

Public Transport System and Demand Determinants: A Stakeholders’ Perspective

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Abstract: The research and the debate on public transport is continuously growing for several reasons. On the one hand, institutions aim to improve sustainable forms of mobility and they see public transport (PT) as a key player in this transition. On the other hand, citizens are increasingly conscious of the necessity of a transition towards a sustainable mobility, but they struggle to consider PT, or other transport modes, as an alternative solution to their private vehicles. Moreover, the dynamic context in which PT operates (e.g., city sprawl) further emphasizes the challenges related to its management. Based on these premises, this study investigates the relationship between users and PT, to understand their interactions and how these can be used by the transport operator to promote the use of PT, fostering modal shift. Specific focus is given to the railway service, a capillary and polyvalent system over short and long distances. This study is articulated in a systematic literature review and validation via a questionnaire. First, it provides a quantitative description of the results, highlighting eventual trends; second, it displays a narrative description of the papers considered to map the current relationship and how these are investigated. In addition, a questionnaire conducted by *Regione Lombardia* is used to validate the identified relationships and understand the needs, assessing which relationships are the most relevant for users. The study highlights the multitude of factors that determine the use of public transport and how each actor involved can manage and influence them. Capillarity, frequency, accessibility, time and cost stand out among the most discussed and investigated ones. This study is a first attempt to classify and extend the existing body of knowledge related to public transport and influencing factors, analysing contributions based on different axes of classification and evaluating them considering on-field data.

Keywords: Public Transport, Demand Determinants, Transport Demand Management, Urban Mobility

1. Introduction

Public Transport Systems (PTS) are characterised by a complex integration of infrastructure and services designed to provide a transport offering aligned with demand. They have recently received increasing attention due to their central role in the transport sector and their contribution to the decarbonization process (De Aloe et al., 2023; Hörcher & Tirachini, 2021). The management of Public Transport Systems (PTS) faces a multitude of ever-evolving complexities. Policies like the SDGs and Agenda 2030, alongside local initiatives like Milan's Area B and Bologna City 30, aim to improve quality of life by reducing private vehicle use and fostering PTS usage. However, the rise of shared mobility services (e.g., bicycles and scooters) exposes critical PTS shortcomings, particularly in first mile/last-mile connectivity, underlining the need for integrated solutions. Additionally, new challenges like the pandemic's ripple effect on user behaviour (e.g., smart-working and e-commerce growth) further complicate the task of Public Transport Operators (PTOs) (de Haas et al., 2020). For example, transport demand in *Regione Lombardia* has increased year over year after the pandemic and it reached pre-pandemic values in 2023 (MIT, 2023), but fewer passengers were detected on the local (-20%) and regional PTS (-25%) (ATM, 2023; Trenord, 2023). Understanding stakeholders' characteristics and user-PTO

interactions is crucial for proposing solutions aligned with everyone's needs and thus to promote the use of PTS. The PTS stakeholders have indeed diverse needs and objectives that must coexist. PTOs often balance a profit motive with user satisfaction and cost reduction. In contrast, passengers, driven by individual characteristics, prioritize travel modes that maximize their "travel utility," considering factors like time, cost, and convenience. Considering these actors, several determinants impacting the decisional process of selecting the travel mode have been identified and investigated (Polat, 2012). For example, the PTO, through the development of infrastructures of service variation can affect the users' decisional process. On this topic, several studies have been performed, either evaluating the service characteristics that can be leveraged to improve PTS usage, either evaluating users' characteristics to investigate how they influence the modal choice. The literature on this topic is fragmented, limiting a comprehensive view of all the levers. Only three literature reviews were previously identified, each with a specific focus: Polat (2012) identified only the operational factors related to the PTO, suggesting further investigation in ranking, and quantifying the effects of each factor. Instead, Jamei et al. (2022) performed a review focusing on the interpretation of accessibility for the different actors involved, suggesting a different perception between users and policymakers. Finally, Hansson et al. (2019), evaluated

the main determinants for regional public transport considering both the users and PTO perspective, asking for a deeper investigation of this system. To enrich the discussion on these topics, the present research will review the existing literature on influencing factors for the PTS and classify it accordingly. In addition, survey data will be employed to rank the perceived importance of each factor with respect to the users' perspective. Further attention will be dedicated to the railway system as it is considered one of the most promising solutions for reducing transport externalities and because railway networks are complex and expensive, and primarily dedicated mainly to passenger transport. In addition, the Lombardy Region has the most extensive and well-connected railway infrastructure in Italy, making it an ideal area of investigation.

