

Article

Analysis on the Choice of Travel Modes of Residents of a Small-Sized Town

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Abstract

Mobility is an essential condition for ensuring the functionality of urban areas. This study analyses the transportation preferences of the inhabitants of Petroșani, a small city integrated into a conurbation with former mining functions (the Petroșani Basin). Data were collected based on household surveys and interviews regarding mobility behaviour. To evaluate travel patterns, the study applies three statistical methods: descriptive analysis, the χ^2 (Chi-square) test and Multiple Correspondence Analysis (MCA). The results indicate significant variations according to gender and the demographic segments analysed (children, adolescents, students, active population, retirees). The MCA model explains 39.3% of the total inertia (Dim1 = 20.9%, Dim2 = 18.4%). The results indicate that the active population occupies a central position, characterized by a diversified mix of transport modes, while other segments present polarized modal behaviours. At a general level, the analysis highlights a clear prevalence of personal car use and pedestrian travel in Petroșani, underlining the need for local mobility policies adapted to the characteristics of the conurbation.

Keywords: urban mobility; small town; travel behaviour; travel characteristics; gender; age

1. Introduction

Transport is a strategic component of urban development, facilitating access to employment opportunities, recreational services and essential social infrastructures (health, education, administration). In order to ensure the competitiveness of public transport systems, it is imperative to align them with the requirements and needs of users, an objective that can only be achieved through a thorough understanding of the determinants of modal choice. The analysis of travel behaviour, which integrates both economic and psychosocial perspectives, reveals a transport demand influenced by interdependent factors. This causal complexity requires the application of robust and diverse data analysis methodologies for rigorous interpretation [1,2].

The mobility of urban residents is determined by a complex interaction between spatial configuration (urban density), socioeconomic profile and subjective attitudes towards low-carbon transport modes [3–6]. High-density residential areas with compact structure facilitate short daily commutes and promote active modes of transport (walking, cycling),



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positively correlating with increased passenger satisfaction. In contrast, residents of peri-urban areas or small towns show an increased dependence on personal vehicles, generating a less sustainable mobility model [4,7–9]. Beyond systemic variables, a series of socio-demographic and spatial determinants, such as income level, age structure and residential location, exert a critical influence on individual mobility paradigms. These factors not only shape modal travel preferences, but also dictate the likelihood of owning a private vehicle, thus conditioning the transition to sustainable transport models [3,10,11].

The dynamics of everyday urban mobility are not the result of a single factor, but a complex manifestation of the interaction between several fundamental dimensions. It is shaped, firstly, by the socio-demographic profile of individuals (age, gender, income level), which defines subjective needs and constraints [12]. Second, the intrinsic characteristics of the trip—the purpose (commuting, shopping, recreation), the distance travelled, and the timing of travel (peak vs. off-peak)—structure the temporal patterns of demand [13].

On the other hand, mobility choices are directly conditioned by the attributes of the available transport system, including not only the availability of the transport mode, but also qualitative indicators such as travel time, reliability, monetary cost and frequency of services [14,15]. Moreover, the spatial configuration, defined by land use and the built environment—housing density, mix of functions, pedestrian accessibility and proximity to points of interest (services, jobs)—acts as a structuring factor of transport demand, facilitating or, conversely, limiting the use of active and sustainable modes [16–19]. Although urban form is a determining variable in urban mobility, it is not the only decision-making factor. Personal attitudes and perceptions towards factors such as road and neighbourhood safety, transport options, comfort and convenience, parental attitudes, socio-cultural norms and socio-demographic profile also play a significant role [7,20,21].

Factors influencing long-distance travel include traveller attributes (such as age and income), trip characteristics (such as purpose and distance), and transportation attributes (such as cost, time, and comfort). Broader influences also include environmental factors, infrastructure availability, and changing attitudes toward travel, such as concerns about sustainability and safety [22,23].

In recent decades, the sustainable urban mobility paradigm has been predominantly shaped by empirical evidence from large metropolitan regions. This focus has left a significant knowledge gap regarding transport dynamics in small and medium-sized cities (SMCs), especially those facing the twin pressures of post-industrial transition and demographic contraction. While the general transport literature extensively documents the socio-economic determinants of commuting, it frequently omits how severe spatial constraints and localized infrastructural failures intersect to dictate modal choices in peripheral urban centers.

This study directly addresses this research gap by exploring the structural and behavioral drivers of personal car dependency in Petroșani Municipality. Unlike standard SMCs, characterized by radial or concentric expansion, Petroșani presents an extremely constrained linear topography, dictated by its position in a narrow mountain valley. This geographical linearity significantly restricts the development of alternative routes and severely compromises the operational efficiency of the local public transport network, which is often perceived as unreliable, poorly connected and structurally deficient. As a result, residents are locked into a high degree of dependence on the private car, transforming the car from a preference into a necessity.

While the existing literature on shrinking cities—such as the former mining towns of the Ruhr region in Germany or the Upper Silesian Industrial Region in Poland—demonstrates a general orientation towards car use during economic restructuring, these international examples have often benefited from massive regional reinvestments in public transport. Thus ref. [24] explains the economic and political mechanisms that force the transition to

car use in areas undergoing industrial restructuring. Also ref. [25] details the explosion of car ownership in post-communist Poland (1990s and 2000s), a direct effect of the collapse of public transport in small industrial cities.

Changes in urban transport behaviour in cities affected by demographic and economic decline are analysed in [26], assessing the impact of structural factors (infrastructure, urban density, public transport network) compared to individual choices (personal preferences, socio-economic factors, car ownership).

In contrast, peripheral post-industrial SMCs in Central and Eastern Europe, such as Petroșani, face severe budgetary constraints that paralyze public transit modernization [27]. By using a complex user-perception survey combined with spatial analysis, this paper goes beyond simply replicating general transport variables. It provides a granular examination of how linear physical geography amplifies public transport deficits, thereby accelerating car dependency in a declining urban context. Thus, the study fills a critical gap in the current geographical and urban planning literature, providing an empirical framework for sustainable transport policies adapted to small mono-industrial, linear and resource-limited cities.

This paper presents the analysis and conclusions of a quantitative study based on a relatively large number of in-depth interviews conducted in the city of Petroșani. The physical-geographical characteristics of the natural environment form the basic framework of the simplicity or complexity of movement in space, which has an impact on the choice of transport. Romania, according to Eurostat, ranks second to last in the European Union in terms of motorization rate with 425 cars per thousand inhabitants, but had the highest increase (86.2%) in the number of registered cars in the period 2012–2022 [28,29]. Therefore, one of the main transport policy strategies of most cities is to reduce the number of cars circulating in the city [30].

It is also known that people focus more on the advantages than the disadvantages. In practice, this means that people perceive the benefits of speed and comfort of using cars more than the negative environmental impact [31].

2. Materials and Methods

As part of the strategic transport planning process, surveys aim to characterize the current mobility behaviour of users. These data collection tools are essential for obtaining empirical information on transport modes, actual travel times and final destinations.

