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KEYWORDS

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Clearly, urban planning is fundamental to achieve a successful integration between public transportation and shared mobility. This is the content of this study which, beyond discussing the recent literature on shared mobility and integration with public transportation, concentrates on one solution to achieve this goal: mobility hubs. A mobility hub is “a publicly accessible physical infrastructure providing a physical location for users to switch between (at least) two shared transportation modes.” Given the limited empirical evidence on mobility hubs in Italy, the authors outline a survey to collect information focusing on both shared mobility services and the characteristics of mobility hubs and users (the survey is currently being administered).

Integrated Public and Shared Mobility in the City: A Review and Pathway towards the Evaluation of Mobility Hubs

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January 7, 2025

Abstract

Clearly, urban planning is fundamental to achieve a successful integration between public transportation and shared mobility. This is the content of this study which, beyond discussing the recent literature on shared mobility and integration with public transportation, concentrates on one solution to achieve this goal: mobility hubs. A mobility hub is "*a publicly accessible physical infrastructure providing a physical location for users to switch between (at least) two shared transportation modes.*" Given the limited empirical evidence on mobility hubs in Italy, the authors outline a survey to collect information focusing on both shared mobility services and the characteristics of mobility hubs and users (the survey is currently being administered).

Keywords: Mobility hubs; Shared mobility; Public transport integration, Urban mobility

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1. Introduction

Sustainable and smart mobility is one of the eight thematic focuses of the European Commission that strives to achieve a climate-neutral society by 2050 (Ryghaug et al. 2023). Great attention is given, by researchers and practitioners alike, to new approaches aimed at diminishing the environmental and social impacts of motor vehicles in urban centers.

One of the most promising perspectives in this regard is the use of public transport systems in combination with shared mobility options to achieve a reduction of traffic congestion and pollution (Machado et al. 2018). Shared mobility plays an important role in reducing urban traffic congestion and travel commuting time, which in turn improves travelers' happiness and job effectiveness (Zhang and Kamargianni 2023). According to Winkler et al. 2023, modal shift policies promoting the use of public transport and micromobility modes have the potential to positively impact the urban space. In general, multimodal transportation schemes combining public transport and shared mobility options enhance connectivity and redundance, and reduce the burdens associated with heavy car use. Shared mobility hubs allow users to switch more easily between different modes of transport (public and shared), therefore decreasing the comparative attractiveness of private cars. In combination with other policy measures (e.g., vehicle electrification, congestion charges), widespread use of shared mobility modes can reduce the transportation sector emissions, thus helping with decarbonization and climate change targets (Fan and Harper 2022). A growing number of studies explore the role that urban transportation needs and socio-economic factors might play in creating mobility options appealing to the community of potential users (Ho and Tirachini 2024).

To harness the full potential of multimodal transportation systems, it is paramount to identify and study the factors affecting the users' decision to take part in shared mobility or to integrate it in their daily transport choices, as well as their preference of shared mobility device, and the role of mobility hubs in urban transportation schemes. This paper provides an overview of the literature on shared mobility, with its diverse modalities and shared mobility hubs in urban centers, as an alternative to individual transportation. Bringing forth an understanding of how this topic has been studied so far and a comprehensive synthesis of existing relevant studies, including user characteristics and indicators, our research takes a step further by leveraging these findings to design a research project aimed at examining transportation patterns and user preferences for shared mobility hubs. By building on previous research, we seek to explore the dynamic interplay between shared mobility services and the infrastructure of mobility hubs, focusing on how users interact with these systems. This approach allows us to address gaps in current understanding and develop data-driven insights that can inform the future development of efficient, user-centered transportation networks.

2. Methodology

A comprehensive literature review was undertaken in academic and scientific databases, such as Web of Science, EBSCO Discovery Service (EDS), Scopus, Google Scholar, etc. including the most relevant published articles in the literature over the last two decades. We searched for relevant keywords, and then used forward and backward snowballing. The review aims to answer the following questions: what factors and aspects of shared mobility and mobility hubs have been analyzed so far? At which conditions are public transport and micromobility complementary? And when are they substitutes instead? What recommendations can be given for future research, and what are the future development trends?
It is important to point out that only scientific and grey literature in the English language was reviewed in this paper. Additionally, the section assessing hub-related literature only includes studies and reports on mobility hubs that comprise at least one shared mobility mode.

