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Mobility as a Service (MaaS) for university communities: Modeling preferences for integrated public transport bundles

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ABSTRACT

In order to investigate the role that Mobility as a Service (MaaS) could play in university communities to reduce car dependency and moderate car-oriented travel behavior, this paper examines individuals' stated interest in adopting MaaS bundles in academic environments, where its potential is still largely underexplored. The study involves a large-scale survey campaign carried out within a university community in Milan (Italy), comprising 1873 answers from faculty members, technical-administrative staff, and students. The paper discusses the factors affecting behavioral intentions towards a potential MaaS adoption on the basis of aggregate statistics and discrete choice models estimates. This research highlights that there is a real opportunity to market MaaS in university communities, but an accurate user-centered design of the MaaS solutions is needed, based on individuals' preferences and actual mobility needs. Results suggest that MaaS has a broader potential user base among individuals under 35 years old and Public Transport subscribers, and that MaaS bundles involving shared mobility services are attractive by residents in the city center, while reserved parking at interchange facilities is more attractive to commuters coming from suburban areas.

1. Introduction

The rapid urbanization and the widespread deployment of shared, on demand, and smart mobility services in cities, even competing with Public Transport (PT), pose a challenge for future urban mobility. Innovative solutions are needed to reshape these trends, steering them towards environmentally, economically, and socially sustainable development that improve accessibility and livability in urban and metropolitan areas. In this context, Mobility as a Service (MaaS) can play a key role by providing the integration of different transport modes and services, offered by various mobility operators, on a single smartphone application, through which users can plan door-to-door journeys, book desired vehicles or seats, and pay travel expenses with a single transaction (Jittrapirom et al., 2017).

MaaS concept may be summarized in three main elements (Vij et al., 2020): (a) mobility integration, to provide access to different transport operators in an area; (b) ticket and payment integration, to book and pay for a series of transport services on a single platform, using a single account, purchasing a unique ticket, in pay-as-you-go or subscription form; (c) information and communication technology integration, to provide real-time information about mobility services in a single application. Different levels of integration of MaaS have been defined. (Sochor et al., 2018) propose a topology constituted by five levels: Level 0 correspond to no integration; Level 1 stands for integration of information (e.g. support decision for finding the best trip option, acting as a multimodal travel planner); Level 2 integrates booking and payment features (e.g. extends the concept of multimodal travel planner towards the possibility of booking and paying for the desired transport services); Level 3 presents the integration of the service offer, including subscription bundles, contracts and responsibilities (e.g. aims at constituting a comprehensive alternative to car ownership, to answer customer's complete mobility needs, focusing on everyday routine commutes rather than on a single occasional trip from an origin to a destination); Level 4 aims to the integration of societal goals exploiting behavioral science techniques (nudging), incorporating game-like elements to encourage desired behaviors (gamification), and providing monetary incentives to promote sustainable and equitable mobility choices. The objective is not only to optimize individual travel experiences, but also to influence user behaviors in a way that aligns with broader societal and environmental objectives.

MaaS has been extensively discussed in literature as shown in (Utriainen and Pöllänen, 2018; Jittrapirom et al., 2017; Arias-Molinares

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and García-Palomares, 2020; Kriswardhana and Esztergár-Kiss, 2023a). On the one hand, (Lajas and Macário, 2020; Polydoropoulou et al., 2020b; Abassi et al., 2023) focused their studies on supply-side challenges related to integrating diverse transport modes, establishing seamless payment systems, and ensuring data interoperability. Moreover, the development of collaborative partnerships between public and private entities to enhance service coverage and accessibility has been a prominent topic (Smith et al., 2018; Wong et al., 2020; Smith et al., 2019; Sochor et al., 2015). On the other hand, many studies have focused on demand-side issues. (Matyas and Kamargianni, 2021; Polydoropoulou et al., 2020a; Krauss et al., 2022) explored individuals' stated preferences regarding the interest in adopting MaaS in hypothetical choice scenarios. Some authors investigated respondents' Willingness to Pay (WTP) for mobility bundles (Reck et al., 2020; Caiati et al., 2020; Matyas and Kamargianni, 2021; Chen and He, 2023; Kriswardhana and Esztergár-Kiss, 2023a). In other papers, attitudinal and motivational factors affecting user acceptance and behavioral intention to uptake MaaS have been assessed (Schikofsky et al., 2020; Alonso-González et al., 2020; Ye et al., 2020; Lopez-Carreiro et al., 2024), among which technology-savviness, privacy issues, environmental awareness, and perceived reliability emerge as primary determinants. Finally, (Kim et al., 2021; Liu et al., 2023; Chen et al., 2023) examined the attractiveness of MaaS solutions for specific demand segments, such as tourists and occasional users, with non-systematic travel purposes.

Despite this vast literature and the growing interest in MaaS as a promising solution for urban transport challenges, the specific application of MaaS in university communities has been largely underexplored, and just a few recent studies can be found in the literature (Gandia et al., 2021; Kriswardhana and Esztergár-Kiss, 2023b; Le Pira et al., 2023; Kriswardhana and Esztergár-Kiss, 2024). Thus, a notable research gap still exists regarding the potential adoption of MaaS among university community members for systematic home-to-campuses commutes. Indeed, university campuses generally represent densely populated areas with complex transport networks and diverse commuting patterns, thus the adoption of MaaS could offer significant benefits in terms of reducing congestion and promoting sustainable mobility practices among community members. The study of Le Pira et al. is a first step towards understanding the potential adoption of a university MaaS app, but it is focused only on the general perceptions towards a MaaS app, so a deeper investigation about the willingness to use it for home-university commuting is required. The research gap is also significant considering that the two studies of Kriswardhana and Esztergár-Kiss and the study of Gandia et al. investigated only the behavioral intentions of students, at the Budapest University of Technology and Economics and in five universities located in the Brazilian city of Lavras respectively. However, universities are dynamic environments with large populations of students but also of faculty members and technical-administrative staff, who regularly commute to and from campuses. In addition, another issue that emerges from the study of Gandia et al. is related to the actual knowledge of an innovative concept such as MaaS in the context where the research has been carried out, being that of a developing country. Thus, potentially conflicting results may emerge from various studies since each university is embedded within a territorial context characterized by a specific transport supply and urban form.

Furthermore, bridging the gap in literature regarding the potential uptake of MaaS among university communities can have broader implications. Insights gained from studying the preferences and behaviors of university commuters can inform the design and implementation of MaaS initiatives not only within university settings, but also in other institutions and companies facing similar mobility challenges. Besides, by demonstrating the feasibility and benefits of MaaS within their own communities, universities can inspire other urban stakeholders to embrace similar initiatives, ultimately contributing to the development of more integrated, accessible, and environmentally friendly transport systems.

This paper aims at providing modeling evidence, based on an extended surveyed sample of students and employees of a university community in Milan (Italy), to answer the following research questions: Which transport modes and features are most appreciated and requested in a MaaS platform by university community members? What socio-economic characteristics and travel habits affect (and to what extent) individuals' interest in MaaS solutions? Which factors specifically influence interest in mobility bundles that integrate Public Transport with other ancillary mobility services, such as bike sharing, car sharing, or parking at interchange facilities?