The research on mode choice behaviour was based on the Revealed Preference (RP) mobility survey method, which collects data on people's actual behaviour to understand their choices and preferences about travel decisions. RP data represents actual behaviour and does not suffer from hypothetical errors for estimating mode and route choice patterns [32].

The mobility study captures a variety of factors that influence the choice of transport mode including socio-demographic details such as age, gender, household composition, income, occupation and vehicle ownership, as well as trip characteristics such as distance, travel time and cost [33–35].

2.1. Case Study

The Municipality of Petroșani, located in the Jiu Valley region (Hunedoara County, Romania), serves as a representative case study for post-industrial urban shrinkage and its direct implications on local transport dynamics. Once a major mono-industrial coal-mining centre, the city has undergone severe economic restructuring over the past three decades. This structural shift has fundamentally altered the local socio-demographic landscape, creating a distinct environment that directly influences current modal split choices and urban mobility behaviours [36].

The socio-economic decline of Petroșani is characterized by two interconnected phenomena: continuous demographic contraction and accelerated population aging. According to the 2021 census data [37], the population (31,044 inhabitants) has decreased significantly compared to the peak of the 1990s (53,662 inhabitants) (Figure 1) [38]. Following the closure of most coal mines [39], the massive emigration of the working-age population led to a significant decrease in the population, generating a decrease in the number of employees from 24,790 to only 8948, resulting in a percentage of the employed population of 29% [29]. A specific indicator of post-mining reconversion is represented by the high share of pensioners, which amounts to approximately 35% of the population [29]. Demographic analysis (1995–2024) reveals a continuous contraction of the school population in most educational cycles, a trend that will be maintained in the short term, except for the university segment (Figures 1 and 2) [29]. This structural decline is directly determined by the decrease in the birth rate, reflected in the reduction of the share of the 0–14 age groups in the total population (Figures 1 and 3) [29].

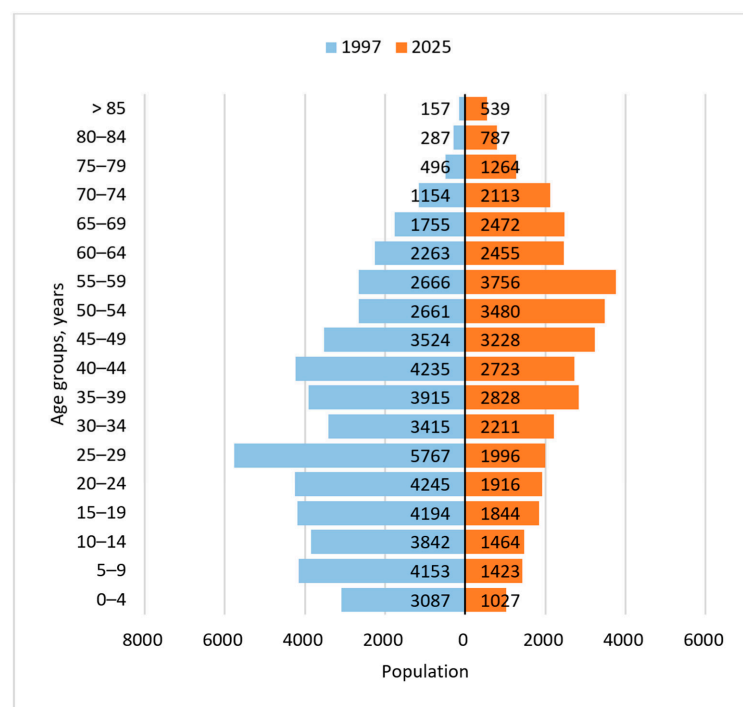


Figure 1. Dynamics of the age and gender structure of the population of Petroșani municipality: comparative analysis (1997 vs. 2025).

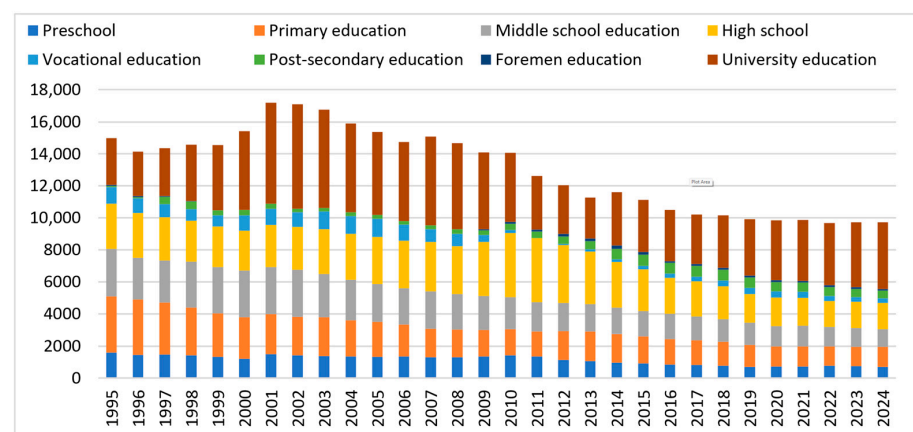


Figure 2. Numerical and structural evolution of the school population in Petroșani municipality during the period 1995–2024.

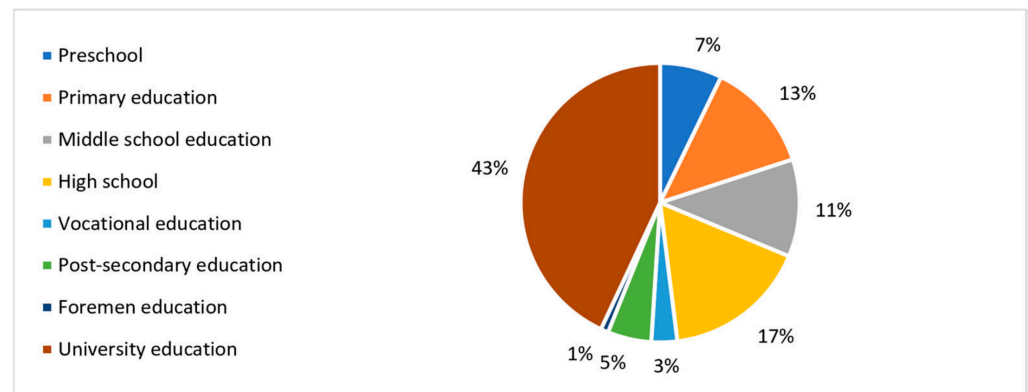


Figure 3. Percentage structure of the school population in Petroșani municipality in 2024, depending on the level of education.

This demographic change has a double impact on the city's transport ecosystem:

- Reduction of peak travel demand: The contraction of the active workforce has systematically altered daily commuting patterns, shifting the volume away from traditional industrial transit corridors;
- Mobility needs of an aging population: The increasing share of elderly residents introduces specific mobility constraints. This demographic group relies heavily on non-motorized transport (walking) or affordable public transit due to decreased private vehicle ownership rates, physical limitations, and lower average incomes.

