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Public Transport Usage and Perceived Service Quality in a Large Metropolitan Area: The Case of Porto

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Abstract: Using public transport as an alternative to private motorized vehicles (PMVs) is becoming increasingly popular in many cities worldwide. To understand what incentives and enhancements are necessary to attract and retain more passengers, a comprehensive understanding of the quality of public transport services is essential. This study aims to broaden the existing literature on the knowledge of public transport services in a large, heterogeneous metropolitan area. A cross-examination between a binary and an ordinal logit model is proposed, using data from a mobility survey in the Porto Metropolitan Area (PMA) in Portugal. The results show that households use PMVs mainly for speed (58.8%), comfort (49.3%), and lack of public transport to the destination (35.7%). Households using public transport cite not driving/owning a PMV (52.6%), lack of alternative transport modes (49.1%), and service cost (38.2%) as primary reasons. The perceived service quality (PSQ) within the PMA exhibits variance on multiple levels, depending on the characteristics of the household and the municipality's location. This study provides policymakers of different cities in the PMA with insight into what incentives would most effectively increase the PSQ and, in turn, attract more passengers. This insight would be valuable in developing strategies to improve public transport usage and reduce PMV usage in the PMA. Adopting these strategies will contribute to reducing environmental impact and reducing traffic congestion.

Keywords: public transport usage; perceived service quality; binary logit; ordinal logit regression; mobility survey

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1. Introduction

Recreation, tourism and business investments frequently increase in urban centers attempting to expand. The socioeconomic opportunities offered in these large centers attract more people, resulting in densely populated central areas [1]. The rise in land values, due to high demand and the need for space, has led residents to seek lower-density urban regions to settle. This phenomenon is known as urban sprawl, which, in the most severe cases, often results in congested cities [2]. Residing in low-density suburbs typically results in a greater dependence on private motorized vehicles (PMVs) as the primary transport mode. Conversely, individuals living in compact or mixed-use neighborhoods tend to rely more heavily on public transport (PT) or lighter modes (LM), such as walking and cycling, for their daily travel needs [3–5].

According to Cervero and Kockelman (1997) [6], the built environment can significantly impact travel behavior through density, diversity of land use, and pedestrian-oriented designs. Most suburban and rural neighborhoods have longer average distances and lower PT offers, discouraging people from using LM and PT in their daily trips. Compared to amenity-rich urban areas, low-density suburbs generally lack potential trip destinations near residential areas [7]. Consequently, when there is an uptick in private trips, road infrastructure is typically the first to expand to accommodate the increased circulation of PMVs, leading to an overload of road infrastructure [8].

In certain cities, such as Ahmedabad (India), Taipei (Taiwan), Bogor, and Tangerang (Indonesia), a decline in the utilization of PT can be attributed to unsatisfactory customer experience, uncomfortable rides, long delays, and inconsistent travel times [9–11]. These factors encourage individuals to use PMVs, which aggravates the negative consequences associated with traffic collisions, reduced physical activity, and raised levels of air and noise pollution [7,12,13].

To minimize the usage of PMVs and move towards a more sustainable citizen-centric mobility system, many cities such as Hamburg, Oslo, Helsinki, and Madrid have studied alternative transportation options, including investing in cycling infrastructure and restricting parking spaces as a means of promoting sustainable mobility [13]. These cities aim to go largely PMV-free, implementing actions to reduce excessive PMV use as much as possible by encouraging PT and LM trips [13,14].

According to de Oña et al. (2013) [15], the success of PT trips is determined by the number of passengers the system can attract and retain. For example, a good experience with, and a positive attitude towards, a transport mode will encourage its use again [16]. PT operators must implement continuous policies for monitoring and enhancing the quality of the public transport system while collaborating with governments. Such collaborations are essential for ensuring that the public transport system satisfies the evolving needs and expectations of commuters [17–19]. Perceived service quality (PSQ) is essential for evaluating PT quality [20]. As stated by Caro and García (2007) and Malik (2012) [21,22], PSQ is a consumer's judgment about the overall excellence or superiority of the service. According to Yarmen et al. (2016) [9], passengers evaluate the quality of services based on factors such as comfort, safety, and performance. Relying on these characteristics, Tyrinopoulos and Antoniou (2008) and Morton et al. (2016) [23,24] concluded that security at terminals, waiting time, cleanliness, and regular vehicle maintenance are also key attributes of service quality.

Beirão and Cabral (2008) [25] argued that while the characteristics mentioned above are essential aspects of PT use, those most relevant to PSQ are primarily related to individual perceptions (e.g., motivation and trip contexts). These characteristics may justify disparate results due to factors influencing the user's decision. Sukhov et al. (2021) and Currie et al. (2013) [26,27] suggested that younger passengers may perceive the quality of PT in a completely different way than adults because they have different attitudes and behaviors toward its use. Thus, measuring PSQ should be a continuous trend among researchers, PT operators, and managers to understand the key elements contributing to public transport service quality [28].

Rasca and Saeed (2022) [29] observed that socioeconomic factors are among the key determinants influencing the decision to utilize PT, with the correlation between these factors and PMV owners being dependent on numerous elements, including income, educational attainment, and occupation. Rachele et al. (2015) [30] stated that individuals with higher socioeconomic status (SES) are more likely to own PMVs than those with lower SES due to the higher cost of ownership and maintenance. Nevertheless, the relationship between car ownership and public transportation may depend on various factors, including the quality and availability of PT in a particular area and the cultural and societal norms regarding car ownership [31].