The remainder of the paper is organized as follows. Given the objective of this study, Section 2 delves into a literature overview of significant studies that have investigated individuals' interest in MaaS. Section 3 is dedicated to the description of the case study context and the adopted methodological, while Section 4 presents the aggregate statistics of the collected data and the estimated models. Section 5 presents and discusses the results of the research, from the description of the survey sample to the estimation of behavioral choice models, while in Section 6 closing remarks are reported.

2. Literature overview

Among the research focused on demand-side studies, those aimed at investigating how socioeconomic characteristics and travel habits can influence individuals' interest in MaaS solutions are certainly the most relevant for understanding the contribution of this paper, and for highlighting the aspects that need to be addressed to bridge the research gap and make MaaS appealing to potential users.

The concept of MaaS at its highest levels of integration is associated to bundling schemes of several transport modes and services, according to the widely accepted taxonomy by (Sochor et al., 2018). Understanding which modes and which payment scheme (i.e. subscription of pay-as-you-go) have a higher appeal to individuals are some of the main points of MaaS research, including this study. (Matyas and Kamargianni, 2019) investigated the interest of individuals towards MaaS bundles, finding out that PT is considered the core of any MaaS plan, while other modes' appreciation is subjected to individuals' current habits and mobility patterns. However, although individuals may not favor certain modes (including shared modes), the MaaS plan can indeed offer enough added value to respondents that they would purchase or at least consider purchasing them. In general, as highlighted by (Vij et al., 2020) and (Ho et al., 2020), individuals prefer pay-as-you-go schemes, which allow higher flexibility over bundled schemes with unlimited access to different transport modes at fixed monthly costs. However, this preference indicates that users tend to retain their current travel habits, thus limiting the potential of MaaS, being multimodality, and leading to less sustainable decisions, since they indicate a lower willingness to utilize PT and active modes compared to monthly subscribers.

Apart from the impact on preferring one transport mode over another, current mobility behavior is an aspect that influences MaaS attractiveness both in positive and negative ways. Therefore, it should be carefully investigated whether it may favor or limit MaaS potential. (Ho et al., 2020) observed that individuals who frequently use car are less inclined towards the use of MaaS compared to PT users: the more the days of car use per week are, the less MaaS is attractive. On the contrary, frequent PT users, that hold a monthly pass, are more likely to consider PT and other integrated modes, while those without a pass are more eager to maintain their travel habits. In addition, (Alonso-González et al., 2020) demonstrated the presence of an underlying mobility integration factor, wherein a positive multimodal mindset correlates with a favorable attitude towards PT and reduced car usage, as confirmed by (Zijlstra et al., 2020). This positive attitude, as further analyzed by (Polydoropoulou et al., 2020c), also determine a higher WTP for MaaS bundles for people that already integrate different transport modes during the same trip. Consequently, individuals exhibiting predominantly unimodal car behaviors appear less inclined to adopt MaaS.

Other factors may play a role in individuals' interest towards MaaS, and some of them are socioeconomic characteristics. As highlighted by (Vij et al., 2020; Alonso-González et al., 2020; Zijlstra et al., 2020), age have a relevant influence in relation to MaaS perception, being younger individuals more likely to adopt MaaS compared to older adults. Furthermore, (Alonso-González et al., 2020) and (Zijlstra et al., 2020) observed that highly educated individuals exhibit a higher interest towards MaaS. Moreover, (Alonso-González et al., 2020) highlighted how individuals residing in densely populated urban areas show the most favorable attitudes towards mobility integration by means of MaaS, as confirmed by (Liljamo et al., 2020) and (Zijlstra et al., 2020). These results coming from stated intention or stated preference surveys were confirmed in (Smith et al., 2023), where the analysis was performed based on the answers provided by the participants in a MaaS trial in Sidney. The participants were primarily frequent users of both Public Transport and private cars, with a large part of the sample (around 80 %) having a car at their disposal. The authors showed that even people owning a private vehicle could be interested in MaaS, but at the same time the outcomes of the survey submitted following the experimentation highlight the difficulties in changing their car dependence. In fact, a major part of respondents stated that they will continue still to use cars after the trial, in the short period, but a future development of the service could make them more willing to adopt MaaS and reduce car use and ownership.

The studies presented have explored the potential adoption of MaaS without focusing on specific contexts or communities, instead considering heterogeneous samples of individuals with diverse backgrounds. While it is important to understand how characteristics such as current travel habits and socioeconomic factors influence the perception of MaaS, the context in which MaaS is proposed could play a significant role and may yield different, even conflicting, results. Therefore, it is sensible to analyze MaaS adoption within restricted contexts. This is precisely what this research aims to do by focusing the analysis on a university community.

Given this consideration, (Kriswardhana and Esztergár-Kiss, 2023b) focused their study on university communities, and found that students prefer to have access to a broad range of routing-related information, while environmental and health details regarding recommended travel solutions are not among the most desired functionalities. Most participants expressed interest in utilizing MaaS platforms for booking, online payment, and ticketing, but those individuals more inclined to adopt MaaS are those seeking advanced functionalities. However, university students seem hesitant to decrease their car usage despite adopting MaaS. Furthermore, in a second study based on the same sample (Kriswardhana and Esztergár-Kiss, 2024), the authors highlighted that university students who had prior experience with shared mobility services exhibit positive attitudes towards MaaS. Likewise, individuals who have access to a variety of transport modes demonstrate a greater inclination to adopt MaaS compared to those reliant solely on PT services. Finally, the study identifies effort expectancy as the most influential factor affecting the behavioral intention of students to adopt MaaS, among the constructs commonly assessed within the theory of acceptance and use of technology (Venkatesh, 2003).

3. Methodology

The context of the study is the metropolitan area of Milan (Italy), as shown in Fig. 1, where campuses of different universities are located within a maximum distance of 4 km from the historic city center. The urban area is provided with high accessibility to Public Transport network, consisting of suburban trains, metros, tramways, and an extended bus network; in addition, high-frequency regional railway lines connect the city with the rest of the metropolitan area of Milan and the other provinces of the Lombardy and Piedmont regions (i.e. Varese,

