

Driving Factors of Household Car Ownership: Development of a National Car Ownership Model for Belgium

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ABSTRACT

This study develops a national car ownership model for Belgium, addressing the significant factors influencing household vehicle ownership across various built densities. Using the multinomial logistic regression model and the MONITOR travel survey data from 2016-2017, socio-economic and demographic factors, residential characteristics, mobility resources, and public transport accessibility were examined. Higher income and larger household size strongly correlate with increased car ownership, particularly in Flanders. In contrast, subscriptions to shared mobility services and proximity to train stations reduce the likelihood of owning multiple cars. The results emphasize the importance of regional policies and sustainable transportation options in managing vehicle demand. This study provides valuable insights for policymakers and urban planners to promote ecological mobility and reduce car dependency, offering a basis for research in other high-density, car-centric regions.

PRACTICAL APPLICATIONS

Understanding the factors influencing household car ownership is crucial to addressing the environmental, social, and economic challenges of high private vehicle dependency. This study highlights the socio-economic and residential location attributes that drive car ownership in Belgium. The findings reveal that higher-income households, especially those living in semi-urban areas of Flanders and Wallonia, are more likely to own multiple cars than those living in Brussels or main urban areas. Households not engaging with shared mobility services also tend to own more cars. These findings emphasize the need for targeted measures that discourage car ownership, such as improving shared mobility services and expanding public transport in semi-urban regions. Addressing income and regional differences can help design mobility strategies tailored to the unique challenges of different areas. By applying these insights, stakeholders can promote energy-efficient and sustainable mobility options to reduce the environmental impact of private car usage.

INTRODUCTION

The global rise in private car ownership poses significant environmental, social, and economic challenges (Sinha 2003; Aschkenazi et al. 2012; Liu et al. 2014; Zhang et al. 2018). This trend, exacerbated by the COVID-19 pandemic, has reversed urban transport emission reductions and increased car use among socio-economic groups previously less reliant on private vehicles (Vega-Gonzalo et al. 2023). Private vehicle reliance contributes to GHG emissions, congestion, health issues, social inequalities, and excessive land consumption for parking, highlighting the need to understand household car ownership patterns for sustainable mobility planning (Nematchoua et al. 2020).

Household car ownership is influenced by socio-economic characteristics, residential location attributes, mobility resources, and psychological factors (Wedagama 2009; Potoglou and Kanaroglou 2008; Oyedepo et al. 2017). However, existing literature often presents contested findings, especially for rural areas. For example, Dargay (2002) found that rural car ownership is less related to vehicle costs than urban ownership. Similarly, Christie and Fone (2003) showed car ownership to be a poor indicator of social deprivation in sparsely populated areas of Wales.

Conversely, Zhao and Bai (2019) highlighted higher household income as a key determinant of car ownership in both urban and rural households. Such inconsistencies underscore the need for a comprehensive approach that accounts for variations in urban, semi-urban, and rural contexts.

While much research focuses on urban (Anowar 2015) or rural environments (Ao et al. 2019), limited studies integrate high-density regions with contrasting mobility policies. Furthermore, many omit variables like shared mobility subscriptions and lack robust comparisons of modeling techniques (Jochem et al. 2020; Cui et al. 2018).

This study addresses these gaps by developing a national car ownership model for Belgium, a country with diverse urbanization and mobility policies (Statbel 2023). Using multinomial logistic regression, we examine how built density, socio-economic factors, and shared mobility influence car ownership. Car ownership models are vital tools for transport and urban planning. They help reduce private car numbers to mitigate environmental, social, and economic issues (Cirillo and Liu 2013; Alberti et al. 2019). Unlike prior research, this study incorporates car-sharing and bike-sharing services, which increasingly disrupt traditional vehicle ownership models (Maltha et al. 2017; Oyedepo et al. 2017). Belgium's regional diversity and car-centric culture offer a valuable case study for understanding car ownership in other high-density contexts (Sluismans et al. 2019).

This research contributes to the literature by (i) resolving contested findings on rural car ownership by analyzing built density variations, (ii) introducing shared mobility as a key determinant, (iii) emphasizing regional diversity's role in ownership patterns, and (iv) comparing modeling techniques to identify robust predictive frameworks. These insights support policymakers in advancing sustainable and inclusive transport solutions.

LITERATURE REVIEW

Numerous studies explore household car ownership, but regional variations limit the applicability of a universal framework (Wedagama 2009). This review examines variables influencing household car ownership decisions at a disaggregated level, categorized into (i) socio-economic factors, (ii) residential location attributes, (iii) availability of mobility resources, (iv) psychological factors, and (v) other factors.

Socio-Economic Factors

Socio-economic characteristics such as income, household composition, age, education, and employment status are consistently identified as key determinants of household car ownership (Chu 2002; Potoglou and Kanaroglou 2008; Wong and Lin 2011; Soltani 2017; Cui et al. 2018; Yao et al. 2022; Schmid et al. 2023; Sefriyadi et al. 2023). Higher household income strongly correlates with increased car ownership (Potoglou and Kanaroglou 2008; Wong and Lin 2011; Clark et al. 2016; Shen et al. 2016; Oyedepo et al. 2017; Klein et al. 2023), while factors like off-street parking and local dwelling densities amplify this relationship (De Gruyter et al. 2024). However, income effects often intersect with other socio-economic factors like employment and education (Prillwitz et al. 2006; Potoglou and Kanaroglou 2008) and, more generally, with other factors such as cultural values and public transport perceptions (Bodunrin and Mini 2024).

