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Mobility as a Service: Insights from pilot studies across different Italian settings

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ABSTRACT

Mobility as a Service (MaaS) has been tested in numerous cities and enables users to travel within an integrated system of collective and shared transport services, with a single travel package or bundle, giving them the ability to plan, book and pay for a trip using a unique technological platform. At this stage of the MaaS system experimentation, a detailed analysis on a small scale enables, through the understanding of the mechanisms governing travel choices, the planning of a MaaS service on a large scale that has the right flexibility to adapt to different territorial contexts. The paper reports the main findings of a study carried out as part of a national research project funded by the Italian Ministry of University and Research. Within this project, evaluation methodologies were developed (Technology Acceptance Model, Revealed Preferences and Intended Preference surveys), pilot surveys were conducted on samples of potential users, and the results were analysed and compared to assess the potential activation of a MaaS and to estimate its impacts on mobility.

Two pilot experiments and an extended test, with a sample of almost 200 users, were carried out in different territorial contexts in Italy: the metropolitan areas of Reggio Calabria and Messina, the extra-urban area of Gioia Tauro and the urban area of the metropolitan city of Cagliari. The activities should be regarded as preliminary and indispensable stage for the design of more extensive investigations, as well as for the planning of a possible MaaS system in the areas examined.

1. Introduction

The recent trends in the sharing economy and the pervasiveness of mobile systems, together with the latest developments in Intelligent Transport Systems, identify Mobility as a Service (MaaS) as the new frontier in transportation, particularly in urban areas, to promote and develop new sustainable mobility solutions. MaaS is designed to allow mobility services more accessible by eliminating the fragmentation and separation between existing/new transportation systems and between modes within the same transportation system. Hietanen [1] defines the concept of MaaS as " The vision is to see the whole transport sector as a co-operative, interconnected eco-system, providing services reflecting the needs of customers. The boundaries between different transport modes are blurred or disappear completely. The ecosystem consists of transport infrastructure, transportation services, transport information and payment services."

The keyword associated to MaaS is integration, to obtain by aggregating the various available transport services, both public and private, into a single service through a single interface. The goal is to achieve a unified model that can meet and satisfy different mobility needs via a platform with multiple functions (providing information on mobility services and payment systems, offering the ability to choose and pay for travel tickets, offering personalized and flexible sustainable alternative means of transport, etc.) accessible even from smartphones, in a personalized manner. Ensuring easy access to the most appropriate transport service, included within a range of predefined integrated, flexible, reliable, and user-oriented movement solutions, allows for improving the travel experience for those who have already chosen sustainable travel and for attracting car users who might decide to change their mode of travel when faced with real and competitive alternatives to private motorized transport. MaaS also represents an opportunity to create a new market open to new operators, although a true business model has yet to be defined.

Despite the clear benefits that pursuing the goals of MaaS can bring,

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in line with current strong environmental policies, there are no large-scale applications that allow for the quantification of its impacts. Various pilot tests have been implemented in Europe and around the world on an urban or regional scale. These tests have highlighted the difficulty of service management, closely related to the multitude of stakeholders involved, who often have different viewpoints on the business model and social goals to be achieved. In Italy, to provide clarity, TTS Italia drafted the "Guidelines for the Development of MaaS Services in Italy" in 2021 and provided the following definition of MaaS: "MaaS consists of a new concept of mobility, which provides for the integration of multiple public and private transport services into a single service, accessible via smartphone, thanks to a platform with multiple functions and a single payment system, capable of responding in a way customized to all specific mobility needs and able to offer a real alternative to a private car". The Italian government, as part of the "Digital Italy 2026″ strategy, leveraging investments (40 million euros plus an additional 16.9 million allocated by the Complementary Fund) dedicated by the National Recovery and Resilience Plan (PNRR), has defined the project "Mobility as a Service for Italy," which includes three lines of intervention: 1) Experimenting with MaaS in territories; 2) Creating an open platform (called "Data Sharing and Service Repository Facilities - DS&SRF"); 3) Enhancing the digital dimension of public transport for the spread of MaaS. Milan, Naples, and Rome are the first three pilot cities selected for experimentation, with their respective territories required to implement MaaS pilot projects within the current year. Subsequently, additional funding has been provided for the municipalities of Turin, Florence, and Bari. However, there are currently several relevant aspects that need to be addressed before MaaS can become mainstream at the national level.