Beirão and Cabral (2008) [25] also identified that owners of PMVs do not simply view their vehicles as a means of transportation; instead, they perceive them as instruments that provide a sense of power, freedom, status, and, in some cases, even superiority. Furthermore, according to Redman et al. (2013) [32], users with emotional attachments to their PMVs require strong indications of perceived quality to motivate them to shift to PT. In certain European cities, affordable fares, comfortable seating, and free Wi-Fi on PT significantly increase their competitiveness with PMVs [33].

This paper aims to investigate the attitudes and opinions towards PT and the modal choices of households in the Porto Metropolitan Area (PMA) based on the most recent mobility survey (IMob) performed in Portugal in 2017. The paper will provide an introductory

view of the mobility behaviors of PMA families. It will initiate, encourage, and guide future research to maintain the continuity of public transport perceived service quality studies.

Two significant analyses will be conducted to achieve the study's objective. The first analysis aims to identify the household characteristics that influence PT usage. In contrast, the second analysis seeks to determine the perceived quality of PT by considering the same household characteristics and locations as those used in the first analysis.

To conduct the former analysis, a binary logit model is applied to the households' characteristics to understand the main factors influencing whether residents choose PT or not. The second analysis will use ordinal regression models to evaluate the subjective service attributes of PT (e.g., quality, comfort, safety) on an ordinal scale adjusted to the household characteristics and locations. Based on both analyses, a relationship between PT usage and PT perceived quality is provided.

This study presents a valuable contribution toward understanding the relationship between PT usage and PT perceived quality in the Porto Metropolitan Area. The area has unique characteristics that may impact PT usage, making it essential to investigate these factors further. The findings provide a valuable framework for developing targeted interventions to improve public transport quality, such as enhancing the frequency of services and increasing the accessibility of PT stops. Additionally, this study highlights the importance of considering users' diversity and preferences.

This paper is structured into six sections. Section 2 provides an overview of the study area, introducing the unique characteristics of the Porto Metropolitan Area. Section 3 outlines the data and methods used for the analysis, including the description of variables and statistical models. Section 4 presents the results of the statistical models used to examine PT usage and service quality. In Section 5, the results obtained in Section 4 are discussed in detail, providing insight into the factors that influence PT usage and perceived quality. Finally, Section 6 provides the study's conclusions and recommendations for future research.

2. Study Area

According to Statistics Portugal (INE) (2017) [34], the PMA comprises 17 municipalities that collectively occupy an area of approximately 2041 km^2, and has a population of about 1.7 million people, representing 17% of the total population of Portugal. The PMA is a large urban area that presents unique challenges when evaluating PT systems. One of the major difficulties in evaluating PT systems in large metropolitan areas such as the PMA is the density heterogeneity within the region. The PMA has high and low population densities located near each other. This results in a predominance of PMV trips, making it more difficult for PT systems to compete with private vehicles in terms of convenience and efficiency [6].

The PMA has dispersed and diverse transport networks, posing challenges in accurately estimating the overall PT usage and measuring its PSQ. Phithakkitnukoon et al. (2012) [35] confirm this heterogeneity, concluding that the geosocial radius in urban areas is approximately 7 km. In contrast, in lower-density municipalities, this ratio is about 15 km. Another challenge in evaluating PT systems in the PMA is the presence of multiple PT operators within the same metropolitan area, which complicates quality control of PT systems, given that each operator may have different standards and procedures.

The PMA can be divided into three distinct types of occupation, as illustrated in Appendix A. The first type is the municipality of Porto itself, which has a high population density and a predominance of upper-middle- and upper-class residents [36]. The commercial center of Porto is a hub of activity within the PMA. The second type of occupation is a circular band around the center of the PMA, where the Porto municipality has experienced residential expansion. These neighboring cities include Matosinhos to the south, Gondomar to the north, Vila Nova de Gaia, and some areas of Maia and Valongo. These areas have a mix of residential and commercial areas and are often more suburban. The third and final type of occupation is an extension surrounding the combined urban mesh of the PMA with

distinctly rural characteristics. This area has lower buildings and a significant population concentration in the agriculture and forestry sectors [37].

3. Data and Methods

From October to December 2017, INE conducted the IMob in the PMA in collaboration with Eurostat. More than 3.4 million trips were made daily, and population mobility accounted for 78.9% of the residents in the area. The IMob 2017 had a total sample size of 18,169 households contacted who provided valid answers and 80,314 trips in the PMA, resulting in a sample size of roughly 2.5% of the total daily trips reported by INE [34].

The survey included people between 6 and 84 years old who had made at least one trip during the survey's reference day. PMVs accounted for 69% of all trips, PTs for 11.1%, and LM for the remaining trips [34]. Furthermore, the survey only included one answer per household concerning their opinion and satisfaction with PMV and PT. The gathered opinions are related to the reasons for using PMV or PT and the evaluation of variables for PT use. As a result, the current study sought to examine the PSQ of public transport by analyzing household-level data (e.g., number of vehicles in the household, number of residents, and number of children in the household, among others).

In order to improve the optimization of the binary logit model and obtain a statistically significant representation of the income and cost variables, it was necessary to reduce the number of categories. The IMob survey contained up to ten response alternatives within these categories. Therefore, we grouped responses with similar values, reducing them to five answer categories. Table 1 represents the independent variables considered for modeling and their description.