2. Methodology

In line with the previously mentioned objective and the previous studies, a literature review is conducted, following four stages as in Mangiaracina et al. (2019): literature search; paper classification; literature analysis; identification of the potential area of investigation. Results were discussed and enriched with the survey conducted in *Regione Lombardia*, to compare and support relationships between the different determinants. The survey was conducted in 2021, obtaining about 10,000 responses from users distributed throughout the territory, allowing to gather the different perceptions between users in the urban and rural contexts.

2.1 Literature Search

The search process is conducted over different steps summarized in Figure 1. First, the context of analysis is identified, i.e., influencing factors in the public transport system. Then, the unit of analysis is defined in a single scientific paper, both from black and grey literature (e.g., conference proceedings) to collect the most updated publication on the topic. The publications were searched by keywords and synonym and their combination in title, abstract and keywords in scientific databases (i.e., Scopus). To identify the publications aligned with the research objective, limitations and criteria were defined. Only publications written in English and published after 2019 were searched to consider the most updated publication on the topic and grasp any possible changes due to the pandemic. A relaxed limitation on the geographical area is given (i.e., Europe) since users' behaviour is affected by the legislation and the context in which they operate. This first step led to the identification of 313 papers. Inclusion and exclusion criteria were defined to select only publications aligned with the scope of the research. Hence only publications which investigate influencing factors, the relationship among them and their relationship with passenger demand were kept. Then a screening of the title and the keywords was performed, reducing the sample to 213 papers. A further reading of the abstracts section of the paper was conducted reducing the sample to 117 papers. Papers where the cause-effect interaction was not investigated were discarded. After the full reading, the final sample is reduced to 55 eligible papers.

2.2 Paper Characteristics

Over the years selected the number of publications remained stable, with a peak of 18 publications in 2020 due to the repercussions of the pandemic on the transport sector. The eligible papers were classified according to the year of publication, journal and research methodology employed. Over the years selected the number of publications remained stable, with a peak of 18 publications in 2020 due to the repercussions of the pandemic on the transport sector. The papers selected were published in 32 different journals, with *Transport Policy*, *Transportation Research Part A: Policy and Practice*, *Journal of Transport Geography*, *Transport Research Part F: Traffic Psychology and Behaviour and Sustainability* among the most recurrent ones. Further classification was performed on the methodologies used by the papers, following the categorization proposed by Meixell & Norbis (2008): analytical models (15%), case study (7%), simulations (4%), survey (55%), conceptual framework (5%), literature review (3%) and others (11%). Considering the selected papers, a common methodological approach emerged to test specific relationships identified (e.g. relationship between user and service determinants). Surveys are the primary data collection method, followed by analysis using various techniques such as regression models, Structural Equation Modelling (SEM), or ANOVA. These techniques help to identify the existence and nature of the relationships between the specific determinants studied and their influence on behaviour (Barros et al., 2021; Cui et al., 2020; Ko et al., 2019; Majumdar et al., 2021).

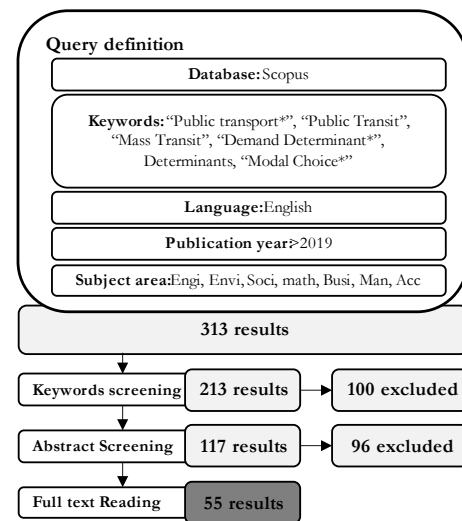


Figure 1. Prisma diagram

3. Results and discussion

To investigate the determinants influencing the users' modal choices, different theoretical lenses are used (i.e., psychological, decisional, economical, and geographical) with different explanations on how and why users perform their transport choices. The users select the transport modes to maximise their own utility, which is declined according to the lens considered (i.e., comfort, time or cost) (Majumdar et al., 2021; Rojas López & Wong, 2019). The literature analysis identified 29 relevant factors influencing users' modal choice. These factors were classified along two

main axes. The first axis examines the relationship between stakeholders and factors, clarifying their roles in managing those factors. The second axis assesses how these factors influence public transport demand and their interrelationships.