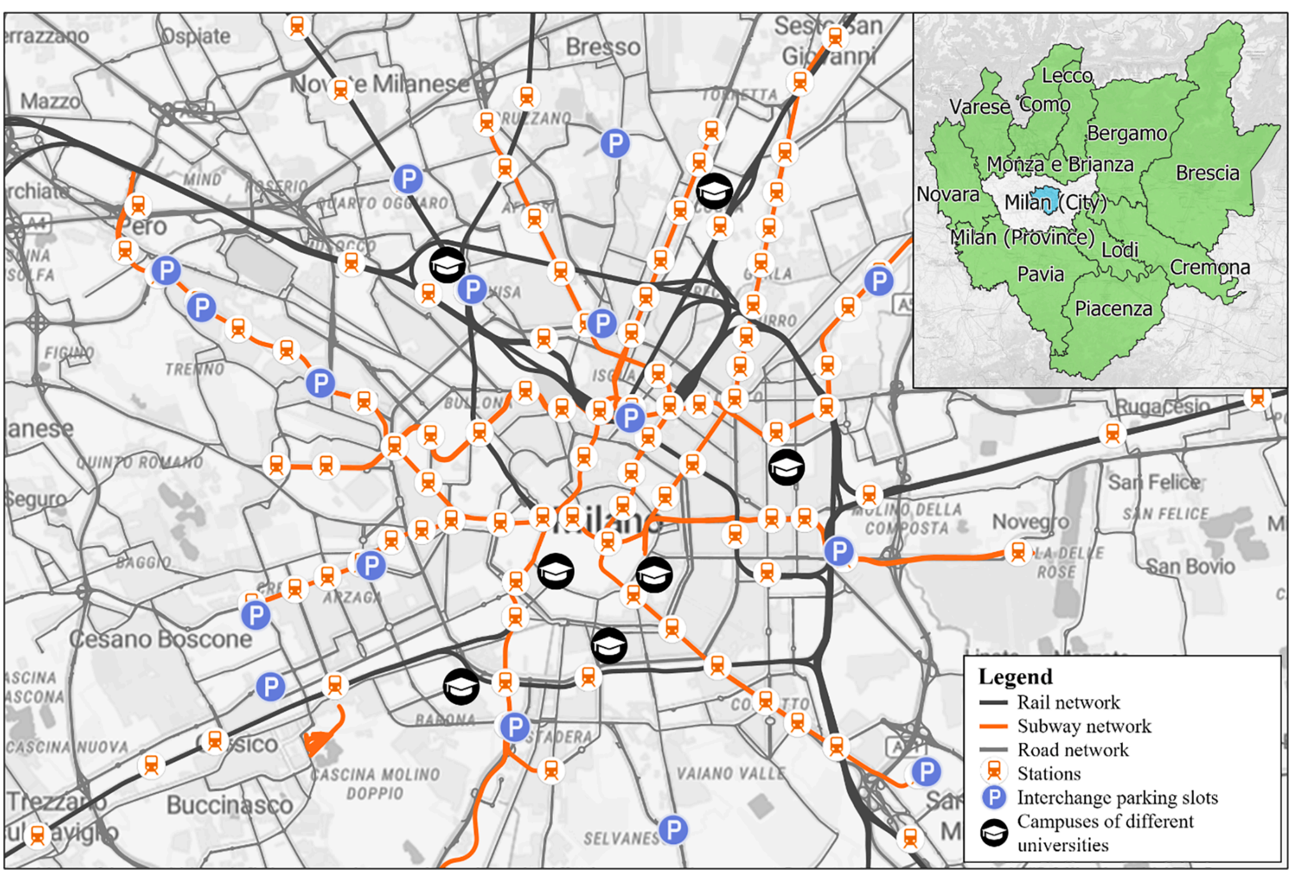

Fig. 1. Main road network, interchange parking facilities, Public Transport network, and the campuses of different universities spread across the city of Milan (Italy).

Como, Lecco, Monza e Brianza, Bergamo, Brescia, Cremona, Lodi, Piacenza, Pavia, Novara). Besides, the city has recently seen the spread of shared-mobility services (e.g., bike, e-scooter, moped, and car sharing) encouraging the reduction of private car use.

3.1. Survey design and data collection

The survey has been carried out among faculty members, technical-administrative staff, and students from a university in the city of Milan, Italy, submitted between May and June 2023. The entire population of the university was invited to participate in the survey through the official mailing lists of students, technical-administrative staff and faculty members; therefore, respondents were randomly sampled. The questionnaire consisted of two main sections described below.

The first section was aimed at collecting individuals' demographic and socioeconomic characteristics, and their travel habits. Respondents were first asked about their role in the university, and other personal details such as age, gender, education level, household condition, working condition, ownership, and availability of a private vehicle. Secondly, they were investigated on the origin and the destination (i.e., the university pole) of their journeys to get to university, the transport mode by which they carry out the journeys, how many times during a normal week they generally perform it, and whether they hold a PT pass or not. In addition to this, they were asked if they are satisfied with their current transport mode choices, eventually for which reasons they are not, and whether the planning of their journeys is supported by a smartphone application or not.

The second section of the survey consisted of questions and choice situations to gather respondents' *Stated Preferences* (SP), aimed at understanding potential users' expectations about a MaaS smartphone application for the university community and interest in MaaS bundles for home-university commuting. A MaaS app should provide an additional service to the commuting routine of users by integrating different transport services and offering a new travel experience through additional functionalities. For these reasons, respondents were questioned about the transport services that need to be included in the app and the functionalities that it should offer to provide an added value to transport routine. In particular, the questions about the functionalities refer to the various levels of integration that a MaaS digital platform can provide, according to the taxonomy proposed by (Sochor et al., 2018). Furthermore, even though the focus of this research is on MaaS adoption for home-university commuting, the potential of this platform might also be exploited outside the university context. Thus, respondents were asked about the probability they would use this MaaS app to undertake other trip purposes, such as shopping and leisure travels during their free time, and about the preferred payment scheme. Lastly, respondents were asked about their interest in the following specific MaaS bundles: PT and bike/e-scooter sharing, PT and car/moped sharing, PT and reserved parking at interchange facilities, as shown in Table 1.

Table 1
Questions of the survey regarding expectations towards MaaS.

Questions	Proposed answers
Q1 – How important do you think it is for a MaaS app to integrate the following transport services? *Likert scale from 1 ("Not at all important") to 5 ("Very important")*	Public Transport Bike sharing E-scooter sharing Moped sharing Car sharing Car pooling Taxi
Q2 – How important do you think it is for a MaaS app to include the following functionalities? *Likert scale from 1 ("Not at all important") to 5 ("Very important")*	Time- and cost-optimized route search Real-time update of traffic and Public Transport timetables Booking and actual availability of shared means of transport Registration of a single account for access to services offered by several operators Electronic payment in a single transaction of the services used Discounts for the use of more sustainable modes of transport
Q3 – If there is a MaaS app that offer all the above-described functionality, would you use it to… *Likert scale from 1 ("Very unlikely") to 5 ("Very likely")*	Travel to the university Undertake other travels (leisure, shopping)
Q4 – Which of the following MaaS solutions would you prefer? *Single-answer question*	Pay as you go – Payment per trip made, depending on duration/length and mobility services used Pass – Payment by subscription to a pre-defined bundle of services (e.g., Public Transport and bike-sharing, and/or other)
Q5 – Would you be interested in purchasing a MaaS bundle consisting of PT and bike/e-scooter sharing services? *Single-answer question*	Yes (Interested in the proposed MaaS bundle) No (Not interested in the proposed MaaS bundle)
Q6 – Would you be interested in purchasing a MaaS bundle consisting of PT and car/moped sharing services? *Single-answer question*	Yes (Interested in the proposed MaaS bundle) No (Not interested in the proposed MaaS bundle)
Q7 – Would you be interested in purchasing a MaaS bundle consisting of PT and reserved parking lots near subway or railway stations? *Single-answer question*	Yes (Interested in the proposed MaaS bundle) No (Not interested in the proposed MaaS bundle)