The backbone of a MaaS system, public collective transport, in Italian cities, particularly in the South, presents numerous critical issues, especially in terms of integration, which in many cases make it still inadequate both from an infrastructural and a managerial standpoint. For example, it often happens that different collective transport services, even when providing service in the same city, are managed by different public and private entities, often competing with each other, thus complicating spatial, functional, ticket, and information integration. Another aspect concerns the complexity of inducing a change in travel behaviour, especially for those who habitually use private motorized vehicles. The culture of car ownership and use is still deeply rooted and woven into lifestyles and activity and travel patterns, strongly influencing the psycho-attitudinal aspects of individuals such as personality, values, attitudes, preferences, habits, etc., which are not given due attention despite these factors playing an important role in the process of changing travel choices. Therefore, MaaS can represent a stimulus to change travel behaviour, but it requires stronger citizen involvement and a more in-depth analysis of psycho-attitudinal aspects for MaaS to lead to a concretely sustainable mobility model (Stromberg et al., 2018; Feneri et al., 2020) [2].

In summary, it is clear that the approach being followed to achieve large-scale implementation is to conduct experiments in multiple pilot sites. Although this strategy is complex and seemingly fragmented, it allows for the collection of valuable information on how variations in transportation supply and management can influence user behaviour and their willingness to adopt new travel habits.

This paper focuses on describing an experiment for the simulation of a MaaS service in three different Italian contexts, two of which were carried out ex-ante as pilot tests (the Strait of Messina and Gioia Tauro areas), and one, in the metropolitan city of Cagliari (Italy), as an extended test based on the experiences gained from the two pilot tests. The focus of this paper will be specifically on the methods used in the extended test developed within the "MyPasS: Mobility for Passengers as a Service" project. The overall goal of the project is to accelerate the implementation and facilitate the scalability of MaaS systems through the development of a MaaS platform for service delivery and a set of open APIs that enhance interoperability with other third-party ITS services.

The experiment in the Strait of Messina and Gioia Tauro involved residents. The experiment in the metropolitan city of Cagliari, through a participatory approach that involved both stakeholders and residents from the initial stages of the project, highlighted the requirements for a MaaS service to be accepted and used. This was achieved through the implementation of qualitative (Focus group), quantitative (Technology Acceptance Model, Revealed Preferences and Intended Preferences surveys), and simulation techniques (application mobile implementation).

The paper is organized as follows: Section 2 provides a brief literature review, while Section 3 outlines the MyPasS project with the main experimentation detailed. Section 4 discusses the methodology employed in the study of Cagliari, followed by Section 5, which presents the main results. Finally, Section 6 concludes the paper by summarizing key points and limits of the research.

2. Literature review about MaaS development

Mobility as a Service (MaaS) has three characteristic elements: the centrality of transport users' needs upon which the design of the transport supply in terms of information, services and infrastructure must be based; the combination of information technologies and transport systems engineering models; the achievement of sustainability goals. The main peculiarity of MaaS therefore concerns the planning, design and implementation of integrated services, based on the concept of shared and connected mobility, obtained as a combination of services to be used as "unicum". Information and Communication Technologies (ICT), together with transport system models, enable new functions for the integration of information and transport services through new operators and digital platforms. A framework for MaaS is reported in Kamargianni et al. [3], Smith and Hensher [4] and Hasselwander and Bigotte [5], Cisterna et al. [6].

MaaS is based on the integration of several information and mobility services, which are presented to the user on a platform as a single travel option. Users can access services, obtain information and pay in a simple and flexible way, considering this option as a valid alternative to using private modes (e.g. car). This is possible not only by building a digital platform (an app or a website) but also by correctly designing the transport services (supply) tailored on users' needs (demand).

The policies of the European Union and the introduction of innovative payment systems have pushed the spread of Mobility as a Service (MaaS) in Europe, with over 40 cities involved at different territorial scales [7].

Helsinki is among the first urban areas where MaaS was organized and offered, based on the implementation of ICT solutions for urban mobility. In this context, the term MaaS has also been defined to identify this type of mobility [8]. Private and public institutions were involved in the experiment. Private companies proposed a first standard called Whim [9], which has also been implemented in other countries. A first key feature of MaaS emerged from this first experiment: it is a system that provides the users with a perception of a hybrid transport system between car ownership and sharing mobility.