The analysis of mobility options in relation to demographic structure (age and gender, Figure 4) highlights significant variations in travel behaviour, mode selection and travel purpose. Thus, women frequently make complex, short and fragmented trips (chain-trips) for household and care tasks, while men prioritize linear, longer-distance commuting to work [40–43].

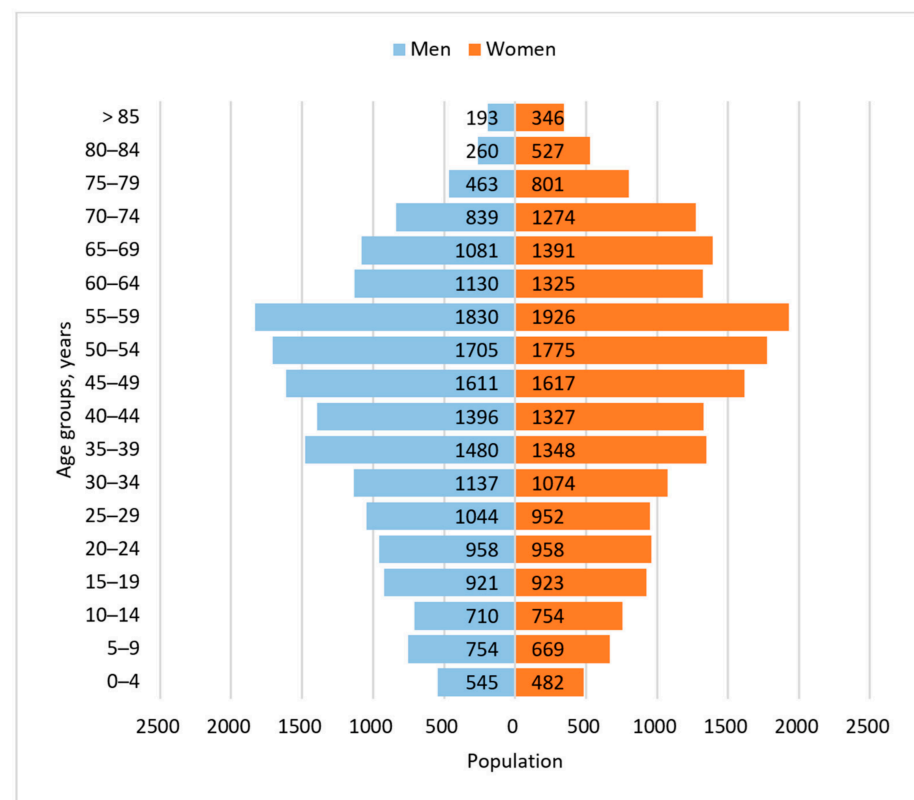


Figure 4. Demographic pyramid of Petroșani municipality: comparative analysis by gender and age in 2025.

The choice of transportation mode to school varies significantly by age; parents control children's transportation decisions, while adolescents benefit from autonomy in this choice. The main determinant of transportation mode remains distance, with a clear transition from short-distance walking to long-distance car or public transportation use [44–47].

Therefore, the research question examining modal choice in Petroșani needs to be contextualized in this fragile socioeconomic framework, where captive users of public transportation coexist with a decreasing number of active commuters.

The physical legacy of the post-mining transition directly dictates the spatial distribution of transport demand. The closure of industrial sites left behind a fragmented urban fabric, characterized by peripheral brownfields and dispersed residential centres, originally built to house mining communities. The thermographic distribution by size of active companies in Petroșani is presented in Figure 5 [48]. Data analysis indicates a concentration of commuting among the working population, with the majority of respondents commuting daily between these perimeters:

- Periphery-to-centre dependency: As economic and commercial activities have been concentrated almost exclusively in the urban centre, residents of the periphery face increased travel distances;
- Economic constraints on the choice of transport mode: Although geographic dispersion increases the theoretical need for motorized travel, the status of the remaining population with low incomes limits the widespread use of private cars.

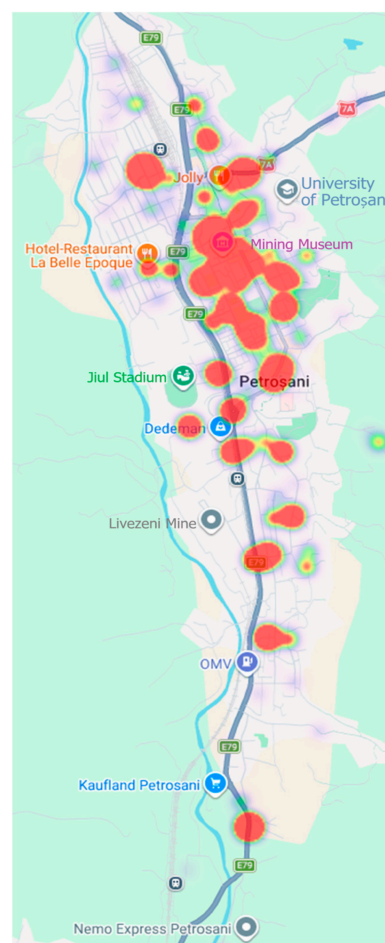


Figure 5. Spatial distribution and intensity of economic activity in Petroșani (2026): Thermographic representation based on company size [48].

This tension between spatial dispersion and economic deprivation reinforces the need to assess how effectively current modes of transportation serve captive passengers stranded in peripheral neighbourhoods.

The structure of the road network in Petroşani acts as a physical determinant of modal choice, limiting the efficiency of public and private transport. The local transport infrastructure is defined by a linear morphology, strongly constrained by the surrounding mountainous topography and the historical zoning of industrial lands. The local road network totals 118 km, with a marked deficit of high-capacity arteries: only 8.6 km of roads are classified as the second technical category, with 2 lanes in each direction [38]:

- Single-axis congestion: urban traffic relies heavily on a main longitudinal road axis, which handles both local commuting and regional transport. The lack of redundant parallel routes increases vulnerability to localized congestion, directly reducing the reliability and competitiveness of public buses in terms of travel time;
- Active mobility deficiencies: The historical emphasis on motorized transportation has left pedestrian networks underdeveloped or poorly maintained in industrial areas, while dedicated bicycle infrastructure remains virtually non-existent.

Therefore, the geometric and qualitative attributes of the road network are not limited to simply accommodating traffic; they actively restrict alternative modal options, forcing commuters to navigate a system that penalizes active mobility and compromises the efficiency of public transportation.

2.2. Sampling and Data Collection Methodology

To ensure high data granularity and optimal representativeness at the local community level, the empirical component of the study was based on quantitative field research. Data collection was carried out through structured field interviews, conducted face-to-face interviews along the main arteries and mobility nodes in Petroşani municipality. The participants in the household survey were selected by simple random sampling, thus ensuring a representative sample for the demographic and socio-economic characteristics of the studied population.