3.1 Stakeholders and Factors

The modal choice is the decision-making process through which the user determines how the trip will be performed and is contemporarily influenced by the characteristics of the travel itself, the individual's socio-economic characteristics, the context in which is performed and personal attributes (Abenoza et al., 2019; Majumdar et al., 2021; Zheng et al., 2021). The influencing travel characteristics are the expected distance and travel time and the purpose of the trip. The latter are divided between systematic trips, which occur repetitively by reason and distance, and non-systematic ones (Beria et al., 2021; Diab et al., 2020; Guzman et al., 2020). Instead, among the possible users' characteristics, socio-economic ones such as age, gender, income, level of education and vehicle ownership emerged as the most recurrent (Barros et al., 2021; Liu et al., 2020; Tao et al., 2019). Finally, the user's perceptions of the different transport modes are investigated and framed according to safety, comfort, information availability and other elements subjective to the individuals (Celse & Grolleau, 2023; Mazúrová et al., 2021; Minhans et al., 2020; Miravet et al., 2021; X. Wang et al., 2020). The user's modal choice depends also on external factors that are contingent on the characteristics of the PTS and the context. In fact, the PTO, knowing the main aspects of the decisional process, levers some service characteristics which are more likely to generate demand while minimizing costs (Cui et al., 2022; Millard-Ball et al., 2022). These determinants can be divided into operational ones, such as frequency, punctuality, capillarity and connectivity with other services (Charreire et al., 2021; Deepa et al., 2023), economic ones, related to the pricing of the transport services (Anupriya et al., 2020; Toro-González et al., 2020; J. Wang et al., 2023), and determinants linked to the perceived quality of the service in terms of safety and accessibility (Friman et al., 2020; Tuan et al., 2022; Vicente et al., 2020). Another stakeholder is the Built Environment (BE), i.e., the human-made surroundings, in which both the users and the PTO operates. The determinants of BE are mainly transport infrastructure and buildings. For the former, on the one hand, there is road density, type and size, and, on the other hand, the capillarity and availability of public transport. (Aston et al., 2021; Ma et al., 2020). The latter determinant, despite being a characteristic of the PTS, it's an interconnected choice between the PTO and the BE. Considering the buildings, instead, the determinants are the density of dwellings and their type, i.e. housing, industrial and shopping centres, universities and hospitals (Otsuka & Reeve, 2023; Yu et al., 2019). Lastly, a final stakeholder with few levers available is the Public Decision Makers (PDM). They can rely on legislation and pricing measures for private vehicles (e.g., direct and indirect taxes) to achieve their goals (Hörcher & Tirachini, 2021; Rahmat & Mizokami, 2020).