3.2. Behavioral choice models estimation

Starting from the respondents' SP on MaaS bundles adoption, binary choice models can be estimated to explore socio-economic and behavioral factors affecting individuals' interest towards the different bundled mobility services. These models express the probability of interest in a specific MaaS bundle (e.g. PT and bike/e-scooter sharing, PT and car/moped sharing, PT and reserved parking at interchange facilities) through the definition of the perceived utility, U_{in}, including observable explanatory variables, and a random residual, ε_{in}, assumed to be identically and independently distributed as a Gumbel random variable (Logit specification). The latent utility U_{in} for an individual *n* associated to the alternative *i*, has the following form (Ben-Akiva and Lerman, 1985; Hensher et al., 2015):

$$U_{in} = V_{in} + \varepsilon_{in} = \beta_n X_{in} + \varepsilon_{in}$$

where V_{in} is the systematic component of the utility, expressed as a linear combination of the vector of the explanatory variables X_{in} (e.g. the socioeconomic characteristics and the travel habits), and the vector of the unknown parameters β_n to be estimated, associated to each explanatory variable. In detail, it can be assumed that some parameters are not fixed over respondents, but they vary randomly around a fixed mean to represent the potential differences in tastes and preferences of respondents. As a result, the k-th parameter can be expressed as (Hensher et al., 2015):

$$\beta_{nk} = \mu_k + \sigma_k \tau_{nk}$$

where μ_k represents the mean of the distribution of marginal utilities held by the sampled population, σ_k represents a deviation of preferences among sampled respondents around the mean marginal utility, and τ_{nk} are the random draws taken from a Normal distribution for each respondent *n* and parameter *k*. The unknown parameters are estimated using the Maximum Likelihood Estimation (MLE) method in the case of models with only fixed parameters, while the models involving random parameters are estimated using the Maximum Simulated Likelihood

Estimation (MSLE) method (Train, 2009; Hensher et al., 2015) and the Modified Latin Hypercube Sampling (MLSH) approach (Hess et al., 2006). In particular, the package Biogeme of the Python programming language was used for the estimation process (Bierlaire, 2023).

The estimated models are binary, because the only two possible choice alternatives *i* are: alternative "1″ corresponding to the choice "interested in the proposed MaaS bundle", and alternative "0" corresponding to "not interested in the proposed MaaS bundle". The systematic utility associated to alternative "0" is normalized to zero:

$$\begin{cases} V_{1n} = \beta_n X_{1n} \\ V_{0n} = 0 \end{cases}$$

In detail, the variables X_{1n} of the systematic utility V_{1n} are dummy variables associated to the proposed MaaS bundles or to the individuals' socioeconomic characteristics and travel habits, such as age group, origin zone, PT pass ownership.

4. Results

4.1. Descriptive statistics

A total of 1949 completed questionnaires were collected. A filtering process, to remove respondents that belonged to low represented groups (i.e., those belonging to university poles outside the Municipality of Milan, for which only few records were captured), led to a final sample of 1873 individuals. Approximately 2 % of the student population (958 respondents out of 49,138 invited individuals) and 15 % of the employee population (915 respondents out 6287 invited individuals) were sampled.

The distributions of the sample by sociodemographic characteristics are reported in Table 2. The sample is split in 57.6 % male and 42.4 % female, being the 65.7 % less than 36 years old. Regarding employment status, 51.2 % are students, 46.8 % are full-time workers, and 2.0 % state to be part-time workers, unemployed, or retired. In terms of educational level, 64.0 % have a bachelor's degree or higher.

Respondents were also asked about their travel habits, and the outcomes of this analysis are reported in Table 3. It came out that 48.0 % of them usually start their trip to university from the Municipality of Milan, 17.3 % from the Metropolitan City of Milan (i.e. the former Province of Milan), and 34.7 % come from other Provinces of the Lombardy, Piedmont, or Emilia-Romagna regions. Regarding transport modes, most of the sample uses public transport (54.9 %), or a combination of public and private transport (18.4 %). Private transport is used by 11.3 % of the sample, while 7.9 % of respondents commute using private bicycle or scooter, and 6.0 % travel by foot. A small part of respondents (1.5 %) state that they move using shared mobility services, such as car, moped, bicycle, or scooter sharing. Only 27.8 % have a private vehicle always available, while the rest do not have it, or they share it with family members or others. Regarding the frequency of trips to university during a week period, 76.2 % declare that they usually undertake it four times per week or more. Finally, respondents were asked whether they hold a PT pass: 76.6 % do have one, while 23.4 % do not.

As regards the mobility services that have to be included in a MaaS app, PT is deemed as the most important service to be included in the MaaS supply, followed by bike sharing and car sharing services; on the opposite, taxi seems to be the least essential service (Fig. 2).

Regarding the functionalities to be included (Fig. 3) almost all the options got the top rate by the 50 % of respondents; real-time updates of traffic and PT timetables is perceived as the most important information that users could get from MaaS.

More than 60 % of respondents would use the MaaS app (Fig. 4) not only for commuting but also for other trip purposes. Finally, *pay-as-you-go* is preferred by users that do not own a PT pass (75 %), while weekly or monthly passes attracts more PT pass holders (59 %) (Fig. 5).

Lastly, regarding the bundles' choice situations, 5619 stated preferences were obtained in total, since each of the 1873 respondents participated to the 3 bundles' choice situations.

The bundle that combines PT and bike/e-scooter sharing is the one that attracted the highest number of respondents (39.2 % of the sample),

Table 2
Sociodemographic characteristic of the sample.

	Variable	Number of respondents	Sample (%)	Italy* (%)
Gender	Female	794	42.4 %	48.9 %
	Male	1079	57.6 %	51.1 %
Age group	Less than 26	838	44.8 %	22.9 %
	26 to 35	392	20.9 %	10.6 %
	36 to 45	177	9.5 %	13.2 %
	46 to 55	268	14.3 %	15.6 %
	56 to 65	162	8.7 %	15.0 %
	More than 65	36	1.9 %	22.8 %
Employment status	Student	958	51.2 %	11.8 %
	Full-time worker	877	46.8 %	58.1 %
	Other	38	2.0 %	30.1 %
Education level	Middle school diploma	5	0.2 %	29.7 %
	High school diploma	670	35.8 %	30.0 %
	Bachelor's degree	252	13.5 %	27.9 %
	Master's degree	551	29.4 %	10.2 %
	Doctor of Philosophy	395	21.1 %	2.2 %

*Source: ISTAT (Census of Italian population).

Table 3
Sample travel habits.