3. Outline of literature background

3.1 Shared mobility and integration with public transportation

Scholars argue that integrating public transit and micro mobility has become a critical matter which could support smart transportation and sustainable urbanization in many cities (Jin et al. 2022). Several studies present a conceptual analysis and review of policies and incentives in place to promote the integration of micromobility and public transport (Grosshuesch 2020; Kager, Bertolini, and Te Brömmelstroet 2016; Sagaris, Tiznado-Aitken, and Steiniger 2017). Public transit options combined with the accessibility of shared transportation is a promising solution for the first and last mile connection problem, making modal shifts more likely and contributing to the creation of more livable cities and equitable transportation schemes (Beale, Kapatsila, and Grisé 2023; Oeschger, Carroll, and Caulfield 2020). In this context, shared mobility can be studied as a complement to public transport (van Kuijk et al. 2022; Wu et al. 2022). Well planned multimodal transportation systems can provide efficient and comfortable transportation options that can compete with private motorized vehicles (Kager, Bertolini, and Te Brömmelstroet 2016). The relationship between public transport and shared mobility ridership is found to be dependent on the level of integration between the different modes of transportation (Oeschger, Carroll, and Caulfield 2020; Oeschger, Caulfield, and Carroll 2023). A higher level of integration, for example when shared mobility hubs and public transport stations are located close to each other, is found to promote ridership (Oeschger, Carroll, and Caulfield 2020; Oeschger, Caulfield, and Carroll 2023; Böcker et al. 2020). A study in New York City found that bike-sharing stations along a bus route were used more often than those unlinked to

a bus route (Campbell and Brakewood 2017). Pricing schemes and payment mechanisms are considered relevant to bolster use of multimodal transportation modes. Uniform ticketing systems, as well as integrated mobile phone apps, might improve integration by making transfers more efficient and improving user-friendliness (Böcker et al. 2020; Oeschger, Carroll, and Caulfield 2020; S. Shaheen and Chan 2016; Oeschger, Caulfield, and Carroll 2023; S.C. Shaheen, Nelson 2016).

Ma et al. 2019 found that the use of public transportation and shared e-bikes ridership are positively correlated. Free floating bicycle-sharing often integrates with and complements public transportation options (Wu et al. 2022). Modal integration between public transport and bike sharing is often associated with short trip duration and higher public transit service frequency (Kong, Jin, and Sui 2020). Yan et al. 2020 highlights the importance of land use and population density around public transport stations for the adoption of bicycle-sharing. The availability of a safe and convenient infrastructure for micromobility around public transport stations, as well as a safe environment to access the public transport stops, are some of the most relevant factors in determining the propensity of commuters to use micromobility options (Oeschger, Carroll, and Caulfield 2020). Dockless scooters are often used to connect to and from public transport modes (Aarhaug, Fearnley, and Johnsson 2023; Chicco and Diana 2022), increasing accessibility, with greater increments in the first mile than the last mile (Liu and Miller 2022). The presence of facilities and amenities such as bars, shops and restaurants are associated with e-scooter trip density, suggesting that the use of e-scooters happens for leisure trips (Chicco and Diana 2022; Christoforou, Psarrou Kalakoni, and Farhi 2023).

Shared mobility devices are also used in lieu of public transportation when the latter is not a practical option, thus often complementing public transport, and competing in other areas (Schwinger, Tanriverdi, and Jarke 2022; Ziedan et al. 2021). Aarhaug, Fearnley, and Johnsson 2023, found that for many e-scooter trips, using public transport alternatives would take at least twice as much time. A study by Moinse and L'Hostis 2024 revealed that in France, for example, users of micromobility devices are willing to travel 2 km or 10 more minutes during access or egress to avoid transfers on public transport. Shared e-scooters sometimes replace walking, cars, and public transport (Glavić et al. 2023). Studies based on survey data found that people use shared e-scooters in place of cars at significant rates, suggesting that in some locations, shared e-scooters could be an effective approach to decreasing reliance on cars (Wang et al. 2023). Shared e-mopeds proved to also be a practical option as individual modes for long-distance trips (van Kuijk et al. 2022).

3.2 Factors affecting choice and use of multimodal transport and shared modes

Several studies characterized users of shared mobility based on their socio-demographics, characteristics, common travel patterns and attitude towards sustainability and the environment. Preference for using integrated shared micromobility and public transport systems is correlated to young age, high educational attainment, high scooter ownership and low car ownership (Ghasri et al. 2024; Chi, Han, and Lee 2023). In general, age, gender, previous experience with micromobility, weekday or weekend travel, and interest in micromobility are found to be significant factors that influence mode choice (Oeschger, Carroll, and Caulfield 2020; Oeschger, Caulfield, and Carroll 2023; van Kuijk et al. 2022; Montes et al. 2023). Users of shared mobility are usually concerned about environmental issues and care about sustainable transportation and the environment (Chi, Han, and Lee 2023).