Household composition further influences ownership. Larger households and those with multiple adults tend to own more vehicles (Ryan and Han 1999; Maltha et al. 2017; Cui et al. 2018). Life stages and life events also matter (Manting 2014; Clark et al. 2016; Dilini et al. 2021; Li 2024). However, evolving trends show a shifting relationship between income and car ownership, with other factors, such as household size, becoming more significant (Maltha et al. 2017). Similarly, Nolan (2010) highlights the importance of permanent income and prior ownership as predictors, yet studies often lack longitudinal data to track these dynamics over time.

While many studies examine socio-economic drivers of car ownership, significant gaps remain. Research frequently overlooks how these factors interact (e.g., income with education or employment type) and vary across urban, semi-urban, and rural contexts. Furthermore, few studies explore how evolving mobility trends, such as shared mobility adoption, influence traditional socio-economic relationships with car ownership (Jochem et al. 2020; Cui et al. 2018). This study addresses these gaps by integrating shared mobility services and examining how socio-economic characteristics influence ownership across diverse Belgian regions.

Residential Location Attributes

Residential location characteristics, including public transit accessibility and population density, significantly influence private car ownership. Proximity to transit stations often reduces car dependence (Crampton 2006; Potoglou and Kanaroglou 2008; Anowar 2015; Holmgren 2020), particularly in high-density urban areas. For instance, households near subway or rail stations are less likely to own cars due to the availability of reliable alternatives (Woldeamanuel et al. 2009; Ding and Cao 2019). However, car ownership remains higher in suburban, low-density areas where public transit options are limited (Wong and Lin 2011). Access to urban services, such as shops and recreational facilities, further decreases the need for private vehicles (Pan et al. 2013; Shen et al. 2016).

High residential density generally correlates with lower car ownership (Hess 2002; Li et al. 2010; Karjalainen et al. 2023). However, this relationship is not universal; in overcrowded areas with inadequate transit infrastructure, such as Manila, car ownership remains prevalent (Rith et al. 2019). Furthermore, Zhang et al. (2021) found that densification of low-density areas reduces car ownership, but over-densification can negate these effects. Similar to residential density, proximity to city centers is linked to lower car ownership (Karjalainen et al. 2023; Berrill et al. 2024).

Additional factors influencing car ownership include parking availability, road network capacity, and access to local amenities. Difficulty in finding parking reduces car ownership, (Guo 2013; Christiansen et al. 2017; Yin et al. 2018; Albalade and Gragera 2020). Private parking availability, such as garages and driveways, significantly increases the likelihood of car ownership (Christiansen et al. 2017; Yin et al. 2018; Albalade and Gragera 2020). Neighborhood crime risk (Sugiyama et al. 2009), slower vehicle speeds, and proximity to job centers (Holtzclaw et al. 2002) also play important roles.

Although many studies emphasize public transit accessibility as a determinant, they often neglect how this interacts with socio-economic differences, such as household composition, income, or the presence of children (Fairhurst 1975; Guerra 2015; Mulalic and Rouwendal 2020). Additionally, gaps remain in understanding how residential characteristics in semi-urban and rural areas influence

ownership patterns, particularly in the context of growing shared mobility options. This study addresses these gaps by examining how built density and transit accessibility interact with socio-economic factors in shaping car ownership across diverse Belgian regions.

Mobility Resources Availability

The availability of alternative transportation options, such as bicycles, e-bikes, motorcycles, or shared mobility services, significantly reduces household car ownership. For example, owning supplementary vehicles like bikes, e-bikes, or motorcycles correlates with fewer household cars Zhang et al. (2018). Similarly, a survey across 11 European cities found that a single car-sharing vehicle could replace up to 20 privately owned cars, demonstrating the transformative potential of shared mobility (Jochem et al. 2020).

Mobility-as-a-Service (MaaS) adoption is influenced by socio-demographics and residential characteristics. For example, in Utrecht, proximity to train stations, age, gender, and income levels shape the willingness to adopt MaaS (Bahamonde-Birke et al. 2023). Similarly, in Norway, younger, single individuals in dense neighborhoods frequently use bike- and e-scooter-sharing, while families in transit-oriented neighborhoods prefer car-sharing (Mouratidis 2022). These profiles highlight how shared mobility services cater to distinct demographic needs.

Despite these benefits, the impacts of shared mobility on car ownership remain underexplored. For instance, car-sharing services, more prevalent in high-density neighborhoods, can reduce ownership but may divert bus users rather than car owners (Ferrero et al. 2018). A notable trade-off exists between car ownership and public transport usage; as car ownership increases, bus ridership declines (Kuhnimhof et al. 2012). Additionally, bike-sharing services strongly influence ownership decisions; individuals using these services are more likely to sell their cars (Jochem et al. 2020).