	Variable	Number of respondents	Sample (%)
Origin zone	Province of Bergamo	92	4.9 %
	Province of Brescia	37	2.0 %
	Province of Como	81	4.3 %
	Province of Cremona	27	1.4 %
	Province of Lecco	60	3.2 %
	Province of Lodi	22	1.2 %
	Province of Monza-Brianza	120	6.4 %
	Province of Novara	25	1.3 %
	Province of Pavia	47	2.5 %
	Province of Piacenza	11	0.6 %
	Province of Varese	129	6.9 %
	Metropolitan City of Milan	324	17.3 %
	Municipality of Milan	898	48.0 %
Transport mode	Public Transport (bus, tram, metro, suburban train)	1026	54.9 %
	Public and private transport	344	18.4 %
	Private transport (car or moped)	211	11.3 %
	Car or moped sharing	16	0.8 %
	Foot	113	6.0 %
	Private bicycle or scooter	148	7.9 %
	Bicycle or scooter sharing	15	0.7 %
Availability of a private vehicle	Yes	538	28.7 %
	Sometimes, because I share it with family members or others	231	12.3 %
	No	1104	58.9 %
Number of days per week in university	Once or less	66	3.5 %
	Twice	84	4.5 %
	Three times	345	18.4 %
	Four times	557	29.7 %
	Five times or more	821	43.8 %
Ownership of Public Transport pass	Yes	1434	76.6 %
	No	439	23.4 %

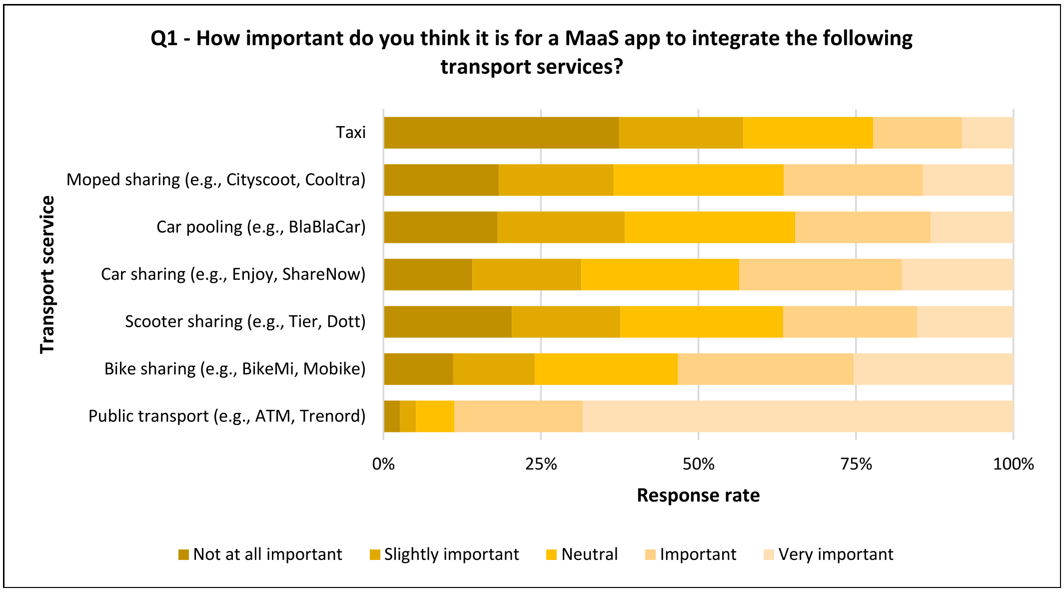

Fig. 2. Trasport services to be integrated in a MaaS app.

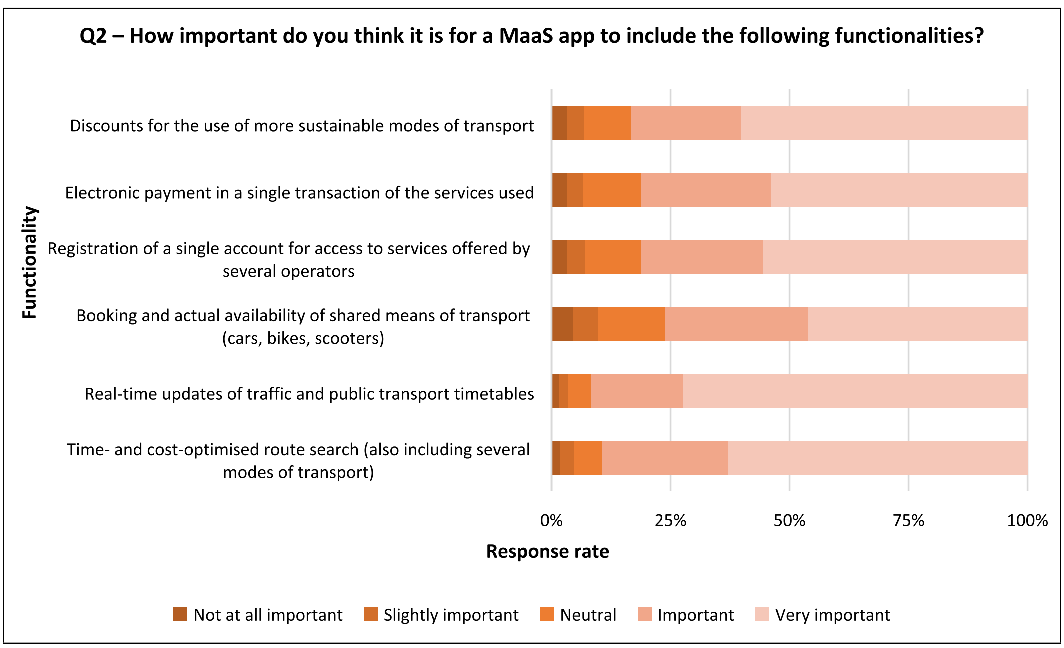

Fig. 3. Functionalities to be included in a MaaS app.

while the percentage of interested respondents for the bundles that couple PT with car/moped sharing and reserved parking was 23.9 % and 24.8 % respectively.

In Table 4, the percentages of interested, and not interested, to each bundle are reported by the characteristic of the sample. From these descriptive statistics it would appear that students have a stronger inclination for MaaS compared to workers, same as for younger with respect to older. It is significant to point out that individuals that start their trip to university from the Municipality of Milan are more likely, than those coming from Provinces, to benefit from MaaS bundles that integrate bike/e-scooter and car/moped sharing, while people from Provinces show more interested in the bundle with reserved parking at interchange facilities. Furthermore, PT users are more attracted to the bundle with bike/e-scooter sharing, while those currently using a private vehicle are more prone to the bundle with car/moped sharing, or reserved parking. The trend on transport mode is strongly correlated to that of the owning of a PT pass: respondents that frequently use PT services, and hold a pass, are more likely to adopt bike sharing, while those occasional users of PT services, through a pay per use ticketing system, expressed their preference toward the other two bundles.

4.2. Estimated models

The first model estimations considered the full sample and two distinct subsamples, one for students and one for employees. For these specifications, different variables were considered: from sociodemographic variables such as "Gender", to travel habits-related variables such as "Current mode satisfaction", "Origin zone", "Public Transport pass ownership", and "Vehicle availability". Additionally, a specific dummy variable for each MaaS bundle was introduced. However, the

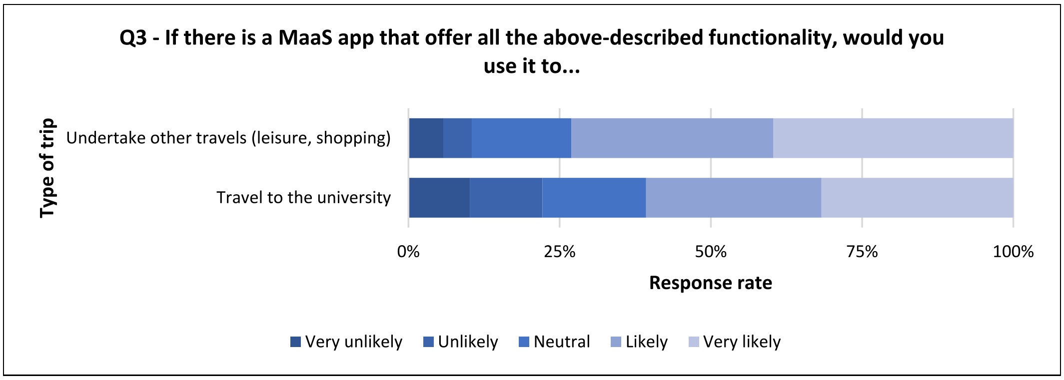

Fig. 4. Type of trip purposes for which a MaaS app would be used.