This direct approach allowed:

- inclusion of households from different areas of the city, providing a balanced and objective picture of the modal share of transport and urban mobility behavior;
- minimization of non-response errors and clarification of possible conceptual ambiguities perceived by participants while completing the questionnaire.

The minimum required sample size n was determined using Cochran's formula Equation (1) [49,50]:

$$n = \frac{z^2 \cdot p \cdot (1 - p)}{e^2} = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 384.16 \approx 385, \quad (1)$$

With $z = 1.96$ (value associated with the desired confidence level of 95%), $p = 0.50$ (maximum variance assumption; estimated population proportion), and $e = 0.05$ ($\pm 5\%$ margin of error for the 95% confidence level), the formula yields a minimum of $n = 385$ [49,50]. The conservative assumption of $p = 0.50$ produces the largest possible sample size estimate, maximizing precision and generalizability. No correction for the finite population was necessary, as the target population is 31,044 inhabitants, well above the 5% threshold.

The final sample comprises $n = 398$ valid respondents, permanent or temporary residents of Petroşani city. The sample size ensures an acceptable margin of statistical error within standard limits for urban social science research (approximately $\pm 4.9\%$), at a 95% confidence level, relative to the general population of the municipality. The

sample structure was stratified to faithfully reflect key demographic characteristics of the investigated population, including variables such as age, gender, education level, and occupational status.

The questionnaire was structured into three distinct modules, designed to capture both the objective and subjective dimensions of mobility:

- General profile and travel log: detailed information on household characteristics and characteristics of the last trip made, including origin, destination, purpose and means of transport used;
- Mobility behaviour and user perception: data on travel habits, including the use of ride-hailing services, decision-making factors in choosing the mode of transport (time, cost, comfort) and the main challenges/barriers encountered in everyday mobility;
- Socio-demographic and economic data: detailed information on employment, educational level, age, gender, family size, household income, driving license status and motorization level (accessibility to cars).

Ethical approval was obtained from the Institutional Ethics Committee of the University of Petroșani, in accordance with the Declaration of Helsinki and the General Data Protection Regulation (GDPR EU Regulation 2016/679); informed verbal consent was obtained from all participants prior to the interview.

2.3. Data Processing

To process the data and identify patterns, trends, correlations and anomalies, the study applied three statistical methods commonly used in mobility behaviour research. These analyses aimed to assess how the population chooses transport modes (e.g., walking, cycling, private car, public transport) in direct correlation with their socio-demographic profiles, with a focus on gender and age [51,52].

The raw data were taken from the Petroșani household survey database. All processing, cleaning and statistical analysis were performed in the R environment (R Core Team, Vienna, Austria), used for data analysis and graphical representation [53]. The workflow integrated the packages from the “tidyverse” ecosystem (Wickham et al., Boston, MA, USA) for efficient data transformation and manipulation, “readxl” (Wickham et al., Boston, MA, USA) for direct data import from Excel files, “FactoMineR” (Lê et al., Rennes, France) for performing multiple correspondence analysis and “factoextra” (Kassambara and Mundt, Kassel, Germany) for interpretation and visualization of multivariate analyses [54–59].

The final sample of the study included 398 respondents, with the data processing process focusing on the fundamental variables established by the questionnaire design methodology [60,61]. These included: gender, age group and mode of transport used. In order to facilitate statistical analysis and interpretation of the results, the age group variable was coded into four distinct categories: Primary/middle school; High school/university; Working population; Retired. To ensure statistical robustness and mitigate data sparsity issues in certain transport modes, the original 10 transport modes included in the raw data set were indicated as distinct behavioural into three macro-categories:

1. Active mobility: includes walking and cycling (codes 1 and 2);
2. Personal car: includes your own car, scooter, van and pickup truck (codes 3, 4, 5 and 6);
3. Public transport: includes taxi, minibus, bus and service bus (codes 7, 8, 9 and 10).

While this consolidation standardizes the analytical framework, it introduces specific methodological trade-offs that require justification.

First, active transport modes (e.g., walking and cycling) were merged despite their distinct infrastructure and physiological requirements. This decision was driven by the shared environmental and health-promoting attributes of both modes within the urban ecosystem studied, allowing for a clearer contrast with motorized alternatives. Second,

public and semi-public transport modes—which include buses, minibuses, taxis, and coaches—were consolidated into a single collective transport category. While this approach synthesizes varying operational dynamics (such as the fixed routes of buses versus the on-demand nature of taxis), it reflects the shared functional dependence of users on external transport services rather than on private vehicle ownership.

Statistically, maintaining 10 independent categories would have severely compromised the degrees of freedom in our econometric/statistical models, leading to overfitting and inflated standard errors due to the small number of cells in minor categories (e.g., minibuses or specialized bicycles). By reducing the categorical dimensionality to three main pillars, we increased the statistical power of the tests and ensured the stability of the regression coefficients, prioritizing macro-structural trends over micro-level modal variations.

To strengthen the rigor of the statistical analysis, the dataset used was limited exclusively to the first and second daily trips recorded (Figures 6 and 7). Subsequent trips (third, fourth, etc.) were excluded from processing because they had a high percentage of missing values, which could have significantly affected the validity of the statistical models applied.

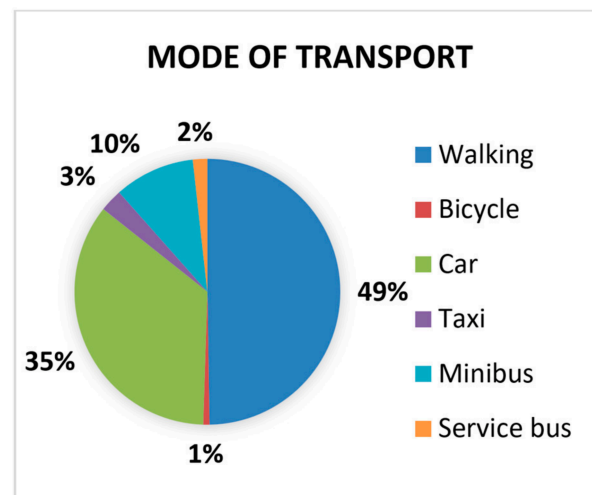


Figure 6. Distribution of transport modes used during Trip 1.

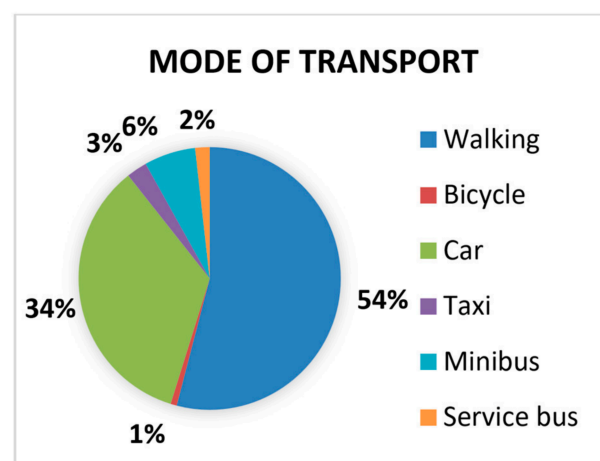


Figure 7. Distribution of transport modes used during Trip 2.