The categories in Table 1 are ordered based on the number of responses received. The category with the least answers is listed first, while the category with the most answers is listed last as the reference category. Under the General Data Protection Regulations, it was not possible to identify individual trips taken by household members on the survey day. The data only provided information on the number of trips made by each transport mode in the household. A binary variable was created to analyze the PT usage by households, with a value of (1) assigned to households where at least one member used PT and (0) assigned to those households where no member used PT.

The PSQ questionnaire comprises the following questions: (1) choose three main reasons out of sixteen for the PMV choice for households that use PMV; (2) choose three main reasons out of thirteen for the PT choice for households that use PT; and (3) rate distinct qualitative attributes of PT on a scale of 1 (very poorly) to 6 (very good) (e.g., price, frequency, comfort, vehicle quality). Only households with limited knowledge of the local PT service responded to the questions about PT quality. These are households with monthly ticket subscriptions or those who took at least one PT trip during the survey day, as proposed by Zhao et al. (2013) [38].

The urbanization process of the Porto Metropolitan Area led to the establishment of a more economically developed central core in Porto, which has become a strong trip generator/attractor pole through schools, jobs, and services, functioning as an anchor for a network of cities that rely on it [39]. Porto's municipality was established as the primary destination for trips to the 11 municipalities that were analyzed and had significant representation in the study, specifically Porto, Vila Nova de Gaia, Matosinhos, Maia, Gondomar, Valongo, Vila do Conde, Póvoa de Varzim, Trofa, Santo Tirso, and Paredes.

Matosinhos, Vila Nova de Gaia, Maia, and Gondomar are the most prominent cities near Porto city center. They are connected to the core of PMA through metro and bus lines. The coastal cities of Vila do Conde and Póvoa de Varzim are also well-connected to Porto city center by bus lines and a metro line, and most of their population reside close to Porto [37]. On the other hand, Paredes, Trofa, and Santo Tirso are located on the outskirts of Porto and are accessible by train and bus. Finally, the remaining cities are further away from Porto. They are linked predominantly by long bus routes, which entail less frequent and longer commutes than the other antecedent municipalities [34].

Table 1. Description of the independent variables.

Continuous Variables	Description		Mean	SD
N_trips_Others	Number of trips per other transport modes		0.2	0.621
N_trips_LM	Number of trips per LM (walking and cycling)		1.19	1.947
N_trips_PMV	Number of trips per PMV (motorcycles and cars)		2.93	3.834
N_trips_TP	Number of trips per PT (bus, train, and metro)		0.56	1.373
N_vehicles	Number of PMV		1.39	0.919
N_Household	Number of household members		2.11	1.139
N_kids	Number of children (Aged < 14)		0.26	0.592
Categorical variables	**Description**		**N**	**%**
Porto	Municipality of Porto		7436	25.2
Gondomar	Municipality of Gondomar		2413	8.2
Maia	Municipality of Maia		3057	10.4
Matosinhos	Municipality of Matosinhos		3723	12.6
Paredes	Municipality of Paredes		1095	3.7
Povoa	Municipality of Póvoa de Varzim		1141	3.9
SantoT	Municipality of Santo Tirso		931	3.2
Valongo	Municipality of Valongo		1172	4.0
Vconde	Municipality of Vila do Conde		1166	4.0
Gaia	Municipality of Vila Nova de Gaia		6470	21.9
Trofa	Municipality of Trofa		902	3.1
M_Income	Average monthly income (categorized)	1—More than 2600 €	2319	12.8
		2—From 1501 € to 2600 €	4067	22.4
		3—Did not answer	1314	7.2
		4—Up to 600 €	2985	16.4
		5—From 601 € to 1500 €	7484	41.2
TP_Expense	Monthly PT expense (categorized)	1—From 30 € to 60 €	2683	14.8
		2—From 61 € to 100 €	878	4.8
		3—More than 100 €	287	1.6
		4—Less than 30 €	2626	14.5
		5—No expenses	11,692	64.4
T_Expense	Total monthly transport expenditure (includes PT ticket, PMV fuel, and parking) (categorized)	1—From 100 € to 200 €	3865	21.3
		2—From 201 € to 300 €	4653	25.6
		3—From 301 € to 400 €	2002	11.0
		4—More than 400 €	1461	8.0
		5—Less than 100 €	6188	34.1

Two statistical techniques were applied to quantify household utilization and PT perceived service quality according to the dependent variable.

A binary logit model was initially applied to investigate the influential factors affecting the household's public transport selection. The logit function is used extensively in discrete choice models and logistic regressions [40,41]. Because of their ability to represent complex aspects of travel decisions, the logit model was used for regression analysis with SPSS software version 27. The logistic regression model estimates the likelihood of a specific event occurring based on the independent variables, which is represented by the following Equation (1):

$$y^* = X_i\ \beta + u_i \quad (1)$$

where X_i is the vector ($1 \times k$) of components 1, X_{2i}, X_{3i},..., X_{ki}, and β is the vector ($k \times 1$) of regression coefficients, u_i has mean zero, and y^* designates an unobserved variable that

assumes value 1 if households used PT, or 0 if they did not use it, according to the following formulation suggested by Greene (2012) [42]:

$$\begin{array}{l} y = 1 \text{ if } y^* > 0, \\ y = 0 \text{ if } y^* \leq 0. \end{array} \quad (2)$$

We evaluated the opinion of the survey respondents regarding PT on a discrete ordinal scale. Using the Python Biogeme software, ordinal logistic rgression models were applied to measure the perceived qualities of PT services (such as price, speed, frequency, safety, and comfort/commodity). The scale was adjusted for the independent variables to ensure accurate results [43]. The ordinal logistic regression model is applied when the number of categories of the response variable exceeds two and when these are ordered. The standard parameterization for the model is shown in Equation (3):

$$\text{logit}\,(P\,(Y \leq j)) = \beta_{j0} + \beta_{j1}x_1 + \ldots + \beta_{jp}x_p \quad (3)$$

For $j = 1, \ldots, J - 1$; J represents the number of levels in the categorical response variable Y (here 6), p is the number of predictors, x_1, x_2,..., x_p are predictor variables, and β_j is the regression coefficient for the predictor variable x_j [42].