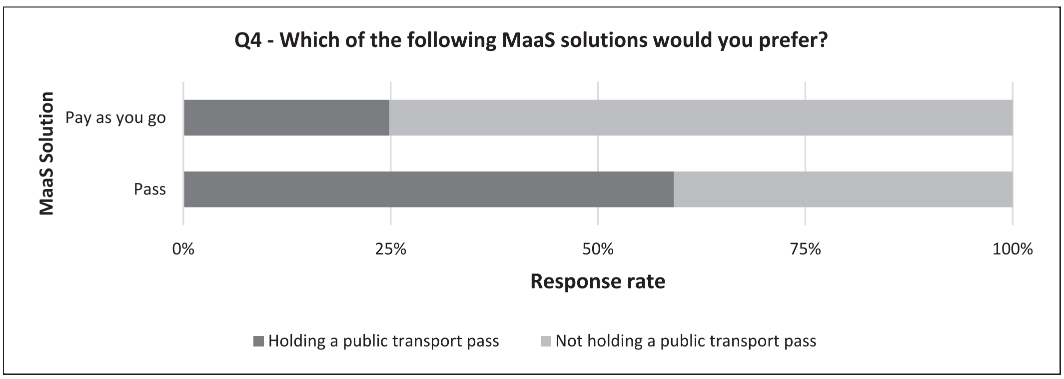

Fig. 5. Preferred MaaS solution for respondents holding PT pass or not.

Table 4
Interest rates in MaaS bundles, for different subgroups of the sample (lines in bold highlights the subsamples for which rates of interest is higher than the one of the full sample).

	PT and bike/e-scooter sharing (bundle 1)		PT and car/moped sharing (bundle 2)		PT and reserved parking at interchange facilities (bundle 3)	
	Interested	Not Interested	Interested	Not Interested	Interested	Not Interested
Full sample	**39.2 %**	**60.8 %**	**23.9 %**	**76.1 %**	**24.8 %**	**75.2 %**
Employment status						
Students	**41.4 %**	**58.6 %**	**25.8 %**	**74.2 %**	**28.0 %**	**72.0 %**
Workers	37.7 %	62.3 %	22.5 %	77.5 %	22.5 %	77.5 %
Age group						
Less than 26	**41.5 %**	**58.5 %**	**25.7 %**	**74.3 %**	**28.4 %**	**71.6 %**
26 to 35	**52.7 %**	**47.3 %**	**27.7 %**	**72.3 %**	22.9 %	77.1 %
36 to 45	**41.2 %**	**58.8 %**	20.9 %	79.1 %	20.9 %	79.1 %
46 to 55	28.1 %	71.9 %	19.9 %	80.1 %	22.8 %	77.2 %
56 to 65	16.7 %	83.3 %	17.3 %	82.7 %	21.0 %	79.0 %
More than 65	13.9 %	86.1 %	13.9 %	86.1 %	13.9 %	86.1 %
Origin zone						
Municipality of Milan	**45.2 %**	**54.8 %**	**29.4 %**	**70.6 %**	19.0 %	81.0 %
Metropolitan city of Milan	35.2 %	64.8 %	22.5 %	77.5 %	**30.9 %**	**69.1 %**
Other Provinces	33.1 %	66.9 %	16.9 %	83.1 %	**29.8 %**	**70.2 %**
Current transport mode						
Public Transport (bus, tram, metro, suburban train)	**44.2 %**	**55.8 %**	23.6 %	76.4 %	18.6 %	81.4 %
Public and private transport	31.7 %	68.3 %	19.5 %	80.5 %	**43.0 %**	**57.0 %**
Private transport (car or moped)	29.9 %	70.1 %	**32.2 %**	**67.8 %**	**35.1 %**	**64.9 %**
Car or moped sharing	20.0 %	80.0 %	20.0 %	80.0 %	20.0 %	80.0 %
Foot	33.6 %	66.4 %	**27.4 %**	**72.6 %**	23.0 %	77.0 %
Private bicycle or scooter	**40.8 %**	**59.2 %**	22.4 %	77.6 %	15.0 %	85.0 %
Bicycle or scooter sharing	**57.1 %**	**42.9 %**	14.3 %	85.7 %	7.1 %	92.9 %
PT pass ownership						
Yes	**41.8 %**	**58.2 %**	23.5 %	76.5 %	24.8 %	75.2 %
No	31.0 %	69.0 %	**25.1 %**	**74.9 %**	24.8 %	75.2 %

comparison between the estimated parameters for the full sample and students' and employees' subsamples highlighted minimal differences in values, also considering the ratio of the coefficients, and the statistical significance of the parameters.

Given that no relevant differences in parameter estimates for the two subsamples were obtained, more advanced behavioral models have been estimated considering the full sample. The estimation process started with a Binary Logit Model with fixed parameters (Model 1), adding to the previous specification the sociodemographic variables “Age” and “Student status”. Subsequently, in Model 2 a Binary Mixed Logit specification was implemented, introducing randomness in the parameters that turned out to be statistically significant in Model 1, in order to verify the existence of heterogeneity among individuals’ preferences. In addition, an individual error component was added, to capture any unexplainable variability between individuals with the available observed study variables. Finally, the panel effect was included in the specification of the model, to consider the non-independence of the choices made by the same individual among different bundles. Furthermore, starting from the latest specification of the Binary Mixed Logit (Model 2), with the exclusion of the variables for which non-significant parameters were obtained, in Model 3 other interactions were introduced to explain part of the heterogeneity in means and variances among individuals’ preferences. The estimates of the β_n parameters for the described models are reported in Table 5.

Model 1 estimates show that age is statistically significant for all the three proposed MaaS bundles: individuals over 35 years old are in general less interested with respect to those under 35. Gender also influences the choice, with females generally less interested than males in the adoption of the proposed solutions. Current mode satisfaction presents a sign consistent with expectations: satisfied transport users are commonly less oriented to adopt new mobility solutions.

Regarding the origin of the commute to university, whose related parameters are statistically significant for all the three bundles, the estimated values and signs of the parameters show that individuals residing in the Municipality of Milan are more interested in Bundle 1 (PT and bike/e-scooter sharing) and Bundle 2 (PT and car/moped sharing), while Bundle 3 (PT and reserved parking at interchange facilities) attracts more those people living outside the city. Moreover, PT pass holders are more interested in Bundle 1 than non-holders, while no statistically significant distinctions are observed in Bundle 2 and Bundle 3. A higher interest in solutions integrating PT and car/moped sharing or PT and reserved parking at interchange facilities is noticed among individuals that have a private vehicle available for their commutes. Finally, the dummy variables associated to each MaaS bundle, all statistically significant, inform of a general higher aversion to Bundle 2 and Bundle 3 with respect to Bundle 1.

