudo R Square: 0.38, ** = p<0.01, * = p<0.05).

Variable	CDML		CDMS		CIC		CDC		Overall sample	
*Car ownership***										
1	148	67.9%	141	80.1%	212	91.8%	204	82.3%	705	80.8%
≥ 2	70	32.2%	35	19.9%	19	8.2%	44	17.7%	168	19.2%
*Company car***										
Yes	87	38.2%	15	8.3%	41	17.4%	54	21.2%	197	21.9%
No	141	61.8%	165	91.7%	194	82.6%	201	78.8%	701	78.1%
*Gender***										
Male	157	68.9%	96	53.3%	121	51.5%	146	57.3%	520	57.9%
Female	71	30.1%	84	46.7%	114	48.5%	109	42.8%	378	42.1%
*Year of birth**										
After 1990	18	8.0%	4	2.3%	16	7.0%	6	2.4%	43	4.8%

Variable	CDML		CDMS		CIC		CDC		Overall sample	
1981-1990	44	19.6%	12	6.8%	65	27.9%	69	27.1%	190	21.4%
1961-1980	102	45.3%	52	29.4%	101	43.3%	107	42.3%	363	40.8%
1951-1960	37	16.4%	55	31.1%	33	14.2%	46	18.0%	171	19.2%
1920-1950	24	10.6%	54	30.4%	18	7.8%	26	10.2%	122	13.7%
Paid employment[5]										
No	52	23.3%	130	72.6%	55	23.7%	73	29.2%	574	35.1%
Yes	171	76.7%	49	27.4%	177	76.3%	177	70.8%	310	64.9%
*Net personal income***										
0-1000	4	1.8%	12	6.9%	13	5.6%	3	1.2%	32	3.6%
1001-1500	18	7.9%	49	28.0%	19	8.2%	28	11.0%	114	12.8%
1501-2000	56	24.7%	62	35.4%	67	28.9%	68	26.8%	253	28.5%
2001-2500	76	33.5%	33	18.9%	59	25.4%	76	29.9%	244	27.5%
2501-3000	40	17.6%	12	6.9%	46	19.8%	46	18.1%	144	16.2%
>3000	33	14.5%	7	4.0%	28	12.1%	33	13.0%	101	11.4%
*Education***										
Low	63	27.6%	97	54.2%	37	15.7%	42	16.5%	239	26.6%
Average	89	39.1%	50	28.0%	82	34.9%	95	37.3%	316	35.3%
High	76	33.3%	32	17.9%	116	49.4%	118	46.3%	342	38.2%
*Household***										
Single	52	22.8%	55	30.7%	29	12.3%	44	17.3%	180	20.1%
Single with children	21	9.2%	16	8.9%	16	6.8%	22	8.6	75	8.4%
Couple no children	71	31.1%	83	46.4%	75	31.9%	71	27.8	300	33.4%
Couple with children	71	31.1%	21	11.7%	108	46.0%	108	42.4	308	34.3%
Other	13	5.7%	4	2.3%	7	3.0%	10	3.9	34	3.8%

5.4 Increasing car use cost

Car ownership is less easy to influence by policy measure than car use, and car use responds more strongly and more quickly to price changes (Dargay, 2007). Therefore, to estimate the persistence of perceived car dependence in the light of hypothetically increasing car use costs, we inserted a question in the survey gauging if increasing car use costs (€ 100 and € 300 respectively) would inflict adapted behaviour, and if so, what change respondents would preferably make. We determined the amounts on the estimated average monthly cost of a car in Belgium, which is € 400, purchase of a car excluded (Van Geyte, 2020). We wanted respondents to think that the suggested increase was conceivable, but we also did not want to set the amount too low, in order to be able to observe change.