3.2 Influence on demand

The second section will explore determinants with a one-way effect on demand (increase or decrease) and those with a two-way effect. While the direction of most relationships can be identified (i.e., how they influence the demand), their intensity is often less investigated given the complexity in its estimation and context dependence. All the determinants of the PTO/PTS can be classified among the “one way”. In fact, it is observed that at an improvement or worsening in a PTO determinant (i.e., an increase in price or a reduction in waiting time) generates a single effect on the demand. The inducing effect on demand arises as the user perceives greater utility in varying the travel mode (Hörcher & Tirachini, 2021). Cui et al. (2022) reported that for every additional bus introduced in an extra-urban context, up to 2.7% more passengers per ride could be boarded, while Diab et al. (2020) reported that every additional stop in a metro system has up to 6% ridership increase. Instead, Cui et al. (2020) reported a user's elasticity at both fares and prices, where for a 10% increase in the price a -3% passengers are expected. As example, in 2022 Deutsche Bahn, experimented a monthly fare of 9€ across the whole country. As a result, rail passengers demand increases by 42% respect to 2019, with peaks during the weekends. In addition, car traffic had a limited reduction (-3%) in big cities as Munich (TUM, 2022). Guzman et al. (2020) pointed out that in addition to cost, the reliability of the services ensures a more continuous demand, especially from specific users, while Deepa et al. (2023) and Ingvardson & Nielsen (2022) identified a positive relation between a high integration/interaction of different PTs and their usage. Similarly, Tuan et al. (2022) and Vicente et al. (2020) report positive impacts when information and service quality are improved, with a limited group of users which remains indifferent. Instead, Abenoza et al. (2019) and Friman et al. (2020), highlight how on-board security perception has a linear and positive effect on the user but is highly influenced by the users' characteristics (i.e., trip purpose and trip frequency). Considering the economic perspective, it emerged that direct and indirect taxation over private vehicles reduces their usage and generates a transfer towards PTS (Harbering & Schlüter, 2020). Barros et al. (2021) conclude that between indirect and direct taxation (i.e., fuel taxation and tolls), the latter is the most effective in generating a reduction in the usage of private vehicles since the users perceive this cost most. Considering the users' perspective vehicle ownership negatively influences the usage of PTS, due to the easy accessibility to this transport mode (Roos et al., 2020). As example, in 2012, Milan established a pricing scheme for the central area of the city, reducing the circulation of private vehicles up to 38%, reinvesting funds in the PTS, encouraging users to use them (AMAT, 2022). Previously, mainly the economic and service dimensions factors were highlighted, which are directly linked to public transport. By contrast, the determinants of the Built Environment (BE) have an influence over all the modes of transport, including also the active and micro-mobility (i.e., bikes). BE planning, which consists of the coherent development of the area close to the PTS with the aim to integrate and facilitate the different modes of transport (i.e., stops and

their accessibility, the possibility of intramodality) has a positive effect on the demand, with different effects according to the system considered (Aston et al., 2021). In addition, proper BE planning allows to capture the peak and off-peak users’ behaviour and influences users’ patterns, improving the use of PTS capacity (Zhu et al., 2019). Among the determinants, parking space availability has a positive impact if located closer to the stops as it is for transfer mode, while a negative one if closer to the destination of the trip. Millard-Ball et al. (2022) highlight a statistical significance between parking space and car ownership where at every additional 0.43 parking space available, residents are 14% more likely to own a car. Instead, an increase in the road density, (i.e., the number of roads) has a positive impact on the propensity to use the private vehicle, while the sizing of roads (i.e., the number of lanes) has the opposite effect, i.e. when their capacity is reduced, it reduces the propensity to use the private vehicle if favour of PTS (Harbering & Schlüter, 2020). As example, in 2012, Transport Scotland, investigated how additional park and ride places in specific station influenced rail demand. For each additional 100 parking places generates up to 10 additional journeys/day (TRIMIS, 2012). Among the one-way factors linked to BE, some factors are mutually dependent. Indeed, considering the population and shop density, it emerges that an increase in them results in more demand for PTS (Yu et al., 2019). At the same time, an increase in population density can be achieved through proximity to public transport (Ingvardson & Nielsen, 2022). Thus, the following situation can arise: the presence of the PTS induces population density, or conversely, population density induces the PTO to create the service, attracting demand. As example, the regeneration of Piccadilly station in Manchester, created around 2000 workplaces, 10 million €/year of rental income and increased the value of the real estate market (ECORYS, 2014). Considering the users, family can be clustered among the one-way determinants. In fact, children’s presence while performing a trip has a negative impact on PTS demand, mainly due to safety and cumbersomeness (Harbering & Schlüter, 2020). It is observed that, on average the gender difference has a limited impact on the modal choice, with women being more likely to use PTS with respect to males. This result is collected during peak hours, not considering that in off-peak periods personal beliefs may negatively influence the safety perception and therefore reduce the usage of PTS (Roos et al., 2020). As a result, gender has a mixed effect.