However, gaps persist in understanding shared mobility's effects across diverse contexts, especially in semi-urban and rural areas where such services are less established. This study contributes by analyzing how the availability of shared mobility options shapes car ownership patterns in Belgium's urban and semi-urban regions, addressing the need for inclusive and sustainable transport strategies.

Psychological Factors

Psychological factors, including beliefs, attitudes, and habits, strongly influence household car dependency (Fujii and Kitamura 2003). Car ownership often represents more than just functional mobility; it is associated with control, freedom, and status. Driving provides a sense of personal autonomy, and car ownership is often tied to societal ideals of success and self-expression (Diekstra and Kroon 1997; Yamamoto 2009). For example, in urban China, owning luxury cars enhances happiness by symbolizing economic success and social prestige (Li 2023). Similarly, in Indonesia, perceptions of comfort, efficiency, and status drive car ownership in cities like Jakarta and Surabaya (Sefriyadi et al. 2023). Emotional attachments to cars transcend economic considerations, as highlighted by Sheller (2004). For low-income households in Maryland and Virginia, subsidized car access has improved mobility, quality of life, and access to essential services, underscoring the tangible benefits of car ownership (Klein 2024).

While environmental concerns encourage some households to shift toward electric or sustainable transport modes (Beirão and Cabral 2007; Lieven et al. 2011), car-centric lifestyles remain entrenched due to symbolic and tangible utility (Wu et al. 1999; Li et al. 2010). Temporal dependencies further reinforce car ownership habits; households with cars are more likely to retain or increase ownership over time (Fujii and Kitamura 2003). Early exposure to car ownership fosters lasting norms and preferences, making behavioral change challenging (Clark 2012).

Other Factors

Household car ownership is influenced by factors beyond socio-demographics and the built environment, including fuel-efficiency policies, vehicle prices, and emerging technologies. Preferences for vehicles offering higher engine performance and cost-effectiveness play a critical role in ownership decisions (Musti and Kockelman 2011; Bhat et al. 2009). For example, a 1% decline in vehicle prices corresponds to a 0.08% increase in car ownership in Chinese cities, while use restrictions lead to a 7.7% decrease (Yang et al. 2022). Similarly, fixed costs like insurance and maintenance impact ownership decisions more than variable costs such as fuel, as evidenced in the Netherlands (de Jong et al. 2009).

Policies promoting alternative fuel vehicles have shown limited impact on ownership levels, underscoring the complexity of shifting consumer behavior (Yang et al. 2022). However, rural areas present distinct dynamics. Greater car dependency and fewer transportation alternatives make fuel prices and vehicle costs less influential in rural settings compared to urban contexts (Dargay 2002; Pyddoke and Swärdh 2015). This study addresses these gaps by incorporating these factors into analyzing car ownership patterns in Belgium's diverse regions, where urban, semi-urban, and rural dynamics coexist.

METHODOLOGY

Modeling Framework

This paper addresses gaps in the literature by focusing on non-metropolitan contexts, which present distinct dynamics and challenges in household vehicle ownership. By adopting a broader perspective, it seeks to enhance our understanding of the factors influencing car ownership across varied urban and rural settings.

To achieve this, we employ household-level disaggregated models to represent the range of car ownership (e.g., 0, 1, 2, 3, or more vehicles). Both ordinal and nominal discrete models are considered. The ordered logistic regression (ORL) model is a common approach, but it assumes parallel slopes, meaning coefficients are constant across levels of car ownership. If this assumption is violated, the ORL model may provide biased results (Cui et al. 2018). In such cases, the multinomial logit (MNL) model is more appropriate, offering flexibility by allowing alternative-specific effects for each car ownership level (Potoglou and Kanaroglou 2008; Bhat and Pulugurta 1998). The MNL model is particularly suited for modeling car ownership as it avoids assumptions of ordinality, relying instead on a robust theoretical framework (Wong and Lin 2011).

However, it is subject to the Independence of Irrelevant Alternatives (IIA) assumption, which states that the relative odds of choosing one alternative over another remain unaffected by the inclusion or exclusion of other alternatives, leading to biased estimates if violated. In our analysis, we carefully selected alternatives to minimize potential violations of this assumption. Additionally, the MNL model assumes that the explanatory variables are independent and that no omitted variable

biases exist. If relevant variables are omitted from the model, or if there are correlations among the explanatory variables, the estimates may be inconsistent. Finally, the MNL model does not account for unobserved heterogeneity among individuals, which could lead to potential biases in estimating the parameters. To address this, we conducted model diagnostics to validate the robustness of the findings obtained from the MNL model.

While discrete choice models are commonly used in household vehicle ownership modeling, some studies have adopted count models to predict household vehicle ownership, considering that observed vehicle ownership levels are non-negative integers (Anowar 2015). The Poisson model is widely used among count models, assuming equal dispersion where the mean equals the variance. However, the equal-dispersion assumption does not always hold in practice, limiting the applicability of count data regression models for car ownership modeling (Anowar 2015).