Table 6: Preferred adaption towards increasing car use costs of 100 euro/month and 300 euro/month (%) (Assympt. Significance Pearson Chi-square **p<0.01)

	CDML		CDMS		CIC		CDC		Sample average	
	€ 100	€ 300	€ 100	€ 300	€ 100	€ 300	€ 100	€ 300	€ 100	€ 300
Do nothing	61.2%	27.2%	50.6%	20.7%	35.3%	6.4%	51.4%	16.9%	49.5%	17.5%
Start car sharing	3.1%	5.7%	6.1%	10.6%	14.0%	15.3%	11.0%	20.0%	8.8%	13.3%
Replace car by cheaper one	10.6%	21.5%	9.4%	15.1%	3.4%	7.2%	6.3%	7.5%	7.2%	12.5%
Reduce car use	18.1%	25.9%	23.3%	21.8%	24.3%	17.0%	21.2%	23.1%	21.6%	22.0%
Sell car	2.6%	10.1%	4.4%	22.3%	15.3%	46.0%	4.7%	23.5%	6.9%	25.8%
Other	4.4%	9.6%	6.1%	9.5%	7.7%	8.1%	5.5%	9.0%	5.9%	9.0%

[5] This variable was not included in the regression.

5.5 Trip purposes carried out by car

Previous research identified grocery shopping, having children, carrying heavy goods and work locations as main factors making a car necessary rather than simply desirable (Cullinane et al., 2003; Stradling, 2007; Mackett, 2003; Lucas and Jones, 2009; Zhao, 2011; Mattioli et al. 2016; Maciejewska, 2019), and it has been argued that travel purpose should be included in multimodality analyses (Olafsson et al., 2016). In order to deepen our understanding of car dependence, in this last part of the analysis, we aim to deduce differences in trip purposes carried out by car. By means of a chi square test, we find significant differences between the clusters for all trip purposes, except for visiting family/friends and daytrips.

Table 7: Car trip purposes (%), per cluster (Assympt. Significance Pearson Chi-square **p<0.01)

	CDML	CDMS	CIC	CDC	Sample average
Visiting family/friends	79.4%	80.6%	77.4%	78.0%	78.0%
Grocery shopping**	80.3%	87.8%	62.6%	70.6%	74.4%
Weekend or holiday trips**	70.2%	52.2%	73.6%	78.4%	69.8%
Daytrips	68.0%	59.4%	63.8%	71.0%	66.0%
Moving large equipment**	53.1%	38.9%	68.1%	69.1%	58.8%
Commuting**[6]	95.3%	65.3%	23.2%	30.5%	50.5%
Escorting children**[7]	60.9%	56.5%	31.4%	37.9%	42.0%
Several services (post, bank, library, pharmacist…)**	30.7%	36.1%	0.9%	5.9%	16.9%

5.6 Cluster profiles

In the dendogram (Appendix 1) two main groups emerged. We indeed notice two clusters where car use is dominant, and two clusters where bicycle use is dominant. Each of these groups can be divided in two separate groups. In the next section, we shed light on their most salient features.

Car-dependent motorists long distance (CDML)

From the group of car-dependent motorists long distance, 89.5% uses a car daily. This is the highest score of all clusters. This is also the group that travels the most VKT: 93.8% travels at least 10,000 km/year, while more than half (53.0%) travels more than 20,000 km/year. Their perceived car dependence is the highest of all clusters: 92.6% agrees with the statement. However, this does not imply that this group is unimodal, as 41.2% ride a bicycle at least weekly. When we turn to the use of public transport, ridership is low. Up to 89.4% never or rarely travels by train. Use of bus and tram is somewhat less exceptional, although for 73.6% this mode is (almost) never considered. Of all groups, this one has the most cars in the household, and is most likely to benefit from a company car (38.2%). Furthermore, we notice that men are overrepresented in this group (68.9%). The income of the CDML is slightly higher than the sample average. Age and education are in line with the average. In the case of an increase of car use cost of € 100, 61.2% of the respondents in this group would not adapt behaviour. When costs increase with € 300, this share drops to 27.2%, although 'do nothing' is still the main consideration within this group. The second most common choice is reducing car use. The car is mainly used for work, leisure time and escorting children.