The results obtained in the first part of the day (Figure 6) indicate a predominance of pedestrian mobility, with almost half of the respondents choosing to travel on foot. This may reflect a compact urban configuration, with short distances between home and frequent

destinations. The use of personal cars (35%) however suggests a significant dependence on individual motorized transport, which may have implications for traffic and local pollution.

In the second part of the day (Figure 7), an increase in pedestrian mobility compared to the morning (+5%), which can be explained by the relaxation of time constraints and a possible preference for light physical activity after work, is observed. The use of personal cars remains constant, suggesting a stable dependence on individual transport.

Correlating the two data sets, it can be seen that pedestrian mobility is likely associated with trips to work or education, which suggests good urban accessibility. At the same time, the low use of public transport (minibus—10%, service bus—2%) may signal an insufficient offer or a negative perception of its quality. The decrease in minibus use may indicate a reduction in the frequency of trips or a preference for other means outside peak hours. Compared to the morning, a transition from functional to personal and recreational mobility is observed. The increase in walking and trips for shopping or recreation indicates a relaxation of the urban rhythm and a possible preference for activities carried out in the proximity of the home. Also, the stability of car use suggests that road infrastructure and parking remain important factors in the mobility decision.

To ensure a complete data set in the statistical modelling phase, the listwise deletion method was applied for the variables included in the analysis (transport mode, gender and age group). Following this processing, the final sample used in the statistical analyses (Chi-square test and multiple correspondence analysis) comprised 398 respondents.

In order to obtain an overview of mobility patterns and transport preferences within the investigated sample, the first stage of the methodology consisted in applying a descriptive statistical analysis [62]. This approach allowed the identification of the frequencies of use of different transport modes (e.g., public transport, personal car, bicycle, walking) and their role in urban dynamics, in the specific context of Petroșani municipality.

In order to test the association between mobility options and the socio-demographic profile of the respondents, defined by gender and age group, statistical tests of independence were applied. For the analysis of the relationship with gender, the Chi-square (χ^2) test was used, the applicability conditions of which were met. For the analysis of the relationship with age group, given the presence of low expected frequencies in the contingency table, Fisher's exact test was applied. Both tests allowed the comparison of the observed frequencies of modal choices with the theoretical expected ones, in order to test whether the distribution of transport modes between different socio-demographic categories is independent of them or reflects real statistical associations [63].

Last but not least, to explore and quantify multidimensional associations between transport modes, gender and age groups, we used Multiple Correspondence Analysis. This multivariate statistical technique is an extension of simple correspondence analysis, ideal for data sets involving more than two qualitative variables. The method allows us to reduce the dimensionality of the data and project the variable categories into a two-dimensional space (factorial design), while preserving most of the inertia (variance) of the original information [64,65].

Through this spatial projection, we have facilitated the visual identification of proximities and behavioural patterns. Thus, we can directly observe how certain demographic segments (defined by the intersection of gender and age segments) preferentially associate with specific mobility options. Smaller distances between points in the graph indicate a strong association, providing a nuanced perspective on travel patterns. This methodological approach helps us extract distinct mobility profiles, essential for underpinning urban planning and transportation strategies tailored to the real needs of each target group [66–68].

Statistical analysis of household survey data allowed a comparison of the main travel characteristics of men and women. The same methodology was subsequently used to

compare travel characteristics relevant for different age groups (children, adolescents, students, the working population represented by several categories and pensioners).

At the same time, conducting a similar analysis in environments with ecological transport options highlights the impact of daily routine (work, education, shopping) and spatial proximity on mobility behaviour. This aspect is essential to illustrate how the compact topography of a small city facilitates the orientation towards active modes of transport [69].

3. Results and Discussion

Travel characteristics were statistically analysed based on survey data, highlighting gender disparities. The same method was used to assess travel behaviour for various socio-professional and age categories, covering the entire demographic spectrum, from young to active and retired populations.

To identify the socio-demographic determinants of urban mobility, the relationships between the main mode of transport and two key variables—gender and age cohort—were statistically assessed. Given the specific context of the small university city analysed, these dynamics provide critical insights into localized transport patterns. Descriptive statistical analysis included the generation of frequency distributions and crosstabs, correlated with valid percentages, to assess the dependence of mobility behaviour on the basic sociodemographic variables: gender (Figure 8) and age group (Figure 9). Thus, these analytical tools provide a clear quantitative perspective, quantifying exactly the proportion of respondents in each cohort who opt for a certain transport alternative. These initial results trace the general profile of local mobility, laying the foundations for the subsequent multivariate analyses presented in the following sections (Chi-square test and multiple correspondence analysis). The integration of these variables in subsequent multivariate analyses will allow for an in-depth investigation of the determinants, facilitating the development of efficient and personalized urban mobility planning policies.

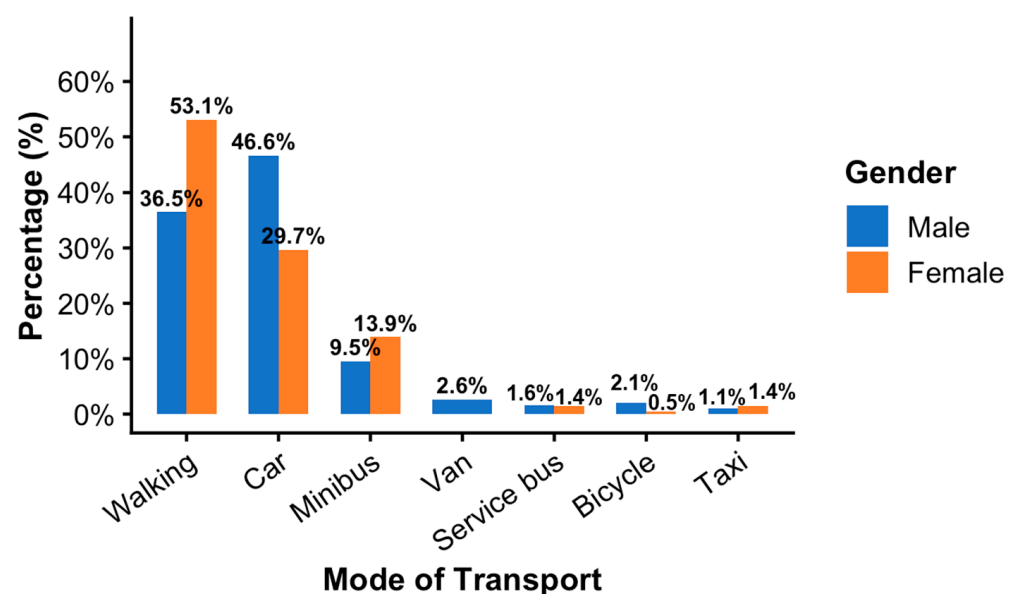


Figure 8. Gender differences in choice of main means of transport (%).