As regards the first specification of the Binary Mixed Logit (Model 2), the variables that did not show statistical significance in Model 1 were excluded. Among these variables, the sociodemographic variable “Student status” is found, as well as variables related to travel habits, “Public Transport pass ownership” for Bundle 2 and Bundle 3, and “Vehicle availability” for Bundle 1. The indicators highlight a general improvement in the estimation: in fact, the Final Log-Likelihood shift from −3198 of Model 1 to −3013 of Model 2, the Rho-square indicator

Table 5
Estimated models for the full sample. ***, **, * Significance at 1%, 5%, 10% level.

	Model 1: Binary Logit Model			Model 2: Panel Binary Mixed Logit Model			Model 3: Panel Binary Mixed Logit Model with heterogeneity in means and variances of the random parameters		
	Full sample			**Full sample**			**Full sample**		
Number of observations	5619			5619			5619		
Null-Log Likelihood	−3895			−3895			−3895		
Final-Log Likelihood	−3198			−3013			−3000		
Rho-square	0.18			0.23			0.23		
Akaike Information Criterion	6429			6069			6040		
Number of MLHS draws (Normal distribution)	–			1000			1000		
Parameter	**Value**	**t-Test**		**Value**	**t-Test**		**Value**	**t-Test**	
Bundle 1 μ (PT and bike/e-scooter sharing)	−0.75	−3.87	***	−0.89	−3.77	***	−1.02	−4.17	***
Bundle 2 μ (PT and car/moped sharing)	−1.45	−6.94	***	−2.19	−10.42	***	−2.20	−10.49	***
Bundle 3 μ (PT and reserved car parking at interchange facilities)	−1.29	−6.22	***	−1.71	−8.21	***	−1.76	−8.44	***
Age μ (Over 35 yo = 1, Otherwise = 0)	−0.60	−7.04	***	−1.02	−5.30	***	−0.87	−4.60	***
Age σ (Over 35 yo = 1, Otherwise = 0)				−0.39	−0.47				
Gender μ (Female = 1, Male = 0)	−0.22	−3.48	***	−0.43	−2.75	***	−0.41	−2.71	***
Gender σ (Female = 1, Male = 0)				0.56	1.19				
Student status μ (Student = 1, Employee = 0)	0.11	1.47							
Current mode satisfaction μ (Satisfied = 1, Unsatisfied = 0)	−0.24	−3.72	***	−0.71	−3.85	***	−0.73	−3.86	***
Current mode satisfaction σ (Satisfied = 1, Unsatisfied = 0)				1.49	4.64	***	1.56	4.60	***
Individual error component σ				1.95	9.84	***	1.98	10.16	***
Interaction	**Value**	**t-Test**		**Value**	**t-Test**		**Value**	**t-Test**	
Origin zone (Municipality of Milan = 1, Otherwise = 0)									
Origin zone * Bundle 1 μ	0.56	5.38	***	1.17	5.27	***	1.26	5.54	***
Origin zone * Bundle 1 σ				0.26	0.33				
Origin zone * Bundle 2 μ	0.76	6.27	***	1.30	6.35	***	1.30	6.34	***
Origin zone * Bundle 2 σ				−0.05	−0.12				
Origin zone * Bundle 3 μ	−0.28	−2.33	**	−1.20	−2.83	***	−0.92	−2.34	**
Origin zone * Bundle 3 σ				−2.25	−3.72	***	−1.94	−3.16	***
PT pass ownership (Yes = 1, No = 0)									
PT pass ownership * Bundle 1 μ	0.34	2.63	***	0.37	1.78	*	0.55	2.51	**
PT pass ownership * Bundle 1 σ				−1.92	−3.93	***	−1.43	−2.51	**
PT pass ownership * Bundle 2 μ	−0.07	−0.51							
PT pass ownership * Bundle 3 μ	0.08	0.56							
Vehicle availability (Yes / Sometimes = 1, No = 0)									
Vehicle availability * Bundle 1 μ	−0.02	−0.20							
Vehicle availability * Bundle 2 μ	0.41	3.23	***	0.82	4.18	***	0.77	3.93	***
Vehicle availability * Bundle 2 σ				−0.02	−0.03				
Vehicle availability * Bundle 3 μ	0.99	8.05	***	1.20	3.58	***	0.90	2.44	**
Vehicle availability * Bundle 3 σ				−3.69	−4.61	***	−2.84	−3.65	***
Heterogeneity in means or variances [Variable]	**Value**	**t-Test**		**Value**	**t-Test**		**Value**	**t-Test**	
PT pass ownership * Bundle 1 μ [Age]							−1.52	−1.89	*
PT pass ownership * Bundle 1 σ [Age]							1.22	2.69	***
Vehicle availability * Bundle 3 σ [Public and Private transport user]							1.24	2.92	***

improves from 0.18 to 0.23, while the Akaike Information Criterion improves as well, from 6420 of Model 1 to 6069 of Model 2.

The estimated parameters show the existence of heterogeneity among individuals according to the satisfaction of the currently used transfer mode, being both mean and variance statistically significant. Differences in respondents' preferences are found also in holding a PT pass with respect to Bundle 1, and in living in the city of Milan, or in having a private vehicle available to commute with respect to Bundle 3.

On the other hand, random parameters associated to age and gender do not introduce significant distinctions among individuals, being the variance of the parameters associated to these variables not significant. Neither starting the commute in Milan for Bundle 1 and Bundle 2, nor private vehicle availability for Bundle 2, make any heterogeneity arise.

Finally, the introduced individual error component is statistically significant, which means that there is a relevant variability in respondents' stated choices that cannot be explained only through the variables at disposal.

The last estimated Binary Mixed Logit specification (Model 3) determine a slight improvement of indicators compared to Model 2: the Final Log-Likelihood improves from −3013 to −3000, the Akaike Information Criterion from 6069 to 6040, while the Rho-square stands at 0.23. In this specification, the variable for which no significant heterogeneity was found in Model 2 were associated with fixed parameters, so "Gender", "Origin zone" for Bundle 1 and Bundle 2, and "Vehicle availability" for Bundle 2. On the contrary, some interactions were added to the specification: an interaction in mean and variance between "Public Transport pass ownership" for Bundle 1 and Age, and an interaction in mean between "Vehicle availability" and "Public and Private Transport users" (i.e. representing individuals that integrate public transport with private transport for their home-university commuting).

The model seeks to partially identify the source of randomness in the non-fixed parameters. The variable age has been found to be statistically significant in explaining the heterogeneity in mean and variance of the PT pass holders with respect to the Bundle 1 (PT and bike/e-scooter sharing): over 35 years old individuals are in general less inclined to adopt such MaaS bundle than their younger counterpart. Analogously, users that currently combine private transport modes with PT services, and have a private vehicle always available, are on average more oriented than others toward the Bundle 3 (PT and reserved parking at interchange facilities).

5. Discussion

The results presented in the previous section regarding the aggregate statistics of the survey and the estimated models are here recalled and discussed. The analysis showed that a considerable level of interest towards MaaS is found among respondents, who seem prone to adopt MaaS solutions to commute.