To summarize: the most salient features of the CDML are high perceived car dependence, daily car use supplemented by weekly bicycle use but low use of public transport, and high car ownership. This group commutes by car, and of all groups, they are the most inclined to escort their children by car. Respondents from this group are more likely to be male with an income that is above average. In case of increasing car use costs, this is the cluster with the lowest propensity to change behaviour.

[6] only those who are employed included (n=574)
[7] only those with children in the household included (n=295)

Car-dependent motorists short distance (CDMS)
Similar to the car-dependent motorists long distance, for respondents of the car-dependent motorists short distance cluster, the car is the dominant mode of transport. In the same vein, their perceived car dependence is high, although slightly less than for the CDML. This group does not frequently travel by bicycle. Nevertheless, we could also consider this group as multimodal, as they compensate their low bicycle use by a higher share of trips by bus or tram. Journeys by train are an exception, as 83.9% never takes a train. As Table 2 shows, the CDMS cover a similar number of kilometres as the car-independent cyclists (CIC) do, although the car trip frequency is much higher (91.1% at least weekly versus 57.1% for the CIC). This could indicate that the CDMS, compared to the CIC, use the car to cover shorter distances. Despite their frequent car use, company cars are underrepresented. This is probably related to the socio-demographic characteristics of the cluster, as people who are not (or no longer) employed are overrepresented here, and to the lower income, as mainly higher income groups receive a company car (May et al., 2019). Also, for age, we notice a higher proportion of older respondents. 65.3% of this group uses the car for commuting, but a car is mainly used for non-work trips, such as running errands (87.8%) and daytrips (80.6%). The proportion of CDMS who use a car for weekend or holiday trips is rather low compared to the sample average (52.2% versus 69.8%). Our data does not allow to check whether this is due to the fact that these respondents seldom engage in multi-day travel or just use other means of transport for such trips. Low education and low incomes are overrepresented among the CDMS respondents, as are singles. In case of an increase car cost of € 100 a month, half of the CDMS does not consider adapting behaviour, and with respect to an increase of € 300 a month, only one out of five would abandon their car. This is remarkably in the light of their lower income. Even though, an equal number would consider reducing car use, or even sell the car. Car sharing does not pop up as a feasible or attractive option to reduce costs. With respect to car trip purpose, we assume that this group primarily visits amenities in the vicinity of the dwelling and that the work location is also situated at limited distance. They use the car less for leisure trips and holidays and feel dependent on a car for essential trips like running errands or accessing services. In that sense, we could consider them as captive car users.

In sum, the CDMS travel by car frequently, although their trips are of limited distance. Their perceived car dependence is high, and it is conceivable they expect difficulties in the case of forced relinquishment of their car. They are more inclined to take the bus or tram than to ride a bicycle. This group is lower educated, has the lowest average income of the four clusters. Higher age groups are overrepresented.

Car-independent cyclists (CIC)
As the name suggests, for the car-independent cyclists (CIC), the dominant mode of transport is the bicycle, and this is the group with the lowest perceived car dependence. With respect to the estimated need of a car to carry out daily activities, only 8.5% of the car-independent cyclists agree with the statement. This group is more multimodal than both motorists groups. Respondents from this group have a significant higher propensity to travel by train, bus or tram, although the percentages remain rather low, and for a majority, public transport is excluded from their travel mode set. Compared to the sample average, respondents in CIC are more likely to have only one car in the household. Females and younger age groups are overrepresented here, as are couples with children. As far as education is concerned, we notice that the CIC are on average highly educated. When we examine how the respondents of CIC would react to an increase of the cost of driving with €100, we notice that, despite low perceived car dependence, the main reaction is to do nothing (35.3%), although this is the lowest share of all four groups. With an increase of € 300, this share drops to 6.4%, and most respondents would consider selling their car (46.6%). Surprisingly, this is a more preferred option than car sharing (15.3%). Regarding trip purpose, the large difference in commuting by car between the car-independent cyclists and the car-dependent long-distance motorists is remarkable. The CIC use a car mostly for visits or holiday trips. Only 62.2% of this group uses a car for grocery shopping. We consider it conceivable that a large share of the

car-independent cyclists tends to use a bicycle for grocery shopping. The same holds for journeys towards services typically in the proximity of the dwelling (bank, library, post office): only 1.2% of the car-independent cyclists use a car.