To analyse the association between the gender of the respondents and their main mode of transportation (Figure 9), a Chi-square (χ^2) test of independence was performed. Preliminary data selection confirmed that all expected frequencies exceeded the minimum threshold of 5 (minimum expected frequency = 26.10), thus validating the mathematical hypotheses of the test. The empirical results reveal a statistically significant association between gender

and travel behaviour ($\chi^2(2, N = 398) = 20.624, p < 0.0001$). To quantify the strength of this association, Cramér's V coefficient was calculated, resulting in a value of $V = 0.228$, which indicates a moderate effect size and is practically relevant in social science research.

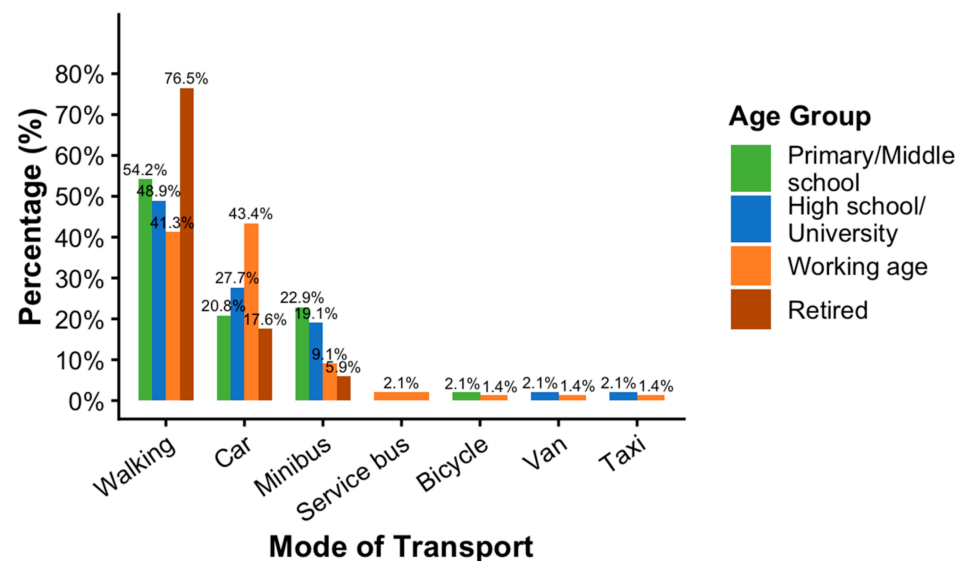


Figure 9. Percentage distribution of main modes of transport by age group.

Descriptive metrics indicate distinct behavioural divergences:

- Active mobility and public transport: Female respondents showed a significantly higher propensity for active mobility (56.0%) and public transport (18.2%);
- Private motorised transport: In contrast, male respondents predominantly relied on private cars (46.6%).

These findings challenge traditional, gender-neutral frameworks often applied to municipal budgets.

Contextualised in recent European literature, this divergence highlights the phenomenon of “car ownership lag” typical of Central and Eastern European (CEE) transitions [70]. In post-industrial contexts, economic restructuring often causes unequal access to private vehicles, making female commuters more structurally dependent on public cadres.

However, as observed in [71] in small cities in southern Europe, local Sustainable Urban Mobility Plans (SUMP) often fail to engage citizens or adapt to these sub-demographic realities due to entrenched car-centric planning cultures and limited municipal resources. The data show that continuing a car-centric budget allocation directly disadvantages the main users of the pedestrian ecosystem.

To bridge this gap, municipal investments need to shift towards inclusive, safety-oriented infrastructure—such as continuous sidewalk networks and improved public lighting—aligning with the street space redistribution and active mobility frameworks supported by the European Urban Initiative (EUI) [72].

From a policy perspective, municipal planning needs to move from car-centric infrastructure to gender-sensitive urban design. As women emerge as the main users of the pedestrian ecosystem and public transport in this university city, municipal investments should prioritize:

- Pedestrian safety and comfort: Expanding sidewalks, continuous paving, and improved street lighting, especially on routes connecting the university campus to residential neighbourhoods;
- Perceived safety: Mitigating safety risks for female pedestrians during late-night commutes, which is highly relevant in urban areas populated by students;

- Public transport optimization: Improving the reliability and safety of public transport hubs to support and capture the number of female travellers.

To explore the relationship between age cohorts and mode choice (Figure 10), the data distribution was initially assessed for a Chi-square test. However, the assumption of an adequate number of cells was violated, as one cell fell below the critical threshold of 5 (Pensioners $\times$ Public Transport = 2.35). To ensure statistical validity, Fisher's exact test was applied, as it calculates exact probability values independent of the minimum expected cell frequencies.

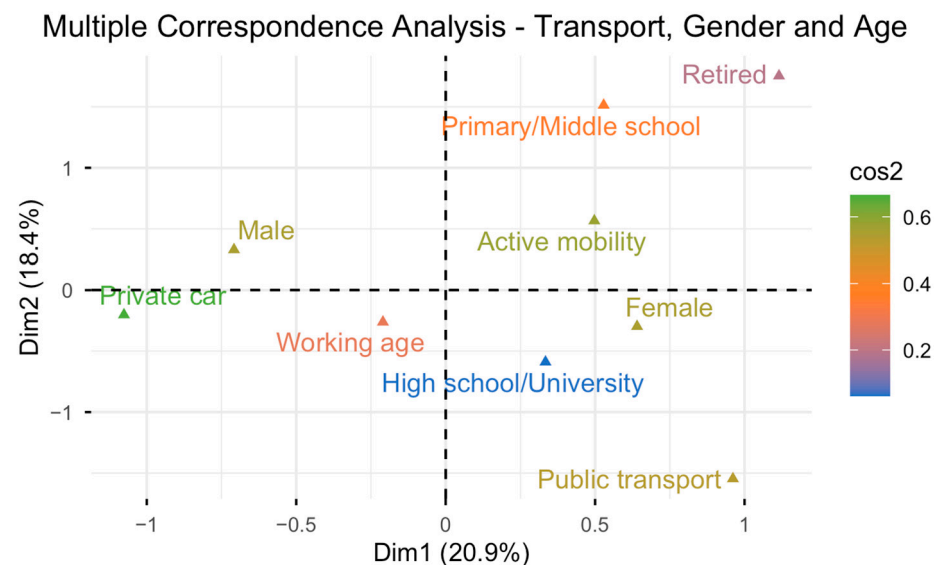


Figure 10. Multiple correspondence analysis (MCA) on the correlation between transportation preferences, gender, and age categories.