The second category of determinants, on the other hand, does not always have a positive or negative impact on demand. This is especially true in user-related determinants, where the user’s characteristics determine these variations. Considering the users’ socio-economic characteristics, i.e., age, income, and education, different demand behaviours can be observed. The relationship between age and income appears to be strong, with a positive correlation between them (Roos et al., 2020). Young people tend to use public transport more as they have a low income and do not have private transport available (Wójcik, 2019). As age increases, there is a lower propensity to use public transport as the user’s income increases and the availability of private

transport increases. Finally, it emerges that elders use less public transport due to accessibility reasons (Cui et al., 2020). In general, for systematic trips, the user will favour the use of public transport (Ittamalla & Srinivas Kumar, 2021). While income and education generally influence modal choice (higher income allows for more options, and lower education correlates with car use), the study revealed a nuanced picture. In some contexts, even highly educated individuals may prioritise private vehicles for commuting. (Friman et al., 2020). Distance also exhibits a complex relationship with travel mode. Short distances tend to encourage public transport use in urban areas where service is frequent. However, in areas with less service availability, even short trips may favour private vehicles (Charreire et al., 2021). In contrast, over long distances, cost and travel reasons moderate the choice, favouring public transport when time and cost are lower (Beria et al., 2021). The resulting relationships can be summarized in Figure 2 where the determinants identified are first associated with the stakeholders. Then, for each determinant variation (i.e., + or -) the effect on PTS demand is reported. Finally, cause effect relationship within determinants is reported too.

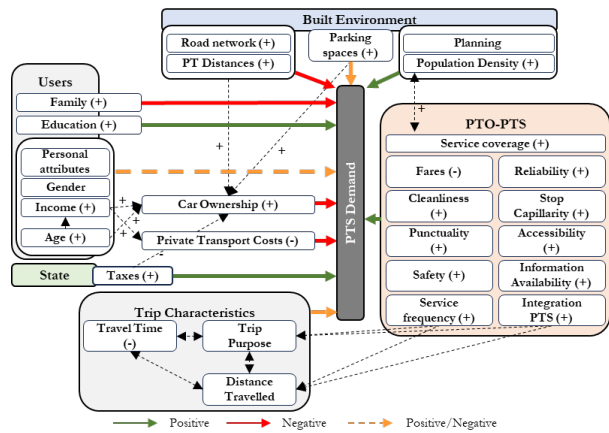


Figure 2. Relationship between the factors investigated

The overall vision of the determinant’s relationship provides some implications for the policymakers and the PTO. Firstly, the determinants available to PTO-PTS and BE are greater than those of users, leaving several potential courses of action for public decision-makers. Secondly, the PTO-PTS levers are among the most effective in improving ridership. However, a variation of these determinants requires investments and resources, requiring an understanding of which could be the most appropriate to develop. In fact, the effect of each lever is subject to the users’ characteristics as well as the ability of both the PTO to communicate the changes and the users to perceive them. Thirdly, the user determinants are few and a PTO has few leverages on them, requiring an understanding of how a proposed action can influence them.

4. Survey

To gain a deeper understanding of user needs and determinants importance across the Lombardy region, the study coupled the previous findings with a survey conducted in 2021 (POLIS, 2021). The results are likely to be influenced by the sanitary situation of 2021, suggesting

incorporating more up-to-date data in future studies and compare how user perceptions have evolved in a more stable post-pandemic environment. The survey, lasting 5 to 6 minutes, was performed on both short and long-distance public transport users (PTS) and was conducted across all provinces in the Lombardy region, with a resulting sample of 10,800 respondents. The 30-question survey utilized a 1-to-10 Likert scale for responses. The overall sampling error is around 0,9% with a confidence level of 95%. The survey firstly assesses the general satisfaction of the users and then the degree of importance of the factors by ranking the 3 most relevant ones. The PTS has an overall satisfaction score of 7,1. In the urban area, punctuality (7,24) is the most important user satisfaction driver. At the same time, for extra-urban routes, the punctuality (7,43), reliability (7,30) and PTS integration (7,27) are the elements of satisfaction.

Table 1: Determinants ranking by the PTS used

	Public Transport Service		
	Railway	Urban	Extra urban
Punctuality	0.74	0.59	0.87
Service Frequency	0.62	0.69	0.59
Reliability	0.44	0.46	0.46
Integration PTS	0.41	0.42	0.36
Travel Time	0.30	0.31	0.35
Crowding	0.24	0.25	0.28
Fares	0.19	0.21	0.18
Service Coverage	0.20	0.19	0.21
Travel Information	0.23	0.19	0.19
Accessibility	0.18	0.19	0.17
Cleanliness	0.10	0.12	0.15
Safety	0.11	0.10	0.07
Customer Service	0.10	0.10	0.12

The determinants ranking analysis reveals that user priorities vary according to the context (urban vs. suburban) and travel mode. Overall, the most relevant service characteristics are frequency (0.66), punctuality (0.66), and transfer connections (0.46). Conversely, crowding and comfort (0.25) and safety (0.04) appear to be the least important factors. This suggests that users prioritize efficiency, reflected in their focus on reaching their destination quickly, over secondary aspects of the travel experience. In contrast, for regional rail users, punctuality (0.76), train frequency (0.61), and connectivity (0.60) emerge as the relevant determinants. This can be attributed to the prevalence of multi-modal journeys among rail users, where punctuality is crucial to avoid missing connections with other transports.