Overall, the main features of the CIC are a low perceived car dependence, low car use but a daily use of the bicycle. The CIC tend to use a car primarily for leisure. This is a highly educated group, of all four the most willing to abandon a car if costs would increase drastically.

Car-dependent cyclists (CDC)
Finally, we turn to the car-dependent cyclists (CDC). As for the former cluster, the bicycle is the dominant mode choice. Nevertheless, 86.2% of this group travels by car at least once a week. Their perceived car dependence is equal to that of the CDMS. Use of public transport is more exception than rule. With respect to socio-economics, most of the features of the CDC are close to that of the sample average, with two exceptions: highly educated respondents are overrepresented and households with children are underrepresented. With respect to increased car use costs, the reactions of this cluster show the most variety of all four. With an increase of € 100, more than half would do nothing, and 21.2% would aim to reduce the car use. If the increase would be € 300 euro, only 16.9% would do nothing. For 20%, car sharing is the preferred option, and 23.5% would sell the car. A similar percentage (23%) would reduce car use. With respect to car trip purposes, leisure trips take the largest share.

To summarize, the CDC are characterised by weekly car use, daily bicycle use, but a high perceived car dependence. They do not stand out socio-economically, although their high education is remarkable. This is the group most willing to start car sharing.

6. Discussion and conclusion

6.1 Summary of findings

In this study, we tested the extent to which people who reside in hypothetically car-independent neighbourhoods travel multimodal and perceive themselves as car dependent. We used the Flemish region as our study case, and defined a car-independent neighbourhood as an area with a high node and a high place value. A k-means cluster analysis with four constituent variables – car use frequency, bicycle use frequency, VKT and the need for a car to carry out daily activities - led to defining four heterogeneous groups of car owners. We labelled the groups as car-dependent motorists long distance, car-dependent motorists short distance, car-independent cyclists and car-dependent cyclists. With regard to our hypothesis – perceived car dependence of people will decrease when their travel pattern is more multimodal – the outcomes go in different directions. Firstly, we found that all clusters are to some extent multimodal. Although research illustrated that car drivers become relatively unresponsive to policy designed to encourage modal shift or that they do not consider other modes (Jones, 2011), we can argue that, with respect to our sample, this is not necessarily the case. This resonates with earlier research pointing out that the degree of urbanization enhances multimodality (Nobis, 2010; Olafsson et al., 2016; Heinen & Mattioli, 2019). Secondly, our cluster analysis yielded, in terms of mode frequency, two groups for whom car use is the main mode of transport, and two groups for whom the bicycle dominates. However, with regard to VKT, these groups do not coincide. Here, the car-dependent motorists long distance are more related to the car-dependent cyclists, and the car-dependent motorists short distance resemble more the car-independent cyclists. Our hypothesis is only confirmed for the car-independent cyclist group, as they note the lowest perceived car dependence. The car-dependent cyclists indicate they need a car to carry out daily activities, so despite high multimodality, the perceived car dependence is high. With respect to the motorists, the short distance group is somewhat less multimodal (in the sense that they rarely use a bicycle or public transport) but feels slightly less car-dependent than the long distance group, for whom the bicycle is a common mode of transport. In general, we can conclude that, for our selected study area, car ownership does not necessarily induce perceived car-dependence for people who can easily get around by bicycle. Nevertheless, even in an urban setting and when exhibiting multimodal travel patterns, people can perceive their car as indispensable. Perceived car dependence is not necessarily correlated with high VKT or high frequency of car use, neither can we conclude that multimodality necessarily leads to less VKT. In our urbanized study area, at least for trips in the proximity of the dwelling to for instance services, people are willing to consider other modes than a car.