Based on our literature review of car ownership models, determining the best-fitting model (count, ordered response, or unordered response model) for our data remains unclear. Previous studies (Bhat and Pulugurta 1998; Potoglou and Kanaroglou 2008) argue that the MNL model outperforms the ORL model in modeling car ownership, but subsequent empirical studies suggest that the number of cars per household should be treated as a discrete and ordered variable. Interested readers can refer to Anowar (2015) for a detailed discussion on the advantages and limitations of ordered and unordered models for car ownership modeling.

In light of these findings, our study investigates the suitability of three major modeling approaches for car ownership: the unordered response model (MNL) (Bhat and Pulugurta 1998), the ordered response model (ORL) (Bhat and Pulugurta 1998), and the count model (Poisson) (Wedagama 2009). To determine the most appropriate model for our dataset, we implemented an ordered logit model using the `polr` function in the MASS package in R. While the model yields reasonable coefficients, it fails to meet the assumption of “parallel lines”, a frequent invalidation (Kim and Mokhtarian 2018). Our attempt to fit the count model (specifically, the Poisson model) also yielded a model that did not satisfy the assumption of equal dispersion. Consequently, we selected the multinomial logit (MNL) model as the fundamental model for this study.

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Our selection of the multinomial logit model is based on the theoretical framework that emphasizes the importance of discrete choice analysis in examining transportation-related decisions. Grounded in consumer behavior theory, this model allows us to capture the probabilistic nature of the decision-making process regarding car ownership. Through this modeling approach, we aim to analyze the complex relationships among variables such as income, household composition, and frequency of using the car as a driver in the context of household car ownership. Moreover, the MNL model holds significant importance for analyzing categorical data. It is well-suited for our research since the data is categorical, and the dependent variable consists of more than two categories.

The MNL model assumes that each decision-maker will choose the alternative within the choices that maximize utility. For our car ownership model, let U_{nj} represent the utility of individual n selecting alternative j (where $j = 0, 1$, or 2). In this context, $j = 0$ corresponds to owning no vehicle, $j = 1$ corresponds to owning one vehicle, and $j = 2$ corresponds to owning two or more cars within the household. The utility function is assumed to have a linear form with both a deterministic component and a random component:

$$U_{nj} = V_{nj} + \epsilon_{nj}, \text{ and } V_{nj} = \alpha_j + \beta_{nj}x_n \quad (1)$$

Here, x_n represents the vector of explanatory variables for individual n , α_j and β_{nj} represent the vectors of parameters to be estimated, and ϵ_{nj} is the unobserved random variable in the utility

function (Wong and Lin 2011). The probability that household n chooses alternative i is given by:

$$P_{ni} = P(U_{ni} > U_{nj}, \forall j \neq i) \quad (2)$$

The MNL assumes that the random variable ϵ_{nj} is independently and identically distributed and follows a Gumbel distribution such that

$$P_{ni} = \frac{\exp V_{ni}}{\sum_j (\exp V_{nj})} \quad (3)$$

We employ the maximum likelihood approach to estimate the discrete choice model, utilizing the SAS9.4 software.

Study Area and Data

Belgium, with an average population density of 381 inhabitants per square kilometer (Statbel 2023), is one of Europe's most densely populated countries. It comprises the Brussels region, home to over 1.1 million residents, and the semi-urban regions of Flanders and Wallonia, which include medium-sized cities (e.g., Antwerp with 508,000 inhabitants and Ghent with 249,000) and rural areas (Chakraborty et al. 2022).

This study uses data from the national online household travel survey (MONITOR) conducted in 2016–2017 (Federale Overheidsdienst Mobiliteit en Vervoer 2019) to develop a nationwide model of household car ownership. The data is augmented with urbanization metrics from Statbel (Statbel 2024a; Statbel 2024b), focusing on population density and the percentage of land used for commercial buildings due to the high correlation among urbanization indicators. The dataset also includes regional indicators to capture key differences in urbanization and public transport accessibility, such as proximity to bus/tram/metro stops and train stations.

Variable selection was guided by prior research, intuitive reasoning, and data availability. Car ownership is defined as vehicles ready for private use, including company cars used outside work. Cases with missing values were excluded. The outcome variable categorizes households into three groups: 0, 1, and 2 or more cars, with the latter grouping necessary due to sample size limitations.

Descriptive statistics (Table 1) provide an overview of dependent and independent variables. To address the 22% of households that did not report income, a separate category (“INC_NA”) was created to account for missing values.

RESULTS

Model Performance

The multinomial logit model was selected to develop the household car ownership model using the logistic procedure in SAS. The authors assessed the multicollinearity of all independent variables by calculating the variance inflation factor (VIF). All VIF values were below 5, indicating low multicollinearity. The proposed model assumed a homogeneous population and investigated the direct effects of socio-economic and built environment attributes on car ownership.

The performance of the multinomial logit model was evaluated using various pseudo-R²-values (Table 2). The metrics provided by Cox and Snell, Nagelkerke, and McFadden support the validity and appropriateness of the model. These statistics are commonly used in logistic regression to assess how well the model fits the observed data.