4. Findings

We examined the reasons influencing the modal choice of households in the context of private motorized vehicles and public transport, focusing on the reasons behind the choice of PMV or PT as the main transport mode. First, we began by investigating the reasons for using PMV, considering the responses from individuals who reported using it as a driver or passenger. Figure 1 illustrates the relative frequency of answers for the primary reasons for selecting PMV as the preferred mode. The reasons for choosing PMV as a transport mode are presented in order of importance, with each bar representing one of the sixteen reasons.

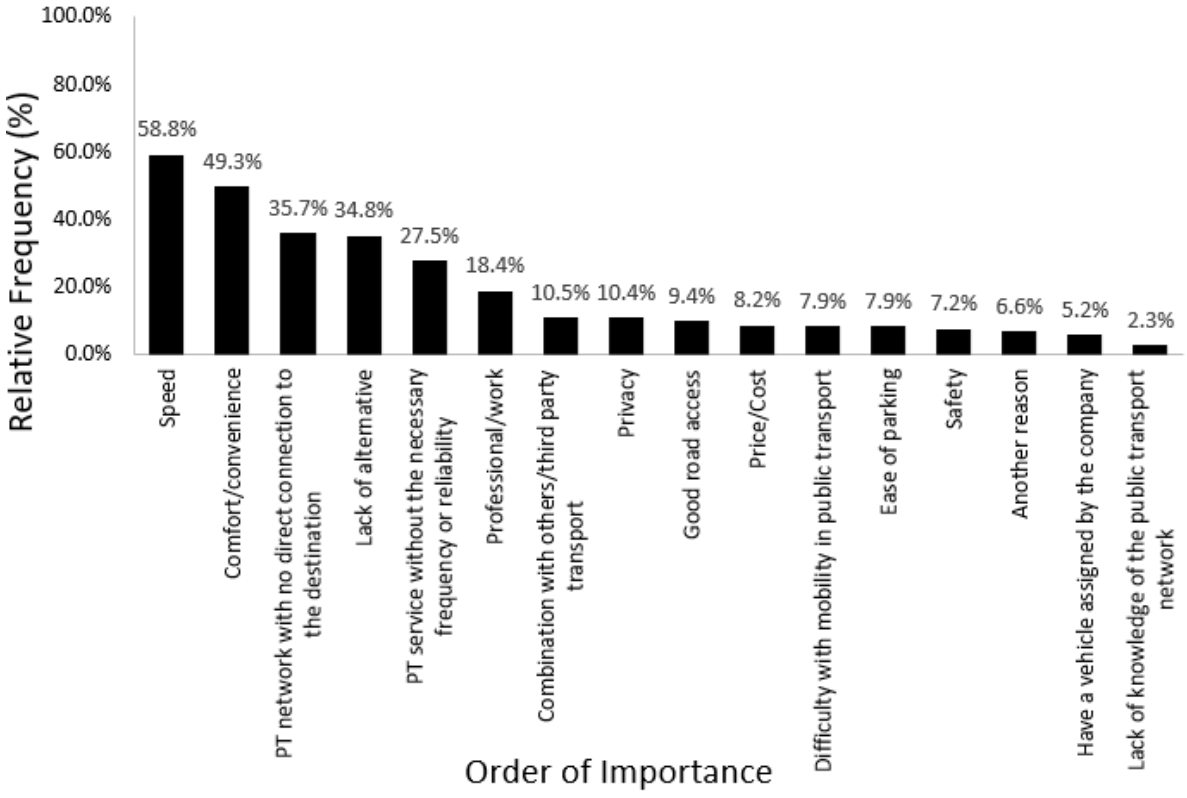

Figure 1. Reasons for choosing PMV.

Figure 1 displays the findings regarding the reasons for choosing PMV as the preferred transport mode, indicating that speed of travel (58.8%), convenience/comfort (49.3%), and lack of direct connection to the destination through public transport networks (35.7%) were the most frequent reasons reported by households. Notably, the absence of public transport to the desired destination emerged as a significant factor, implying a potential PT-user if the PT connectivity in the PMA is improved.

In Figure 2, we present the results of the survey's second question on the reasons for using PT during trips. The reasons are ranked in order of importance, with each bar representing one of thirteen possible factors influencing the decision to travel by PT.