Our analysis further elaborated on differences in each of the identified clusters regarding socio-economic features, car trip purposes, and preferred adaption in the case of increase of car use cost. The four clusters reflect well-established correlations between travel behaviour and socio-economic characteristics. Previous research indicated clearly that males travel longer distances than females (Axisa et al., 2012, Marcén & Moralis 2021; Wachter & Holz-Rau, 2021; An et al., 2021). The overrepresentation of men in the car-dependent motorists long distance cluster illustrates that, also for our selected area, this gender gap remains present. However, based on our research, we cannot infer that men consequently experience a higher perceived car dependence. More than to the presence of multimodal patterns, VKT is, as established by previous research, merely associated with income (Lucas et al., 2016; Molin et al., 2016; Ihlandfeldt, 2020; Van Eenoo et al., 2022). As income rises, it becomes more likely people undertake social and leisure trips (Lucas et al., 2016). Indeed, we noticed that the cluster with the lowest income, the car-dependent motorists short distance, is the least inclined to undertake leisure trips. As far as education is concerned, we notice that both cyclists groups are highly educated. This finding corresponds with research in Germany which highlighted the presence of an increasing educational gap between cyclists and non-cyclists (Hudde, 2021). A similar result was found for The Netherlands (Molin et al., 2016). However, for The Netherlands, elderly seemed to cycle more than the elderly in our sample. This might be due to the differences of bicycling safety and the available bicycle network, which is of a higher quality in The Netherlands. As households with children are overrepresented in the car-independent cyclists group, and underrepresented in the car-dependent cyclists group, our results also illustrate that perceived car dependence goes not necessarily hand in hand with the presence of children. As such, the birth of a child does not directly leads towards adopting car-oriented behaviour (Molin et al., 2016; Oakil et al., 2016; McCarthy et al., 2019).

Finally, with respect to car trip purposes and increasing car use costs, some elements deserve to be highlighted. As previously explained, we did not find strong evidence for the ratchet-effect Jones (2011) refers to, although we notice a tendency towards it in both motorists groups. In urban areas, the ratchet-effect could manifests itself far and foremost with people who feel dependent on their car for what we could consider essential activities, like commuting and grocery shopping. It is likely that they turn to the car sooner for trips that could have been carried out by other modes. Despite the presence of multimodality, the attachment to the car is strong. This confirms the asymmetry Dargay (2001) discovered: once the household budget allows the purchase of a car, people become accustomed using it. When income drops (or in our case: a larger share of the household budget needs to be transferred to maintaining the car), this does not necessarily leads to relinquishing the car. In that sense, financial incentives to reduce car use or to abandon the car risk not being very successful. Even in the case of an increase of € 300 a month, for the car-dependent motorists short distance – notably the group with the lowest average income – only one out of five would consider abandoning the car. The car-independent cyclists are less dependent on a car for daily trips, and this might explain why their perceived car dependence is lower. For them, a car is more for convenience or to carry out flexible leisure trips. This resonates with a study from Berlin (Schwedes & Hoor, 2019: 7), where a group was identified as 'keeping a car for opportunity's sake'. These are people who live their daily lives without a car and travel mainly with sustainable modes while the car is convenient for certain activities and trip purposes (groceries, carrying heavy goods, weekends and holidays). These people circulate around the thin line between a car as a necessity and a car as a convenient back-up, in line with findings from research we referred to in the introduction (Ikezoe et al., 2021, von Behren 2021, Selzer, 2021, Johansson, 2021). It is likely that this group finds an increase of car use cost of € 100 still acceptable, but will relinquish the car when this amount triples. Furthermore, we find it remarkable that the willingness to start car sharing is limited in this group, as this could combine the convenience of a car with reduced costs. Regarding the car-dependent cyclists, our analysis does not enable us to identify the underlying reasons why this group feels car-dependent. Several lines of thought are imaginable. It could be suggested that they as well are attached to the car as a convenient back-up for a bicycle, or, alternatively, maybe their feeling of car dependence is rooted in daily experiences where they encounter situations that leave them no alternative to their car. It is also conceivable that this group consists of people who have to carry out car-dependent trips quite often due to personal or work-related circumstances, which might explain that they travel the second most VKT of the four groups. These circumstances could explain their higher willingness to start car sharing when car costs increase. Car ownership provides them with the desired back-up.