Table 3 compares the predicted and actual number of households possessing zero, one, and two or more cars. The model demonstrated an overall classification accuracy rate of 69.3% ($= 3.2\% + 41.2\% + 24.9\%$), indicating the reliability of this multinomial regression model. The predictions for one car and two or more vehicles are more precise (respectively, $81.7\% (= 41.2\% / (1.3\% + 41.2\% + 7.9\%))$ and $64.7\% (= 24.9\% / (0.1\% + 13.5\% + 24.9\%))$), particularly the accuracy in predicting a single vehicle. However, the likelihood of accurately predicting zero vehicles is much lower ($29.1\% = 3.2\% / (3.2\% + 6.5\% + 1.3\%)$). This discrepancy may stem from the relatively small sample size of households without cars compared to the other categories. Additionally, the category of one car takes precedence in the study. These accuracy results highlight the model’s reliability in addressing household car ownership across different categories. However, the relatively lower precision in predicting zero cars underscores the challenges of accurately modeling small subsets within the dataset.

Model Estimates

The category of zero cars was chosen as the reference, and the probability of each category was compared to this reference. Table 4 presents the likelihood ratio test results, which examine the overall relationship between car ownership and each independent variable. These statistics serve as indicators for evaluating predictors that significantly contribute to predicting car ownership. The likelihood ratio tests identified employment status, age, income, household composition, driving license possession, and proximity to train stations as key predictors significantly influencing car ownership. Thus, from all the considered variables (as described in Table 1), only the season ticket for the train and the presence of a bus, tram or metro stop within 500m of the home were not included in the final model, as these variables were not significant at the 5% level of significance. The insignificance of proximity to bus stops may reflect the comprehensive nature of Belgium's integrated public transportation system.

The parameter estimates are provided in Table 5. Recall that these estimates are with respect to households without a car, and for categorical variables, the reference category is coded as zero. Note that the reference category is arbitrary, which means the significance of parameter estimates changes depending on the chosen reference category. Therefore, it is crucial to look at the type III likelihood ratio tests presented in Table 4 to determine whether a variable is significant.

To illustrate the interpretation, consider the examples of age and blue-collar workers. For age, the odds that a household owns one car compared to not owning a car increases by 1.9% ($\exp(0.019) - 1$) for each additional year the reference person in the household is older. The odds that a household owns two or more cars compared to not owning a car increases by 1.0% ($\exp(0.010) - 1$) for each additional year the reference person is older. For professional occupation, white-collar workers are the reference category. The parameter for the odds of having one car compared to not owning a car is not significantly different from zero ($p\text{-value} = 0.455$), indicating no significant difference between blue-collar and white-collar workers. However, the odds of owning two or more cars compared to not owning any cars are 41.6% ($\exp(-0.538) - 1$) lower for blue-collar workers compared to white-collar workers.

DISCUSSION

This section presents the results from the econometric approach to better understand the underlying factors driving household vehicle ownership in Belgium.

Socio-Economic Factors

Self-employment emerges as a key factor influencing car ownership, with self-employed individuals being more likely to own two or more cars compared to blue-collar workers. This trend aligns with studies highlighting higher car ownership rates among the self-employed, attributed to greater flexibility in work-related travel patterns and increased mobility needs (Cui et al. 2018). Conversely, professionally inactive individuals exhibit reduced mobility requirements, which correlates with a lower likelihood of owning multiple vehicles, a finding consistent with prior research linking employment type to varying levels of vehicle ownership (Potoglou and Kanaroglou 2008). Furthermore, white-collar workers are more likely to own a second car, reflecting their income levels and lifestyle demands (Kermanshah M 2001). In Belgium, additional factors, such as access to free or subsidized public transport, further shape car ownership trends, underscoring the nuanced relationship between professional occupation and mobility patterns.

Households with lower levels of education are less likely to own two or more cars than those with higher education levels, which aligns with the study by Oyedepo et al. (2017). Furthermore, higher education not only correlates with higher income levels, which enable car ownership, but it also influences mobility choices through environmental awareness and attitudes toward sustainable transport (Flamm 2009). This duality underscores the complexity of education's role in car ownership decisions. While households with higher education levels may own multiple vehicles, they are also more likely to adopt shared mobility services or public transport for specific travel purposes.

Gender did not influence household vehicle ownership. However, previous studies suggest that gender roles in mobility decisions are evolving. Female household members increasingly influence car ownership decisions, reflecting broader changes in workforce participation and household dynamics. While gender was not statistically significant in this model, it remains an important

variable for future studies to explore (Basu and Ferreira 2020).

Households with older members are more inclined to possess a car, as age increases the probability of having one car and two or more cars. Older individuals prefer the flexibility and independence provided by car ownership, especially in suburban or rural areas where public transit options may be limited. This aligns with findings that retired individuals rely heavily on cars to maintain their social and economic activities (Anowar 2015). Those without a driver's license are less likely to own a car, aligning with intuitive expectations and existing literature (Potoglou and Kanaroglou 2008; Oyedepo et al. 2017).