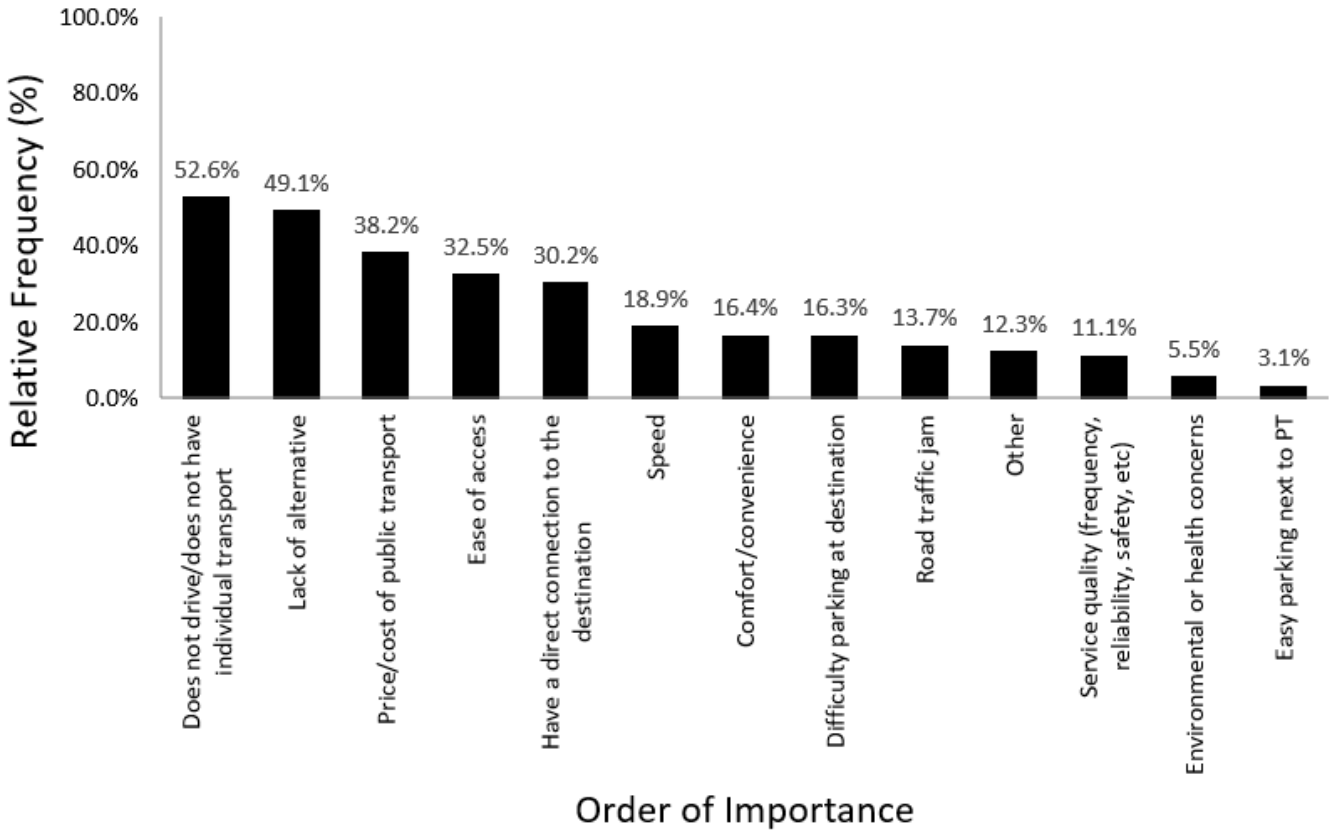

Figure 2. Reasons for choosing PT.

The findings revealed that not driving or not owning a PMV (52.6%), lack of alternatives in transport modes (49.1%), and the cost of the service (38.2%) were the primary factors influencing the decision to use PT (Figure 2). Surprisingly, the first reason is directly connected to the PMV, suggesting that these individuals would prefer to travel by PMV rather than PT if they have the chance, which may reflect the low quality of PT service in the PMA. These insights can have significant implications for policymakers and transport planners in their efforts to promote sustainable mobility options in the PMA, attract new users for PT, and maintain the existing users, which is essential for the long-term success of public transport as a sustainable transport mode.

The following analysis presents the household characteristics that indicate public transport as their primary transport mode. The results were obtained using maximum likelihood estimation to fit a logit mode. As presented in Table 2, most of the variables are significant at the 95% confidence level.

The column labeled β presents the regression coefficients, expressed in log-odds units, while the column labeled Exp(B) displays the corresponding odds ratios. A variable's inclusion in the model is determined by whether its β coefficient is statistically different from zero, with significance defined as Sig. (p-value) ≤ 0.05. We examine Exp(B) to

determine the likelihood of a given variable being associated with increased usage of PT relative to our reference variable. Values of Exp(β) greater than 1 indicate a positive association, while values less than 1 indicate an inverse association. Our binary model's dependent variable is (1) if the household uses PT, and (0) if it does not.

Table 2. Results of the logit model.