6.2 Policy implications
An issue to address is whether policy attention should mainly focus on the groups with the highest likelihood of mode switching, like the car-independent cyclists, or should reducing VKT, crucial in the light of continuous increase of greenhouse emissions, be on top of the agenda. Of course, both are needed. The effectiveness of policy actions depends on the level of governance. We consider the local level more suited to politically intervene in straightforward measures like improving bicycle infrastructure and land use policies that strengthen proximity. Our results confirm that multimodality already prevails in urban areas, and that car owners display aspects of multimodal behaviour, even when they travel by car frequently and they cover substantial VKT. As such, they are already experienced with sustainable modes like the bicycle or public transport. A stronger focus on making these modes more accessible could further reduce car use. In urban areas, to a certain extent, the bicycle is capable of replacing car trips in the proximity of the dwelling. However, we notice that older people, lower incomes and lower educated groups, are less inclined to cycle. This could be due to a lack of suitable bicycles in the households, a lack of space to store them, physical fitness but also to safety issues. Designers of bicycle infrastructure could take such concerns more into account. The regional and federal level in their turn have an important role to play regarding public transport. We notice that older people and lower incomes have the highest propensity of using bus or tram. They could strongly benefit from an expansion of the network and higher frequencies. As higher VKT leads to higher greenhouse gas emissions, we think the train can have an important role, especially for leisure, with increased service provision during weekends and nighttime hours. Measures that favour the bicycle and public transport, have to be combined with car-restrictive measurements. Regarding this issue, we think a reflection on the unequal impacts of car-restrictive measurements and how to deal with these equity concerns is a topic that deserves more attention. The car-dependent motorists group short distance, a lower-educated group with a lower income, are probably the most vulnerable to car restrictive financial measures. They probably already reduce VKT as much as possible as a cost-saving strategy. Car-reducing regulations that rely on financial incentives, tend to disproportionally hit this group (De Vrij & Vanoutrive, 2021), while higher incomes can easily 'buy their way out'. Policy should take these concerns into account. Finally, policy makers should not consider multimodality as a goal in itself, as multimodality not necessarily leads to less VKT or less car use. The main goal needs to be reducing car ownership and car use and the implementation measures to reach that goal, taking into account equity concerns.

6.3 Limitations and further research
A major limitation of this study is the sample bias. However, we believe the obtained profiles to be present in the population. Our results are comparable with other findings and similar studies, which gives confidence in its reliability. Nevertheless, the findings must be approached with some caution, and the exact proportion of each cluster within the population should be subject to further research. Moreover, we limited our study area to urban settings. Broadening the scope and including suburban and rural areas could further shed light on the presence of perceived car

dependence in areas where multimodal patterns might be less common. Another issue that deserves further attention is the threshold people experience regarding car sharing, as for our sample, car sharing is not a preferred alternative. This could also be important in the light of the development of Mobility as a Service. As a concluding remark, we only inquired after the need for a car for daily activities. As such, we cannot make statements regarding the importance of a car during leisure time (although we found that the car is mostly used for leisure trips). This illustrates the thin line between a car as an absolute necessity and a car as a luxurious back-up. Thus far, we lack the insight needed to estimate what policy affects one group over the other. We think this can be subject of further research, and we position this within the debate on essential versus convenient trips . What for an outsider might be interpreted as a redundant car trip, can be perceived to the insider (the respondent) as a trip for which a car is essential. This opens up a very delicate discussion on how to define 'excessive car use': where to draw a line, and who is entitled to draw that line? A more in-depth research could further disentangle the barriers between fluid notions as actual and perceived car dependence.