Larger households are more likely to have one car and even more likely to have two or more cars compared to not having a car. In contrast, households with children under 18 are less likely to have one or multiple cars. The presence of young children decreases the likelihood of owning more than one car. Research has indicated that having more children under 18 can impact the available funds for multiple vehicles (Soltani 2017). However, research has also shown that as the number of children increases, the likelihood of owning a car for transportation or childcare purposes increases (Wong and Lin 2011). As children grow older, the household's mobility needs rise, increasing the probability of owning multiple vehicles (Ryan and Han 1999; Soltani 2017). These findings highlight the lifecycle effects on household car ownership. Larger households face diverse and often competing mobility needs, such as commuting, childcare, and leisure activities, which increase their dependence on private vehicles. In contrast, single individuals, particularly those residing in urban areas, may rely more on public transport or shared mobility due to fewer constraints on their time and fewer financial resources (Caulfield 2012; Heinonen et al. 2021).

Built Environment and Regional Variations

Car ownership varies significantly by region in Belgium, with households in Flanders owning more cars than those in Wallonia. This disparity reflects differences in population density, land use, and proximity to rail stations. Higher population density and greater use of land for commercial purposes reduce car ownership, as compact urban areas like Brussels offer accessible public transport, shared mobility options, and nearby essential services, discouraging reliance on private

vehicles (Potoglou and Kanaroglou 2008; Flamm 2009; Matas et al. 2009). Conversely, less densely populated regions like Flanders and Wallonia see higher car ownership due to limited public transport infrastructure, longer commutes, and private parking availability (Kim and Mokhtarian 2018).

Proximity to rail stations significantly decreases car ownership, with households near train stations more likely to rely on public transport, emphasizing the importance of rail networks in reducing vehicle dependence (Ryan and Han 1999; Potoglou and Kanaroglou 2008; Kim and Mokhtarian 2018). However, bus, metro, or tram proximity showed no significant effect, possibly reflecting Belgium's integrated multimodal transportation system, where rail infrastructure is often the backbone of urban and intercity mobility. The complementary roles of bus and tram systems may dilute their isolated effect on car ownership (Potoglou and Kanaroglou 2008).

Influence of Shared Mobility Services

Subscriptions to shared mobility services, such as car-sharing and bike-sharing, significantly reduce car ownership. Households not subscribed to these services are more likely to own one or multiple cars, underscoring the role of shared mobility in decreasing private vehicle dependency. These services provide cost-effective and flexible alternatives, particularly in urban and semi-urban areas, where parking constraints and high maintenance costs make private car ownership less practical (Jochem et al. 2020). Research also highlights that affordability is a key driver for adopting shared mobility, which shifts household preferences toward multimodal transportation options (Flamm 2009; Kim and Mokhtarian 2018).

Shared mobility services strengthen the ecosystem of alternatives to private vehicles, reducing ownership even among higher-income households. However, their impact depends on integration with public transportation and the availability of shared infrastructure. Urban areas with well-connected shared mobility systems exhibit a stronger shift from car dependency, while rural or suburban regions face adoption challenges (Jochem et al. 2020).

Limitations and Future Research Directions

The findings emphasize lower car dependency in densely populated areas with accessible public transportation and various restrictions and costs associated with vehicle ownership. However, car ownership increases as the number of children in the household rises, reflecting transportation and childcare needs (Wong and Lin 2011; Soltani 2017).

This study utilized cross-sectional MONITOR data, which, while detailed, does not capture changes in car ownership over time or include variables like lifestyle choices and attitudes toward sustainable transport. These limitations restrict the ability to analyze emerging trends, such as preferences for electric vehicles, shared mobility, or remote work. Panel data in future studies could address these gaps by providing longitudinal insights into behavioral shifts.

The absence of variables related to household attitudes, psychological preferences, or awareness of sustainable mobility options represents a significant limitation. Incorporating such data in future studies could yield deeper insights into how perceptions and social norms influence car ownership, particularly as shared and electric mobility options continue to expand.

While the multinomial logit model effectively analyzes household car ownership patterns, its assumption of independence among choices may oversimplify the decision-making process. Advanced models, such as mixed multinomial logit (MMNL) or nested logit models, could better account for unobserved heterogeneity and complex decision structures. Furthermore, incorporating random effects could help capture variations in household characteristics and preferences more accurately.

The findings of this study are specific to Belgium, with its unique socio-economic, cultural, and transport infrastructure context. Future research should validate these results in other regions or countries with differing urban densities, public transport availability, and cultural attitudes toward car ownership. Expanding the analysis to include diverse geographical areas could enhance the generalizability of these findings.

Emerging mobility solutions, such as mobility as a service (MaaS) and shared mobility, remain limited in Belgium. However, initiatives like the Green Deal “Shared Mobility” offer the potential

for studying their impact on car ownership. Future research could explore how policy and infrastructure development influence the adoption of these alternatives, providing actionable strategies for sustainable transportation systems.