	β	Std. Error	Sig. (*p*-Value)	Exp(B)
N_Household	0.531	0.028	0.000	1.701
N_Kids	−0.133	0.05	0.008	0.876
N_Vehicles	−0.278	0.035	0.000	0.757
N_trips_PMV	−0.074	0.009	0.000	0.929
N_trips_LM	0.091	0.012	0.000	1.095
N_trips_Others	−0.162	0.041	0.000	0.850
Monthly income (5) From 601 € to 1500 € *				
Monthly Income (1) More than 2600	−0.348	0.088	0.000	0.706
Monthly income (2) From 1501 € to 2600 €	−0.130	0.067	0.052	0.878
Monthly income (3) Does not answer	0.009	0.112	0.935	1.009
Monthly income (4) Until 600 €	0.117	0.074	0.115	1.124
Expense PT (5) No expenses *				
Expense PT (1) From 30 € to 60 €	3.246	0.069	0.000	25.677
Expense PT (2) From 61 € to 100 €	3.422	0.095	0.000	30.635
Expense PT (3) More than 100 €	3.248	0.149	0.000	25.749
Expense PT (4) Less than 30 €	2.311	0.070	0.000	10.086
Porto	1.914	0.087	0.000	6.783
Gondomar	1.782	0.112	0.000	5.943
Maia	1.735	0.113	0.000	5.671
Matosinhos	1.768	0.103	0.000	5.858
Paredes	1.710	0.176	0.000	5.527
Povoa	1.228	0.194	0.000	3.415
SantoT	1.200	0.199	0.000	3.319
Valongo	1.740	0.152	0.000	5.699
Vconde	1.423	0.180	0.000	4.148
Gaia	1.805	0.090	0.000	6.08
Trofa	1.743	0.194	0.000	5.717
Constant	−5.245	0.106	0.000	0.005
−2 Log likelihood	10,497.638			
Cox & Snell R Square	0.321			
Nagelkerke R Square	0.518			
	Hosmer and Lemeshow Test			
Chi-square	39.001			
Sig. (*p*-value)	0.092			

* Category of reference.

The results of our analysis indicate that larger households are more likely to choose PT over PMV, as the probability of using PT increases by 1.7 times (70%) with the addition of each person in the household. Conversely, the likelihood of using PT compared to PMVs decreases by almost 88% for every additional child in the household. Rhoulac (2005) and McDonald (2008) [44,45] suggest that this may be due to parents perceiving PMV transportation, especially for school trips, as safer and more convenient [46–48]. Additionally, the likelihood of using PT increases by approximately 10% for each additional LM trip in the household. This finding is consistent with previous research by Saelens et al. (2003) and Humpel et al. (2004) [49,50], which observed that mixed-use areas with good PT connectivity and suitable walking environments could promote the use of public transport [3–5].

Wets and Zwerts (2006) and Mwale et al. (2022) [51,52] have reported that higher-income households exhibit a preference for using PMVs during their trips, a trend also

observed in the PMA. Specifically, households earning more than €2600 per month have a 70% lower probability of using PT than households with earnings ranging between €601 and €1500 per month (category of reference). Additionally, the likelihood of PMV being the primary transport mode increases by approximately 25% for every new vehicle purchased per household. Anderson (2010) [53] observed that the greater the availability of PMVs, the lower the likelihood of people using other transport modes.

When examining the use of PT per household in the major cities of the PMA, we found that all have statistically significant results and positive values for the estimated parameters. The municipalities with the highest PT usage are Porto, Gaia, and Gondomar, three of the five municipalities in the PMA with the highest population density. Ewing et al. (2004) [54] pointed out that individuals residing in areas with higher population densities are less likely to travel by car and more likely to use PT on their trips.

Subsequently, an analysis reflecting the households' perception of PT quality is presented. The ordinal model findings for each question answered are reported as odds ratios adjusted for geographic region and household factors to analyze variations in the public transport PSQ regarding different PT aspects. The proportional odds hypothesis is tested using Harrell's method to validate the fit of the ordinal models [55]. Six ordinal models were utilized to analyze the PSQ (on a scale of 1 to 6) regarding PT price, speed, frequency, safety, comfort, and vehicle quality. Each model variable logically produced consistent results, thereby allowing the assumption to be maintained and the null hypothesis to be rejected. For simplicity in presenting the results, only the odds ratio outcomes are displayed in Table 3.

Table 3. Odds ratios of the six ordinal logit models.

ODDS RATIO	Price	Speed	Frequency	Safety	Comfort	Vehicle Quality
M_Income	1.112	1.086	1.063	1.069	1.056	1.09
TP_Expense	0.906	n.s. *	n.s.	0.936	0.925	n.s.
N_Vehicles	1.215	1.254	1.353	1.24	1.177	1.21
N_Household	0.924	0.895	0.915	0.926	n.s.	0.914
N_Kids	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
T_Expense	0.859	0.886	0.913	n.s.	n.s.	0.931
Porto	n.s.	1.444	1.265	1.498	1.484	1.488
Gondomar	0.747	n.s.	n.s.	n.s.	n.s.	n.s.
Maia	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Matosinhos	n.s.	n.s.	n.s.	0.658	0.761	0.593
Paredes	n.s.	n.s.	n.s.	2.573	2.588	2.042
Povoa	n.s.	n.s.	2.33	n.s.	2.17	n.s.
SantoT	2.38	n.s.	n.s.	n.s.	2.005	n.s.
Valongo	n.s.	n.s.	2.133	2.147	2.198	1.662
Vconde	n.s.	2.001	2.338	2.657	2.091	2.461
Gaia	n.s.	n.s.	n.s.	n.s.	n.s.	0.713
Trofa	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

* n.s. not significant at a 95% level of confidence.

Table 3 reveals that all variables in the six models, except for the number of children and the cities of Maia and Trofa, exhibit at least one statistically significant value. Concerning the average monthly income, the odds of positively evaluating service attributes increase (OR > 1) as income levels rise, specifically to price perception. Similarly, an increase in the PMVs in a household is associated with a higher likelihood of a positive evaluation of public transport PSQ. This positive evaluation of public transport PSQ among those households may be attributed to public transport not being their primary transport mode [56]. Additionally, the probabilities suggest that an increase in family members is linked to a decreased PSQ. Considering monthly PT and transportation costs, the likelihood of a negative evaluation of PT services increases (OR < 1) as spending costs increase.