Public Transport seems to be the focal point of the integration, as the study of (Tsouros et al., 2021) also points out, being the preferred transport mode to be included in a MaaS app by margin over other modes. The second and the third modes deemed important for integration are bike sharing and car sharing, while taxis do not seem essential for this purpose. The findings on the likelihood of transport services to be included in a MaaS app confirm the evidence presented by (Aba and Esztergár-Kiss, 2024), with PT and taxis being the most and least preferred services, respectively. Car and bike sharing are behind PT in terms of importance as well, with the difference that car sharing is preferred over bike sharing in the study of Aba and Esztergár-Kiss. Regarding the preferred payment scheme, the findings of this research highlight that there is not a clear dominance of the pay-as-you go scheme over the subscription scheme, in contrast to what (Vij et al., 2020) and (Ho et al., 2020) observed. However, in this study, it is evident that respondents holding a PT pass are more willing to subscribe to MaaS bundles, while respondents without a PT pass seem to retain their current travel habits, limiting the use of MaaS to sporadic occasions, as even the literature suggests.

When the different transport modes are organized in bundled schemes, the greatest attractiveness is reached by the bundle that mixes PT and bike/e-scooter sharing services. This evidence is in contrast with the results of the study conducted by (Matyas and Kamargianni, 2019), where car sharing was the most popular solution to be included in a MaaS bundle among individuals interested in purchasing it (83.5 % of preferences), with bike sharing standing behind it (46 % of preferences).

This research highlights that there is a real opportunity to market MaaS in university communities, but an accurate user-centered design of the supply is needed. For this purpose, the modelling evidence provides useful information. MaaS finds its wider catchment of potential users among individuals under 35 years old, under which students fall primarily, as one could expect given their major predisposition to use smartphone apps in their everyday activities. This result is derived from both the descriptive statistics of the survey and the estimated models, and it is consistent with the researches introduced in the literature overview section (Vij et al., 2020; Zijlstra et al., 2020; Kriswardhana and Esztergár-Kiss, 2024).

The choice over which mobility services should be integrated in the bundles together with PT must consider the external factors regarding where these bundles are offered. One of these factors is the origin of the home-university trip (e.g. the residing zone), for which the literature review, in (Liljamo et al., 2020) and (Zijlstra et al., 2020), highlighted a clear generic trend: individuals residing in density populated areas have a favorable aptitude towards MaaS. In this study, this fact is deeply analyzed among the different mobility bundles: users residing in the Municipality of Milan perceive Bundle 1 (PT and bike/e-scooter sharing) and Bundle 2 (PT and car/moped sharing) more attractive than Bundle 3 (PT and reserved parking at interchange facilities), which, on the other hand, is mostly preferred by individuals coming from the suburban areas. These highlight that such pattern is homogeneous among all individuals for the first two bundles, while heterogeneity is observed among individuals' interest towards Bundle 3. This evidence related to residing zone suggests that when bundles of integrated transport services are proposed in urban areas, shared mobility services should always be offered, while when they are proposed in suburban areas, supplying reserved parking might be preferable since it could be more welcomed by residents of these zones.

The relationship between being frequent PT users and more potentially prone to use MaaS, as noted by (Ho et al., 2020; Alonso-González et al., 2020; Smith et al., 2023), was actually found only with respect to individuals' interest in Bundle 1, which integrates PT with bike/e-scooter sharing services. Bundle 2 and Bundle 3, which involve the use of cars or mopeds, are instead preferred by individuals with private vehicle availability (mainly car users). Car or moped sharing can constitute a valid alternative to the usage of a private motorized vehicle, especially to reach zones that are not well connected through PT services, and relying on PT for the other trips. Reserved parking at interchange facilities can incentivize park and ride practices, particularly for individuals that live in suburban areas and already make integrated multi-modal travels. Therefore, individuals that already hold a PT pass might be more willing to adopt a MaaS bundle than those who do not, especially when dealing with light mobility sharing services. This aptitude may be due to the fact that this category of users already relies mainly on PT for their commuting, and not on private motorized vehicles, and might be interested to cover short first/last mile trips in areas that are not properly served by PT by means of shared bike or e-scooter. Anyway, the interest observed in private vehicle users for the bundle including car sharing should suggest that MaaS could be of interest also for car users, that could potentially shift towards mobility solutions that combine PT with other sustainable travel options.

The model estimation process also suggests that there is still room for further in-depth analysis, to improve the understandings of the elements that influence the interest towards MaaS, which have not been observed in the survey, and to effectively design the supply of MaaS according to people's mobility needs. Among the limitations of this research there is certainly the proposal to respondents of a limited range of possible MaaS bundles, without considering potential integration within the bundle of different services that do not include PT (for example, reserved parking at interchange facilities combined with bike sharing services) or the integration within the bundle of more than two types of services (for example, PT combined with car sharing and e-scooter sharing services). Other types of MaaS solutions for different target audiences could be explored in future investigations. Finally, it should be noted that the evidence and policy recommendations of this research, given the diversity of university contexts, should be carefully considered, but could be generalizable for other universities that are situated in a territorial, economic, and transport environment similar to that of the metropolitan area of Milan. Indeed, the analyzed university campuses are located in highly accessible areas within a city where a wide range of mobility services are available, and one of the most efficient PT systems in Italy is provided, although not yet fully integrated with ancillary mobility solutions. Therefore, the interviewed students and employees are accustomed to using collective and shared means of transport, and may be inherently supportive of experimenting with multimodal solutions that improve access/egress to/from campuses, especially if they enhance the first/last mile access to/from PT services and the mass rapid transit network.

6. Conclusions

Mobility as a Service has the potential to contribute to the mitigation of the car-dependence that afflicts cities nowadays, and the negative effects that derive from it (i.e. traffic congestion, environmental issues, as described in Section 1). The attractiveness of MaaS has been investigated both through the aggregate analysis of the survey data (Section 4.1) collected among employees and students of a university of the city of Milan, and the estimation of behavioral discrete choice models (Section 4.2).

As the results of this study suggest, there is real potential for MaaS in university communities, but its supply should be carefully designed considering the context of application. Therefore, any MaaS solution should include an accurate user-centered design phase, considering individuals' preferences and actual mobility needs. Indeed, young individuals seem to be, as expected, naturally prone to benefit from MaaS solutions, especially those already having a sustainable mobility behavior, i.e. who commute by PT and hold a pass. Moreover, users' acceptance of different mobility services may differ among individuals with different commuting routine, for instance regarding residing zone: residents in the metropolitan area of Milan were seen more interested in bundles including shared services, while residents outside the metropolitan area were more attracted by reserved parking. Finally, MaaS could be seen positively also by individuals that strongly rely on private vehicles nowadays, expanding its catchment through a supply of shared cars aimed at reducing private car usage and ownership.

For all these reasons, MaaS constitutes an opportunity to orient people towards sustainable mobility behavior, and universities, given their characteristic mindset that constantly look for innovations, are the ultimate context where to start this process. In order to fully exploit this potential, further research is needed to address the limitations of this study and provide a solid base for a user-centered design of the MaaS solutions.

CRediT authorship contribution statement

Pierluigi Coppola: Writing – review & editing, Supervision, Conceptualization. **Fulvio Silvestri:** Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation. **Luca Pastorelli:** Writing – original draft, Visualization, Formal analysis, Software.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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