After Helsinki there have been further experiences with MaaS implementations, with few of them having been experimented with significant material or immaterial elements. Among these, the experience in London should be mentioned. The first Intended Preference survey reported in the literature was carried out there, by completely defining the service ex ante, proposing MaaS as a new alternative, different from those available to the users [10]. This approach was further developed in Zurich by investigating the potential success of service packages compared to single services through the introduction the unified bidding and payment platform [11]. Another experience worth mentioning is that of Sydney where the bundle was developed, moving from a blocked bundle (Whim in Helsinki) to an open set with the possibility of profiling for the user [12,13]. Among other experiments, Citymapper[1] is an app that has aimed to facilitate urban mobility since 2011 by integrating information related to a wide range of public transport modes. The solution is currently available for 71 cities in Europe and 27 in the USA and Canada. Citymapper ranks at integration level 1. However, for the city of London, the Citymapper Pass has recently become available, which is a subscription that allows users to access numerous transport services. This offer integrates both ticketing functionality and payment. Additionally, the Pass can be integrated with smartphone wallets, allowing it to be used virtually. These advancements classify it at integration level 3 for the city of London.

The UbiGo[2] project was developed between 2013 and 2014 in Gothenburg and was subsequently launched in Stockholm in 2019, operating in an area of 375 km^2 and achieving integration level 3. Jelbi,[3] launched in Berlin in 2019, integrates public transport and shared mobility over an area of approximately 900 km^2, reaching integration level 2. In Denmark, MinRejseplan,[4] launched in 2018, is a national service that achieves integration between levels 2 and 3. Among the most recent developments, in Barcelona, Smart Mobility Lab (2023) is testing smart mobility solutions, including shared electric vehicles and planning apps, with urban integration at level 2. In the same year, the Mobility as a Service (MaaS) UK project in London aims to create a national platform that integrates all public and private transport services, achieving integration level 3. Kira, launched in 2023 in Toronto, Canada, is an integrated mobility app that combines public transport, bike-sharing, and ride-hailing services, reaching integration level 3 at the urban level. Finally, in the current year, MaaS 2.0 in Amsterdam aims to enhance integration between different mobility providers, with a strong focus on sustainability and accessibility, positioning itself at integration level 4 nationally. Project AIR in Berlin will test an app that combines public transport, bicycles, and electric scooters, with the goal of reducing environmental impact while maintaining integration level 3 at the urban level.

A further experience worth mentioning is the Italian one, where unlike previous experiences at a local level, a national coordination level is introduced [14]. Italy is the country that promotes an intermediate level of aggregation between the MaaS Operators and the operators of the transport services, according to the UITP indications [15]. The intermediate level of aggregation includes two layers: National Access Points and Regional Access Points. Local organization and sales platforms must refer to these two levels [16]. Among the initiatives at the national level, OpenMove[5] was developed in Trentino and operates in a regional area with 550,000 inhabitants, achieving level 3 integration. The Living Lab MaaS[6] Torino, launched in 2018, experiments with solutions across an urban area of 130 km^2, oscillating between levels 2 and 3. BIPforMaaS,[7] launched in 2019 in Piemonte, aims to develop a MaaS ecosystem over an area of 25,000 km^2, with a potential user base of over 4 million inhabitants and a goal of achieving level 3 integration. Nugo[8] is an app promoted by Ferrovie dello Stato that aims to facilitate integrated door-to-door collective mobility, simplify travel planning, and meet passenger needs throughout Italy. The scale factor can be defined as national, as the solution is currently deployed in 20 regions (not uniformly), aiming to cover as much of the Italian territory as possible with level 2 integration.

The current state of research allows us to identify the essential elements of MaaS based on the past literature on Transport System Models [17], presenting them in an organic and integrated form: basic supply and bundle components [18], demand components starting from induced demand [19,20], extension to the dynamic components of supply and demand [21], system design with sustainability goals [22, 23].