The impact of PSQ varies across cities, with only Gondomar and Santo Tirso exhibiting statistical significance when assessing the perceived PT price. The estimated values indicate

that, in Gondomar, the PT price is perceived as low, whereas, in Santo Tirso, households perceived the PT price as high. Porto, the most urbanized city in the PMA, offers various public mobility options, including metro lines, trains, and buses [36,37]. The opinions of Porto residents are statistically significant in all categories, except for PT price value, with all ORs ratios being greater than one (OR > 1), indicating a positive PSQ trend for households in this city.

The cities of Póvoa de Varzim and Vila do Conde had the highest statistically significant ORs with a positive tendency for good evaluation (OR > 1), particularly for frequency and comfort. These cities, located on the coast and with high tourist attractions, are connected to Porto by bus lines and a metro line, providing households with favorable chances of positively evaluating PT in terms of comfort, convenience, and frequency of service. Conversely, Matosinhos and Vila Nova de Gaia had statistically significant odds of less than one, with Matosinhos having 40.7% greater chances than other cities of expressing a negative opinion about the PT vehicle's quality, and Vila Nova de Gaia having 28.7%. Notably, only Matosinhos received a negative rating for safety, with 34.2% fewer odds than other cities. Finally, except for Matosinhos and Vila Nova de Gaia, comfort and vehicle quality were the most significant PSQ values for all cities, with the highest probability of a good PSQ evaluation.

5. Discussion

The study provides important insights into the factors influencing passenger satisfaction with public transportation services. These insights can guide policymakers and transportation providers in their efforts to improve service quality and better meet the needs of passengers. The study's results also shed light on public transportation usage and perceived service quality, providing evidence of the relationship between these two factors and highlighting potential implications for policy and practice.

The study's findings indicated that various factors could influence the decision to use public transport and alter its perceived service quality within the Porto Metropolitan Area. These factors include availability, cost, individual motivation, preferences, and specific demographic and situational characteristics.

Our analysis showed that households with larger family sizes and those living in particular municipalities (Gaia and Matosinhos) with lower vehicle quality ratings exhibited a diminished overall perception of public transportation quality. Further, households with higher average incomes and more vehicles had a higher overall rating of public transport services, despite being less likely to use PT. Households with the most children make more trips by PMV; as a result, they do not express relevant opinions about the quality of PT. The primary reason for using PT is not directly related to the service but to a lack of private vehicles or a driver's license. Beimborn et al. (2003) [57] call these individuals captive public transport users who generally do not have a private vehicle available to make their trips and therefore have no other option but to use the PT. Belgiawan et al. (2014) [58] discovered the same pattern: many students wanted to buy a car after graduating from high school and only used PT because they felt the need.

The models also indicated a positive correlation between increased transport spending and decreased public transport's PSQ. This study's findings also align with the ones that revealed lower fares could improve customer perception of PT quality [26,59]. This indicates that even PMV users can find PT appealing when the service qualities are at least as attractive as PMV trips [60]. PT managers must collaborate with the local government to fulfill PT users' requirements. This collaboration is necessary to determine the essential services that require prioritization for investment. Rather than expanding the current road infrastructure, PT managers and local governments should focus their investments on services that complete the customers' needs, according to the PSQ [12–14]. Further, operators and policymakers need to consider different demographic and situational factors when designing and promoting PT services, focusing on making PT services more competitive with PMVs [61].

The adoption of efficient and reliable mass transit services, along with the provision of access to services through light transport modes, are two fundamental strategies for transforming urban transport systems. These strategies offer potential benefits for reducing the environmental impact of urban transport, including decreased air pollution and energy consumption [62–67]. Moreover, these sustainable transport measures can potentially address the public transport issue in the PMA and significantly reduce the number of PMV trips. In addition to mitigating the environmental impact of urban transport, these measures can improve the efficiency of urban transport by reducing traffic congestion and journey times, thus enhancing the quality of life for urban residents [13,14,68].

Efficient and reliable mass transit services, coupled with access to light transport modes, have the potential to create an inclusive and accessible urban transport system, while reducing the financial burden of transport costs on individuals [69]. De Vos et al. (2022) [3] highlighted the significance of passenger satisfaction with the quality of public transport services, as it encourages ridership retention. Therefore, promoting sustainable transport modes that offer high levels of service quality and accessibility is essential in achieving the goals of a sustainable urban transport system in the PMA [13,14,18].

Despite the significance of understanding individual factors that may influence PT usage and the passenger PSQ, the study was limited to specific cities in the PMA, and only aggregated data at the household level were analyzed. Consequently, the study was precluded from examining the effects of individual characteristics on PT usage and PSQ. Further research is warranted to investigate other factors, including the proximity of stops and stations near households, and to better understand how individual characteristics influence PT usage and PSQ. Prior research has demonstrated that PT providers frequently overestimate the quality of service they deliver relative to customer evaluations. This phenomenon stems from supply-oriented evaluation methods, which typically concentrate on overall average performance metrics, rather than individual client experiences [3].