Concerning the 12 provinces of the region, punctuality and frequency are the most recurrent determinants, ranging from 1,4 to 0,4, according to the area. Crowding and travel time were revealed to be relevant as well to some specific areas (e.g., Pavia and Mantova). This can be interpreted as these provinces are less connected with the rail system towards the main pole of attraction of the region (i.e., Milano). Table 1 represents the factors clustered per transport mode, while Table 2 represents the scores of the individual service-related factors across the regional provinces. Since the survey was conducted in the first post-pandemic period some shift in the users' behaviours are reported. In particular, it emerged that a large portion of the sample (49%) didn't change its travel habits, while the rest either reduced the number of trips (30%), either

travelled in less crowded period (18%), or used less the PTS (19%). The elder population (over 65) is the one that changed most its mobility habits. It emerged, that the crowding and safety factors become more relevant for the users to select the transport mode.

Table 2. PTS Determinants ranked by provinces

	Punctuality	Service Frequency	Reliability	Integration PTS	Crowding	Travel Time	Service Coverage	Fares	Accessibility	Travel Information	Customer Service	Cleanliness	Safety
Bergamo	0.7	0.6	0.4	0.4	0.2	0.4	0.2	0.2	0.2	0.2	0.1	0.2	0.1
Brescia	0.4	0.7	0.3	0.4	0.2	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.1
Como	1.4	0.7	0.8	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Cremona	0.6	0.4	0.5	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.1	0.1
Lecco	0.9	0.5	0.5	0.4	0.2	0.5	0.2	0.2	0.1	0.2	0.2	0.2	0.1
Lodi	0.9	0.3	0.5	0.4	0.3	0.1	0.1	0.2	0.1	0.2	0.2	0.2	0.1
Mantova	1.3	0.4	0.5	0.2	0.5	0.1	0.1	0.2	0.1	0.1	0.1	0.3	0.1
Milano	0.7	0.7	0.4	0.4	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1
Monza	1.1	1.1	0.4	0.4	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.0
Pavia	1.0	0.4	0.3	0.4	0.3	0.6	0.2	0.2	0.2	0.2	0.1	0.1	0.1
Sondrio	1.2	0.7	0.6	0.7	0.1	0.2	0.2	0.1	0.1	0.3	0.0	0.1	0.0
Varese	1.0	0.7	0.5	0.4	0.3	0.3	0.1	0.2	0.1	0.1	0.1	0.2	0.1

5. Conclusion

When developing public transport policies, all the stakeholders involved, and their different needs must be considered. The aim is to leverage these needs to create a more attractive service. An extensive and comprehensive classification of the main determinants is somewhat lacking as the previous literature and focused on a specific stakeholder (i.e., the users). To the best of the authors' knowledge, this study is a first attempt to extensively classify the literature on transport demand determinants. This study offers valuable contributions for both academics and practitioners. For academics, it builds on existing research by comprehensively classifying public transport determinants and highlighting their interrelationships. Additionally, it enriches the discussion by providing insights into the contextual relevance of these determinants, emphasizing the need for context-specific service development (Abenoza et al., 2019). To practitioners, the study clarifies the levers available to them. Finally, the study provides insights into users' perceptions of PTS/PTO determinants, allowing policymakers to integrate this information into their decision-making processes. In conclusion, the main limitations of the work and consequent future developments should be highlighted. Firstly, the study falls short of quantifying the strength of the relationships, which can be achieved through extensive empirical and modelling research. Secondly, the survey used is administered to PTS users, thus assessing the current users' needs and not the ones of the non-users. Additionally, understanding the reasons why non-users don't utilize PTS and strategies to convert them into riders remains crucial, independent of demand shifts caused by changing determinants. Finally, the literature reviewed is consistent with the objectives of the work, but it cannot be excluded that some papers were unintentionally omitted.

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