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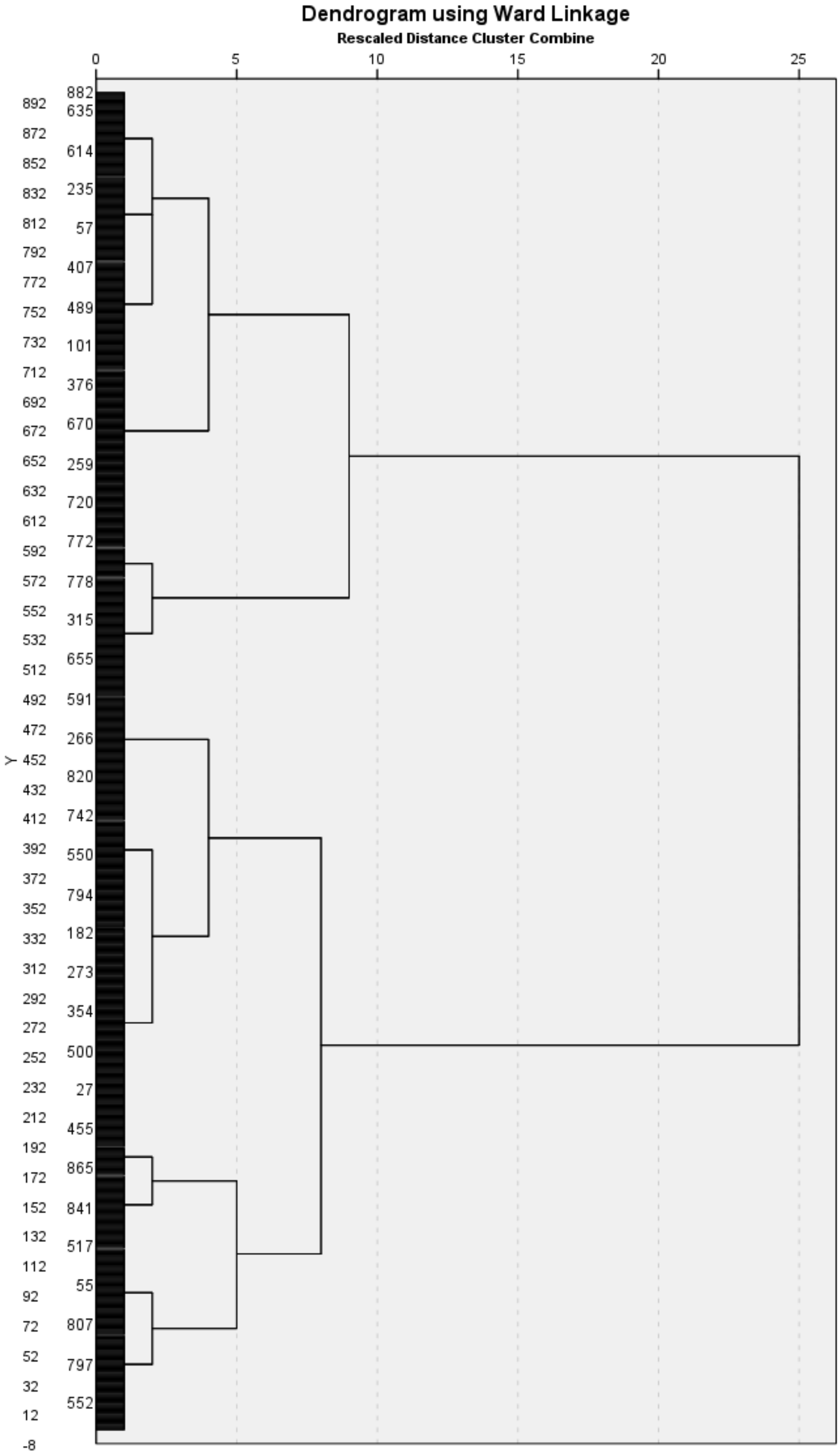
Appendix 1


Dendrogram using Ward Linkage
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