Behavioral and Policy Implications

Frequent car use strongly correlates with household car ownership, as regular drivers often view cars as indispensable, even when alternatives exist. Behavioral interventions like carpooling promotion and flexible work arrangements could help reduce reliance on private vehicles. Larger households are more likely to own cars due to diverse mobility needs, while households with young children tend to own fewer cars, likely due to financial constraints. However, as children grow, their mobility needs increase, often leading to additional car ownership. This lifecycle dynamic highlights the importance of family-focused solutions like carpooling and subsidized transport services.

Higher education, while linked to greater car ownership due to income and professional demands, also fosters preferences for sustainable transport. This dual relationship presents opportunities to target higher-educated groups with campaigns emphasizing the financial and environmental benefits of shared mobility options (Flamm 2009).

Policy strategies based on these findings include investments in public transit to enhance frequency, reliability, and affordability, particularly in urban areas like Brussels. Expanding shared mobility programs and integrating them with public transport can reduce private vehicle dependency, especially in suburban regions. Family-oriented policies such as subsidized childcare transport and school-focused carpooling programs address specific mobility needs. Additionally, education campaigns focusing on the hidden costs of car ownership and promoting sustainable alternatives can influence behavioral shifts. Equitable access to sustainable mobility, including subsidies for low-income households and improved options for individuals with disabilities, is essential to ensure inclusivity.

Belgium's high population density and car ownership rates make it an important case for future research. Policies like the Green Deal on Shared Mobility reflect a growing focus on

sustainable transport, underscoring the need for ecological, inclusive, and economically viable mobility solutions.

CONCLUSION

Private vehicle reliance remains widespread, with significant environmental and policy implications. This study analyzed household car ownership in Belgium, incorporating socio-economic and demographic variables, residential characteristics, shared mobility subscriptions, and car usage frequency. The multinomial logistic regression model effectively captured key determinants of car ownership, emphasizing socio-demographic, environmental, and mobility-related factors.

The study's main findings confirm previous research, emphasizing the significance of socio-demographic and economic characteristics, built environment attributes, and availability of mobility resources in explaining household car ownership patterns. Income and employment status are key socio-economic drivers of car ownership. Larger households, higher-income groups, and self-employed individuals are more likely to own multiple cars. Conversely, professionally inactive individuals exhibit lower car ownership levels due to limited mobility needs. With respect to the built environment and regional factors, higher population density and proximity to train stations are associated with lower car ownership, particularly in urban areas like Brussels. Meanwhile, residents in suburban and rural areas of Flanders and Wallonia demonstrate higher car ownership rates due to limited transport alternatives and greater reliance on private vehicles. Concerning shared mobility services, subscriptions to these services significantly reduce car ownership, particularly for households that would otherwise own multiple cars. This highlights the potential of shared mobility as a viable alternative to private vehicle dependency, especially in urban settings.

The findings underscore the need for policies tailored to regional and demographic differences, focusing on reducing car dependency and fostering sustainable mobility options: *(i)* invest in public transit to enhance affordability, accessibility, and reliability, *(ii)* expand shared mobility services, *(iii)* promote behavioral shifts by educating households on the hidden costs of car ownership and parking and the benefits of shared and sustainable transport, *(iv)* introduce family-focused transport options to address lifecycle-specific mobility needs.

While this study provides valuable insights, its cross-sectional data limits the ability to capture temporal changes in car ownership patterns. Future research should explore panel data to track shifts in mobility behavior, particularly in response to trends like remote work and electric vehicle adoption. Incorporating psychological variables such as attitudes toward sustainability and advanced modeling approaches like mixed multinomial logit can provide deeper insights. Validating these findings across diverse geographic contexts would also expand their applicability.

Belgium's transition to sustainable mobility is urgent to reduce environmental impacts and enhance equity. This study provides a foundation for evidence-based policies that address regional and demographic mobility needs, fostering an inclusive, energy-efficient transportation system.

DATA AVAILABILITY STATEMENT

All data, models, and codes supporting this study's findings are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

The authors confirm their contributions to the paper as follows: study conception and design: S.H. Bahreini, S. Reiter, M. Cools; data collection: S.H. Bahreini, M. Cools; analysis and interpretation of results: S.H. Bahreini, M. Cools; draft manuscript preparation: S.H. Bahreini, S. Reiter, M. Cools. All authors reviewed the results and approved the final version of the manuscript.