6. Conclusions and Future Recommendations

In conclusion, this study sheds light on the complex factors influencing household decision-making regarding public transport usage and perceived service quality in the Porto Metropolitan Area. The findings underscore the need to consider different demographic and situational factors when designing and promoting PT services. Policymakers and operators must prioritize measures that make PT services more attractive and competitive than PMVs. Investing in advanced technologies, such as real-time tracking, predictive analytics, and digital payment systems, has the potential to provide customers with greater convenience, comfort, and speed when choosing a transport mode [70–73]. Indeed, as transportation technology advances, it presents new opportunities to enhance PT services and improve the overall customer experience.

Our findings suggested that policymakers should consider citizens' preferences when designing public transport networks and policies. For example, our study reveals that service frequency and reliability are crucial factors in household decision-making regarding PT usage. Therefore, policymakers and operators should aim to increase the frequency and reliability of PT services, particularly during peak hours and in underserved areas. One example of how to achieve this is by implementing bus lanes, which implies the involvement of the municipalities in this operational strategy.

In general, the study contributes to the ongoing endeavors aimed at enhancing the public transport services in the PMA. The study highlighted the need for collaborative efforts between PT managers and local governments to prioritize sustainable transport modes and reduce the environmental impact of private motorized vehicles. However, further research is needed to explore factors such as the number of stops and stations near households, how density heterogeneity affects perceptions of PT service quality, and the importance of continuous measurement of PSQ to ensure a deep understanding of the preferences and needs of public transport users. This information can help policymakers and operators better tailor their services to meet the needs of households in the Porto

Metropolitan Area, promoting PT services that are sustainable, efficient, and responsive to the changing demands of users.

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Appendix A

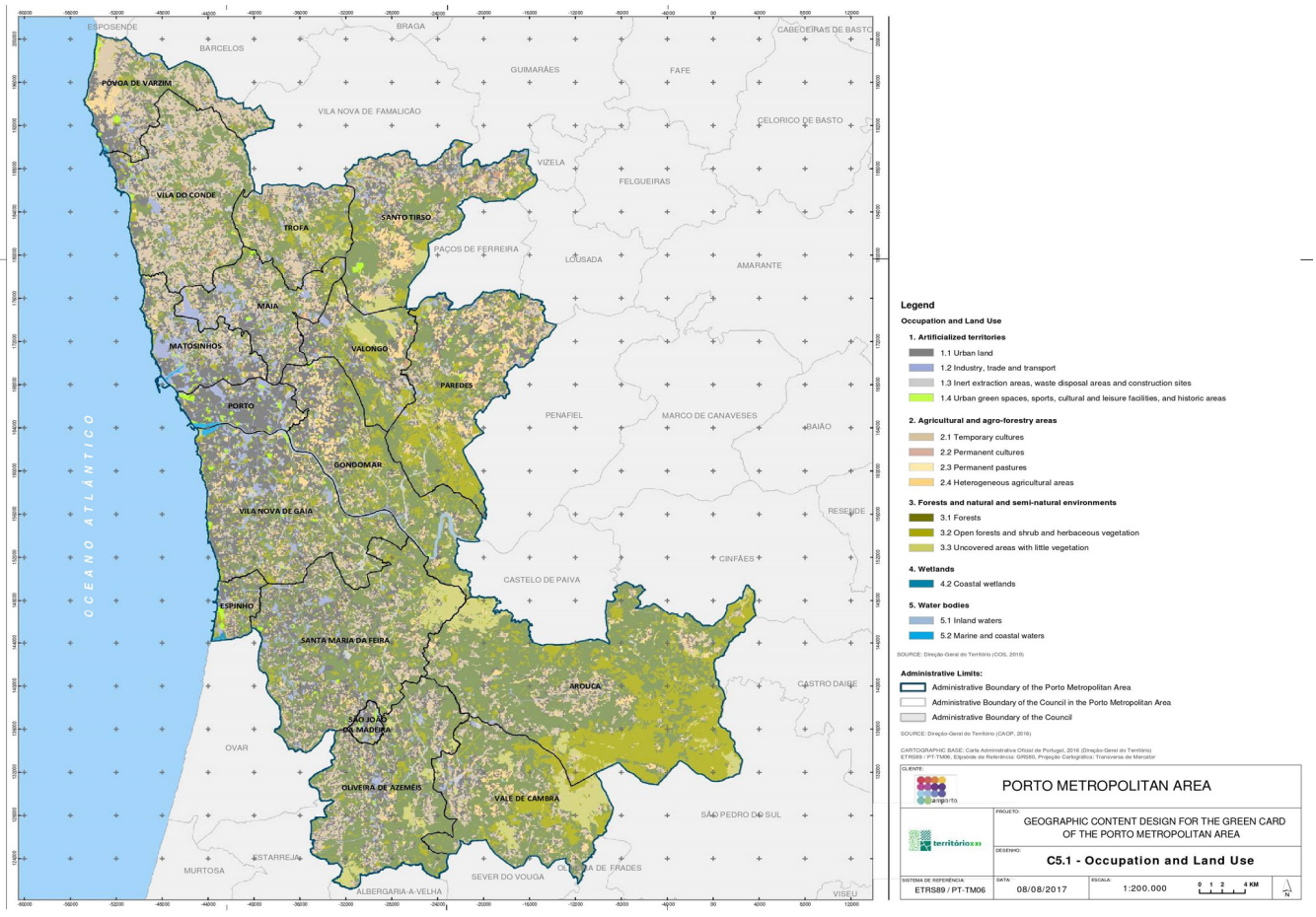

Figure A1. Occupation and land use of Porto Metropolitan Area.

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