Micro-mobility mode choice is greatly affected by distance, weather conditions, air quality, accessibility, elevation rise, and time of day (Reck, Martin, and Axhausen 2022; Hu et al. 2022). Trip distance, for example, is found to be significantly associated with users' mode options, indicating that bike-sharing schemes usually serves short distance transfer users, normally trips between 1 and 5 km (Bergantino, Intini, and Tangari 2021), while ride sourcing mainly serves long-distance transfer users (Bi, Ye, and Zhang 2021). The availability of transit facilities, parking lots, and the proximity to bus or metro stations had a substantial positive impact on the demand for free-floating bike-sharing (Hu et al. 2022). Docked bikes tend to be used mostly for short trips connecting to and from major public transit transfer stations (Lazarus et al. 2020). Thus, integrating bike sharing hubs with public transport station could increase the number of multimodal trips (Reck et al. 2021). E-scooters are found to be mostly used near universities, and in central business districts (Reck, Martin, and Axhausen 2022). The presence of facilities and amenities such as bars, shops and restaurants are associated with e-scooter trip density, suggesting that the use of e-scooters happens for leisure trips (Chicco and Diana 2022; Christoforou, Psarrou Kalakoni, and Farhi 2023).

Travel cost affects choice of transportation mode. Strategies such as membership plans and discounts may contribute to attracting car users to switch to multimodal transportation including shared modes and public transportation (Luo et al. 2023).

Mobility options of a mobility hub can be integrated into a MaaS service (Athanasopoulou et al. 2022). MaaS can facilitate trips by suggesting the most efficient combination of transportation modes to reach a destination, and by allowing users to make reservations or pay for different transportation modes all in one place (Hachette and L'Hostis 2024).

3.3 Definition and characteristics of shared mobility hubs

The concept of "mobility hub "started to emerge in the early 2000s, but has gained popularity in the last two decades, with a constantly increasing volume of literature worldwide on the topic (Hachette and L'Hostis 2024; Roukouni et al. 2023). Mobility hubs allow users to switch

between different modes of transport (public and shared), therefore potentially leading to mode substitution or integration with public transport, disincentivizing the use of private transportation (Aydin, Seker, and Özkan 2022; Luo et al. 2023). A study on a pilot mobility hub in the city of Munich, for example, revealed that users of shared mobility services joined and/or used other mobility services more often because of the mobility hub (Miramontes et al. 2017).
Several different definitions and characterizations of mobility hubs exist in the literature, based on different frameworks and variables, such as location, and the service they provide (Geurs et al. 2024; Hached, L'Hostis, and Gragera 2023). Most definitions focus on the mobility and transfer components of hubs and include the presence of multiple modes and transfer between modes as requirements for mobility hubs. Researchers agree that a shared mobility hub can generally be described as a publicly accessible physical infrastructure providing a physical location for users to switch between (at least) two shared transportation modes (Geurs et al. 2024; Hached, L'Hostis, and Gragera 2023). A common element in the definitions of (shared) mobility hubs is the presence of shared mobility services such as shared bikes, scooters or cars (Miramontes et al. 2017; Shaheen et al. 2020).
Because the concept of shared mobility hubs is still relatively new and emerging, there is no consensus among researchers regarding the appropriate way of defining mobility hub typologies. Hubs classification can be based on different parameters, such as spatial scale (influence radius), size, target users, urban location, transportation function (entry, transfer, destination), and role in the transportation network (Roukouni et al. 2023). Regarding the urban context, for example, shared mobility hubs can be classified as follows: City Centre, Urban Transit Nodes, Emerging Urban Growth Centers, Historic Town Centers, Suburban Transit Nodes and Key Destinations (Aono 2019; Roukouni et al. 2023).
Availability of different shared vehicle types adds value to the shared hub by appealing to different groups of transport users and population segments (Bösehans et al. 2023). On site access or proximity to public transport is considered as an essential characteristic of a shared mobility hub (Miramontes et al. 2017).
Other features of shared mobility hubs as mentioned in the literature are the availability of amenities, such as shelters, wayfinding, lockers, activity centers, digital pillars with information and ticketing, and proximity to retail and service destinations (Geurs et al. 2024). Amenities, a sense of space and services provided can incentivize public and shared transport usage and affect the waiting and ticketing experience, as well as the users' perception of safety (Arnold et al. 2023). Together with transit stops and micromobility parking, ride hailing pickup and drop-off zones may also be present (Anderson et al. 2017; Shaheen and Cohen 2020).