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TABLE 1. Sample Description

Variable	Label: Description	Count ¹ Mean ²	% ¹ SD ²
<i>Dependent variables</i>			
Number of cars ¹	ZERO*: 0	935	11.0
	ONE: 1	4280	50.4
	TWO OR MORE: ≥ 2	3272	38.6
<i>Independent variables</i>			
Age ²	AGE	52.42	14.96
Gender ¹	MALE*: Male	4668	55.0
	FEMALE: Female	3819	45.0
Professional occupation ¹	JOB_BCW: Blue-collar worker	437	5.2
	JOB_WCW*: White-collar worker	2706	31.9
	JOB_CS: Civil servant	1225	14.4
	JOB_LSE: Liberal profession/ self-employed	274	3.2
	JOB_STU: Student	275	3.2
	JOB_INA: Inactive	3570	42.1
Education level ¹	EDU_LOW*: Low (max. secondary school)	4373	51.5
	EDU_HIGH: High (min. Bachelor)	4114	48.5
Driving license (car) ¹	DRL_NO*: No	577	6.8
	DRL_YES: Yes	7910	93.2
Net monthly household income ¹	INC_LOW*: 0 - 3999 Euro	5300	62.4
	INC_HIGH: More than 4000 Euro	1298	15.3
	INC_NA: Refusal to answer	1889	22.3
Household size ²	HHSIZE	2.42	1.20
Children under 18 ¹	CU18_NO*: No	6833	80.5
	CU18_YES: Yes	1654	19.5
Subscription to a bikesharing system ¹	SBIKE_NO*: No	7938	93.5
	SBIKE_YES: Yes	549	6.5
Subscription to a carsharing system ¹	SCAR_NO*: No	7935	93.5
	SCAR_YES: Yes	552	6.5
Season ticket Bus/Tram/Metro ¹	STBTM_NO*: No	5610	66.1
	STBTM_YES: Yes	2877	33.9
Season ticket Train ¹	STTRAIN_NO*: No	6988	82.3
	STTRAIN_YES: Yes	1499	17.7
Region of home location ¹	REG_BRU: Brussels	504	5.9
	REG_WAL*: Wallonia	1519	17.9
	REG_FLA: Flanders	6464	76.2
Bus/tram/metro stop within 500m of the home ¹	DBTM_NO*: No	2467	29.1
	DBTM_YES: Yes	6020	70.9
Train station within 2km of the home ¹	DTRAIN_NO*: No	5329	62.8
	DTRAIN_YES: Yes	3158	37.2
Population density ²	POPD	1348.58	2479.23
Land use ² : % commercial buildings	LU_COM	0.98	0.89

¹: Categorical variable; ²: Continuous variable; *: Reference category in MNL model

TABLE 2. Pseudo- R^2 -values

Cox and Snell	Nagelkerke	McFadden
0.36	0.42	0.23

TABLE 3. Confusion Matrix

Observed	Predicted		
	Zero	One	Two or more
Zero	3.2	6.5	1.3
One	1.3	41.2	7.9
Two or more	0.1	13.5	24.9

TABLE 4. Type III Likelihood Ratio Tests of the Car Ownership Model

Variable	Chi-Square	DF	P-value
Age	33.7	2	<0.001
Gender	2.9	2	0.233
Professional occupation	148.8	10	<0.001
Education level	29.0	2	<0.001
Driving license (car)	456.5	2	<0.001
Net monthly household income	176.9	4	<0.001
Household size	754.2	2	<0.001
Children under 18	156.2	2	<0.001
Subscription to a bikesharing system	10.8	2	0.005
Subscription to a carsharing system	12.9	2	0.002
Season ticket Bus/Tram/Metro	173.7	2	<0.001
Region of home location	21.2	4	<0.001
Train station within 2km of the home	111.3	2	<0.001
Population density	10.0	2	0.007
Land use: % commercial buildings	19.1	2	<0.001

TABLE 5. Parameter Estimates of the Car Ownership Model

Parameter	One car			Two or more cars		
	Est.	S.E.	P-value	Est.	S.E.	P-value
Intercept	-2.156	0.278	<0.001	-4.593	0.352	<0.001
AGE	0.019	0.004	<0.001	0.010	0.004	0.023
FEMALE	-0.049	0.083	0.560	0.048	0.093	0.606
JOB_BCW	-0.142	0.190	0.455	-0.538	0.206	0.009
JOB_CS	0.269	0.134	0.044	-0.199	0.145	0.170
JOB_LSE	0.222	0.314	0.479	0.609	0.321	0.058
JOB_STU	0.181	0.280	0.518	0.155	0.296	0.602
JOB_INA	0.114	0.119	0.341	-0.749	0.133	<0.001
EDU_HIGH	0.369	0.091	<0.001	0.538	0.100	<0.001
DRL_YES	1.945	0.109	<0.001	3.414	0.195	<0.001
INC_HIGH	-0.088	0.163	0.589	0.981	0.166	<0.001
INC_NA	0.138	0.102	0.174	0.301	0.113	0.008
HHSIZE	0.590	0.060	<0.001	1.479	0.066	<0.001
CU18_YES	-0.506	0.153	0.001	-1.551	0.164	<0.001
SBIKE_YES	-0.214	0.159	0.178	-0.600	0.194	0.002
SCAR_YES	-0.534	0.160	0.001	-0.619	0.189	0.001
STBTM_YES	-0.669	0.084	<0.001	-1.256	0.098	<0.001
REG_BRU	0.225	0.238	0.344	0.376	0.315	0.233
REG_FLA	0.464	0.105	<0.001	0.480	0.116	<0.001
DTRAIN_YES	-0.265	0.081	0.001	-0.814	0.092	<0.001
POPD ¹	-0.000	0.000	0.215	-0.000	0.000	0.002
LU_COM	-0.138	0.064	0.030	-0.352	0.082	<0.001
¹ : POPD	-0.000031	0.000025	0.215	-0.000127	0.000040	0.002