Fisher's exact test gave a significance level of $p = 0.05$. Since this probability lies exactly at the conventional threshold of statistical significance, it should be interpreted with caution. To clarify the practical power of this relationship beyond the binary p -value threshold, the effect size was calculated using the Freeman-Halton extension of Cramér's V for larger contingency tables, resulting in $V = 0.115$. This value indicates a weak to moderate practical association, suggesting that while age cohorts influence mobility choices, the effect is subtle and highly nuanced across different life stages.

Descriptive data highlight that active mobility (walking) dominates both ends of the age spectrum, although it is driven by different socio-economic factors:

- Student/youth demographic: represents a substantial share of active transport, with 53.0% relying on walking, 24.0% using private cars and 21.0% using public minibuses;
- Older people (retirees): rely even more on active transport, with 76.5% walking as their main mode of travel, 17.6% relying on cars and only 6.0% using minibuses.

Behavioural patterns at both ends of the demographic spectrum reveal a structural, rather than preferential, deficit in the city's transport ecosystem. The results highlight a missed opportunity for sustainability. As the urban centre analysed completely lacks dedicated bicycle networks and public micromobility sharing schemes (e.g., bike sharing or e-scooters), the reliance of young people on motorized transport reflects an infrastructural void rather than an innate resistance to sustainable transport modes.

This finding directly confirms the warnings in [70], who argue that although small cities in Central and Eastern Europe have a unique strategic window to bypass the traffic jams of the West, they risk becoming locked into a permanent car dependency if transport management fails to bridge the academic and operational gap. To prevent this lock-in effect

among younger generations, small non-metropolitan communities need to adopt agile governance models and aim to integrate micromobility.

Rather than labelling the municipal transport system as generally inefficient, our empirical data reveals a highly localized accessibility gap, specific to vulnerable age groups. Fisher's exact test captures an extremely low usage rate among seniors (Pensioners $\times$ Public Minibuses = 6.0%), with a co-perpetrator percentage of 76.5% of pensioners relying exclusively on walking.

This statistically verified exclusion implies that the current microbus framework contains severe structural age-specific barriers. In post-industrial cities, these barriers often manifest themselves in vehicles with high steps, suboptimal routes that bypass critical infrastructure for seniors (healthcare, civic centres), or restrictive schedules.

This localized immobility reflects the structural challenges addressed in the assessment of the eastern flank conducted in [73], which highlighted how the lack of integrated digital transport tools and responsive planning isolates peripheral demographic segments.

Moreover, this extreme dependence on pedestrian infrastructure in conditions of institutional neglect aligns with comparative case studies in the UR-BACT Network Report [74]. Looking at small European towns facing rapid population ageing and industrial decline—such as Żory (Poland) and Trostyanets (Ukraine)—URBACT frameworks demonstrate that public transport in declining urban centres cannot operate on a purely commercial logic.

Multiple correspondence analysis (MCA) provides a detailed insight into mobility patterns and socio-demographic differentiation. The quality of representation of each category in the two-dimensional space of the graph (Figure 10) is quantified by the square of the cosine ($\cos^2$) [75,76]. A high $\cos^2$ value, highlighted chromatically by shades of green, indicates a faithful projection into the factorial plane, allowing the interpretation of the respective position with a high degree of confidence. Conversely, low $\cos^2$ values (marked by shades of blue) suggest that those categories are not optimally captured in the two dimensions, requiring caution in interpretation.

Thus, the categories “Personal car” and “Male” register a higher quality of graphical representation. In contrast, the variables “Public transport” and “High school/University” present lower $\cos^2$ values. This reduced dispersion indicates that the relationships of these categories with the set of variables are complex and cannot be exhaustively explained only by means of the first two dimensions of the model.

Interpretation of factor axes. The first dimension (Dim1), which explains 20.9% of the total variance of the data, represents the main axis of differentiation of mobility behaviour. This axis highlights a clear polarization, separating the use of personal cars (located on the left side of the graph) from active mobility and public transport (located on the right). This configuration reflects the fundamental opposition between private motorized transport options and alternative/collective forms of travel.

The second dimension (Dim2), responsible for 18.4% of the variance, captures a different stratification dynamic, being independent of the first axis. It separates categories such as pensioners and primary school pupils (positioned at the top) from students, high school students and public transport users (positioned at the bottom). This distribution indicates that Dim2 mainly captures structural differences generated by age cycles and the specific mobility routines associated with them.

Proximity and association analysis. Spatial proximity within the factor map indicates an increased probability of association of the respective categories in the analysed sample. For example, the close positioning of the “Male” category to “Personal car” confirms the hypothesis of more frequent use of one's own car among men. Similarly, the grouping of the variables “Female”, “Active mobility”, “Pensioners” and “Primary/secondary school”

suggests the existence of common behavioural patterns. This proximity shows that these demographic segments frequently adopt similar travel modes, probably due to specific travel needs (for example, proximity of housing to educational institutions or proximity urban trips of pensioners).

The application of MCA graphically validated the structural associations identified by the inferential statistical tests. The factor model explains a cumulative proportion of 39.3% of the total variance of the data set (with Dim1 = 20.9% and Dim2 = 18.4%). A careful analysis of the correspondence space map indicates that the subgroup of the active population is positioned in the geometric centre of the graph. This central positioning suggests a reduced dispersion from the origin of the axes, which indicates the adoption of a diversified and balanced mobility mix, avoiding exclusive specialization on a single mode of transport.

Sustainable urban mobility depends on both physical facilities and psychological, cultural and financial factors that favour individual transport. However, the implementation of the compact city concept and proximity policies in cities with short distances has proven to be an effective strategy, capable of stimulating active mobility (walking and cycling) by increasing the share of these trips by up to 20% [68,77,78].

Instead, our results dictate that public transport accessibility should be treated as a key socio-economic stabilizer. Transport policies in small post-industrial cities need to actively mitigate demographic vulnerability through age-specific and age-friendly service adaptations, rather than through generalised municipal reforms.

The marginal significance and modest effect size indicate that, in a small university city, age-specific mobility is strongly compressed by geographical proximity. The compact urban form naturally favours high pedestrian rates across generations, but distinct age-specific infrastructure adjustments are needed:

1. **Introducing sustainable micro-mobility frameworks:** Although the young demographic segment presents a strong base for active mobility (53.0%), a significant combined share (45.0%) still relies on motorised transport (24.0% cars, 21.0% minibuses). A crucial aspect is that the city under review currently lacks a dedicated network of cycle paths. In a compact university city, the absence of safe cycle paths acts as a direct barrier to sustainable modal shifts, forcing students to choose either walking for short distances or motorised modes of transport for medium distances. Municipal policies should prioritise the construction of a core network of protected cycle and e-scooter paths connecting student accommodation with core university facilities. Introducing safe micro-mobility options could effectively transform short and medium-distance motorised car journeys into sustainable active transport.
2. **Addressing the vulnerability of ageing pedestrians:** The fact that over three-quarters of pensioners (76.5%) walk as their primary means of transport is a critical finding for a small city. While this indicates low motorized dependency, it also exposes older people to prolonged physical exertion and environmental hazards. In contrast, the remarkably low use of public minibuses (6.0%)—which initially triggered the mathematical restriction for the Chi-square test—warrants serious policy reflection. This suggests that the current minibus network may suffer from accessibility barriers, such as high vehicle steps, poor route coverage near medical or residential areas, or a lack of an age-friendly program.
3. **Age-inclusive urban infrastructure:** To prevent the social isolation of older people as physical faculties decline, urban planners need to move from “neutral” spaces to age-inclusive design. This includes implementing low-floor or accessible public transportation fleets, adding rest benches at regular intervals along major pedestrian corridors, and expanding crosswalk timers at intersections near university and civic centers.