3.4 Existing studies and data on shared mobility hubs and shared mobility hubs users

The concept of shared mobility hubs has recently risen to popularity among practitioners, policy makers, and researchers alike, driven by the spread of shared transport in all cities in Europe. Consequently, international scholarly literature on shared mobility hubs has been growing exponentially over the last decade (Roukouni et al. 2023). Several studies researched suitable locations for mobility hubs and best ways to determine such locations (e.g., Aquilué Junyent et al. 2024; Xanthopoulos et al. 2024; Aydin, Seker, and Özkan 2022), while others focused on the characteristics of mobility hubs users (Bösehans et al. 2023), and their needs (Tran and Draeger 2021).

An increasing number of EU-funded projects, such as SmartHubs (EIT) and SmartHubs (ERANET-JPI Urban Europe) focused on this topic. The latter project's team, for example, conducted living labs in Brussels, Munich, Rotterdam, Vienna and The Hague from 2021 to 2024 to investigate various dimensions of mobility hubs and formulate policy recommendations. The study involved a large-scale survey and choice experiment collecting information about user's profiles, usage patterns, and preferences for attributes of the hubs.

Research on shared mobility has also been conducted at the Italian level, with several studies focusing on various aspects of this evolving transportation model. These studies have explored topics such as user attitude towards shared mobility in general, and perception of shared scooters (Campisi et al. 2024), the impact of shared mobility services on urban sustainability, and the integration of shared mobility into urban transportation systems (Candiani et al. 2024). However, most of this research has been limited in scope, often focusing on specific cities or services. Several research studies on shared mobility and mobility hubs carried out in Italian cities investigated shared mobility ridership and coverage using a spatial approach (e.g. Chicco and Diana 2022; Giuffrida et al. 2021). Yet, existing studies have not yet fully examined the broader dynamics of shared mobility in combination with mobility hubs and user characteristics on a national scale, particularly using both revealed preference (RP) and stated preference (SP) data, leaving room for further exploration and deeper insights. While individual aspects of shared mobility and mobility hubs have been explored, a gap remains in the understanding of how these factors interact across diverse user groups and geographic regions. Integrating RP and SP data would provide a more comprehensive picture of actual behavior and potential future choices, offering insights that are critical for formulating effective transportation policies and infrastructure planning at the national level.

4. Findings and discussion

Our research highlights that, while shared mobility and mobility hubs have been widely studied at the international level, there is a significant gap in the Italian context. To date, no study in Italy has focused specifically on the intersection of shared mobility, mobility hubs, and user

characteristics at the national level. International research has explored the role of these services in urban mobility systems, but a comprehensive analysis that integrates these elements and examines how they apply to the Italian landscape is missing.

Based on the literature review on shared mobility, the research teams of the universities of Bologna and Bari are currently developing a detailed survey focusing on both shared mobility services and the characteristics of mobility hubs and users. This survey, combining both RP and SP data, aims to explore user preferences, behaviors, and perceptions of shared mobility options, as well as the design, accessibility, and functionality of mobility hubs. It will be distributed across nine major Italian cities, enabling us to capture regional differences and gather insights on how these factors influence the adoption and effectiveness of shared mobility solutions. The results will contribute to a deeper understanding of how mobility hubs can enhance shared mobility systems in urban settings.

The first part of the questionnaire asks about demographic and socioeconomic details, questions regarding mobility and travel habits, and on the quality of the transportation services used. The RP part of the survey includes questions regarding both the interviewees' actual commute trip, and their second-best commute mode choice. The data to be collected is aimed at reconstructing the users' profile, and will provide information regarding mobility patterns (e.g., change at station, transfer time, type of intramodality used) allowing to study transport behavior, mode preferences and mode substitutability. The second part of the questionnaire includes questions on SP, and scenarios developed with hypothetical mobility hub options. Inputs from the RP section will be used to customize the stated choice experiments. This part will elicit preferences for different mobility hub alternatives declared by users in a hypothetical context, uncovering information about the mobility hubs characteristics that are relevant to travelers, such as preferred amenities and means of transportation offered.

The proposed research is innovative in that it addresses a gap in the existing body of knowledge by focusing on shared mobility and mobility hubs across major cities in Italy. While previous studies have explored aspects of shared mobility on a regional or city-specific level, there has not yet been a comprehensive study conducted at the national scale in Italy. This research is unique in its scope, as it seeks to capture data from nine major cities, providing a broader understanding of the dynamics, challenges, and opportunities associated with shared mobility and mobility hubs throughout the country. This national-level approach will offer valuable insights that can inform both local and national transportation policies.

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