Finally, transportation infrastructure in small cities should not be planned uniformly; it should capitalize on compact urban form to support active transit for young people while reducing accessibility barriers for older people.

This makes it possible to quantify how non-rational determinants (e.g., behavioural inertia, social norms, and environmental concerns) alter stated preferences. This dynamic provides a profound insight with direct applications in theoretical modelling and policy development [79].

Our results on modal choice in small cities highlight a persistent reliance on individual motorized transport. This trend extends the impact of private vehicles beyond greenhouse gas (GHG) emissions, amplifying urban noise pollution—a critical factor for public health and quality of life [80]. Although emerging micromobility, especially through light electric vehicles (e-scooters), offers a high potential for short-distance car substitution and local decarbonization, its integration in small cities faces major structural barriers [81]:

- Infrastructure deficiencies: poor quality of the road surface and the absence of dedicated tracks drastically reduce the attractiveness of micromobility;
- Operational limitations: seasonal climate and low load capacity restrict the use of e-scooters to occasional utility trips;
- Safety risks: the incidence of accidents and the vulnerability of users require strict regulations and immediate urban reconfiguration.

Therefore, the transition to sustainable urban transport in small cities cannot be achieved by simply adopting emerging technologies, but requires an integrated approach that links mobility policies with investments in safe infrastructure.

Despite the contributions made to the understanding of urban mobility behavior, this study presents a number of inherent methodological limitations that must be taken into account:

- Sample constraints: the relatively small sample size is a main limitation, potentially reducing the statistical power of the applied Chi-square tests and increasing the susceptibility to sampling errors. Therefore, generalizing these trends to other urban contexts requires caution, as there is a risk that some subtle behavioral correlations may not have been captured;
- Exclusion of the income variable: the absence of direct data on income limits the exhaustive modeling of the socioeconomic profile of the participants. Although this decision was dictated by high non-response rates and data unavailability, the lack of a direct financial indicator limits the depth of causal analysis within the Multiple Correspondence Analysis (MCA);
- Category aggregation trade-off: grouping the initial 10 transport modes into three macro-categories—active transport (walking and cycling), public/shared transport (buses, minibuses, taxis and coaches) and private motorised transport (personal car)—represents a deliberate trade-off between granularity and statistical viability. While this approach was essential for ensuring valid contingency tables in the Chi-square test and for the stability of the factors in the MCA, it can obscure certain operational nuances, such as differences in service quality between mass public transport and the taxi regime.

Future research directions will aim at expanding the sample to different urban strata to validate these exploratory results, as well as integrating alternative economic indicators (e.g., residential area or possession of a permit/vehicle) capable of capturing socioeconomic dynamics without compromising the confidentiality of respondents.

On the other hand, it is important to mention that the present structural research presents certain methodological limitations, not including in the analysis model essential variables such as travel time and costs associated with transportation (fares, fuel, maintenance). These economic and temporal variables traditionally exert a major influence on individuals' mobility behaviour.

4. Conclusions

This study investigated the socio-demographic determinants of urban mobility behaviours in a small university city, focusing specifically on how gender and age cohorts influence the selection of primary transportation modes. By directly anchoring municipal planning recommendations in empirical evidence, this research moves from generalized urban theories to data-driven policy perspectives.

The empirical findings yield several critical conclusions directly supported by statistical analyses:

- **Gender disparities in active and motorized transportation:** The Chi-square (χ^2) test of independence confirmed a statistically significant association between gender and travel behaviour ($\chi^2(2, N = 398) = 20.624, p < 0.0001$), showing moderate practical strength ($V = 0.228$). This mathematical relationship is driven by a pronounced reliance on sustainable public transport among female respondents, who use active mobility (56.0%) and public transport (18.2%) in significantly higher proportions than male respondents, the latter predominantly relying on private cars (46.6%). Therefore, local transport policies cannot be treated as gender neutral; infrastructure budgets must prioritize pedestrian safety, continuous sidewalk networks and improved public lighting to support the main user base of the pedestrian ecosystem;
- **Generational variance and accessibility barriers to micro-transport:** Application of the Fisher exact test revealed a statistically significant, albeit subtle, relationship between age cohorts and mobility choices ($p = 0.05, V = 0.115$). Descriptive data exposed critical spatial behaviour patterns at both ends of the age spectrum. While a small majority of the youth/student demographic relies on walking (53.0%), a substantial segment remains split between private cars (24.0%) and public micro-buses (21.0%). Given that the urban centre analysed lacks a dedicated network of bicycle lanes and public micro-mobility sharing services (such as bike sharing or e-scooters), the results indicate a structural deficit, rather than an inherent preference for motorized travel among young people;
- **Targeted public transportation assessment:** Rather than broadly characterizing the municipality's public transportation system as inefficient, the empirical data highlights a highly localized and demographic-specific accessibility gap. Fisher's exact test was statistically required by an extremely low call frequency among the elderly cohort (Pensioners $\times$ Public Minibuses = 6.0%). In contrast, 76.5% of pensioners rely exclusively on walking. This statistically verified low ridership among older adults strongly implies the presence of age-specific structural barriers in the existing minibus framework—such as high-step vehicle configurations, suboptimal route distribution near critical senior infrastructure, or restrictive schedules—rather than a general failure of urban transportation.

In conclusion, urban and transportation planning in compact university cities needs to abandon generic, car-centric frameworks and adopt highly targeted, demographic-specific infrastructure interventions. Future municipal strategies should capitalize on the high level of active mobility found in this study by introducing interconnected micro-mobility networks for the student demographic, while systematically removing physical and operational barriers in the public transport network to make room for vulnerable elderly populations.

Future studies could investigate the association between household income and transport mode choice, in order to establish whether sustainable choices such as walking or cycling are primarily related to age and gender, as examined in the present study, or whether other confounding factors, such as income, exert a stronger influence. Such re-

search could help determine whether financially accessible public transport policies could incentivize a shift away from personal car use toward more sustainable mobility options.

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Data Availability Statement: The data presented in this study are available on request from the corresponding authors due to ethical and confidentiality reasons. This study used secondary data from official statistical sources and public repositories cited in the text, supplemented by primary data collected through a questionnaire applied to citizens in the Petroșani municipality. All relevant information and analytical results supporting the conclusions of the paper are included in full in this manuscript.

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