Given the centrality of user needs in implementing the MaaS paradigm, it is necessary to introduce consolidated tools to collect information and data about users' mobility choices. In fact, it is possible to refer to different sources of information and statistical tools for the direct and/or model-based estimation of travel choices. To this end, motivational surveys can be designed and carried out with the aim to collect disaggregated information about travel choices from a sample of individuals. The tools offered by emerging ICTs enable the collection and referencing of such information at a spatio-temporal level. The type of investigation and the size of the sample depend on the type of analysis, project and therefore model to be built. Generally, the surveys are aimed at reconstructing users' choices in the current transport configuration to obtain an estimate of the current transport demand (Revealed Preferences, or RP, surveys). It is also possible to conduct surveys to reconstruct users' choices in hypothetical scenarios associated with possible evolutions of the system (so-called "scenarios") to obtain forecasts of future demand (Intended Preferences, or IP, surveys).

The investigations are useful for the development of Transport System Models (TSMs) and therefore subsequently for the planning, design and implementation of sustainable mobility services. The correct design of motivational surveys therefore has a fundamental role for the construction of simulation models of transport systems and in supporting them in the planning, design and implementation of transport systems. TSMs are the core of a Decision Support System (DSS) that allow decision-makers to identify a sustainable mobility configuration. ICT and DSS are integrated into an Intelligent Transport System (ITS) that enables the implementation of the MaaS paradigm.

Despite the relevant role of direct surveys, they can be very expensive. For these reasons, it is necessary to design the surveys by integrating different consolidated methodologies, empowered by the functionalities of the emerging ICT tools.

Given the above background, in the current study we want to present the results of a study conducted in the metropolitan city of Cagliari (Italy) of a MaaS pilot test, where a sample of citizens used a MaaS application for two weeks and were then asked to respond some scenarios.

3. The MyPasS research project

The "Mobility for Passengers as a Service" (MyPasS) research project was funded by the Italian Ministry of Universities and Research as part of industrial research and experimental development projects in the 12 Areas identified by the PNR 2015–2020. MyPasS aimed to develop actions that promote the spread of the MaaS model in Italy and to experiment with technological and operational solutions with the ambition of contributing to the improvement of urban mobility and generating significant economic impacts in the ITS field and in transportation. The project had a total duration of 30 months (with two extensions due to the COVID pandemic, which prolonged it by an additional year) and involved various entities, both public and private, from the industry and academia: leading entity ALGOWATT S.p.A.; project partners: Akkodis, ARST S.p.A., Corvallis, Engineering Ingegneria Informatica S.p.A., Evolvea S.r.l., Fit Modis Innovation, Greenshare S.r.l., Municipia S.p.A., Università Mediterranea di Reggio Calabria, University of Cagliari.

MyPasS was aligned with the latest guidelines that aim to reduce regulatory fragmentation and promote an integrated urban mobility market and aims to achieve the following results:

- develop, test, and disseminate integration technologies between various systems (planning, fare, booking, payment) that enable new forms of mobility as a service;

[1] https://citymapper.com/cities
[2] https://www.fluidtime.com/en/ubigo/
[3] https://www.jelbi.de/
[4] https://www.rejseplanen.dk/
[5] https://www.openmove.com/
[6] http://www.comune.torino.it/ucstampa/2018/article_625.shtml
[7] http://www.bipformaas.it/
[8] https://www.nugo.com/nugoweb/

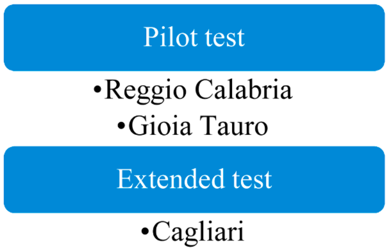

Fig. 1. Phases in different Italian experimental tests.

Table 1
Main characteristics of study areas of Strait of Messina and Gioia Tauro.

	Land use	*Transport services*
Strait of Messina	Discontinuous area Two metropolitan cities within 20 km Inhabitants 1000,000 Surface area 2000 km^2	Bike and car sharing Bus services (regional and national) Rail services (regional and national) Maritime services (High Speed and ro-ro ferry) Air services (national and international)
Gioia Tauro area	Continuous area 33 municipalities within 50 km Inhabitants 150,000 Surface area 1000 km^2	Bus services (urban, regional and national) Rail services (regional and national)

- develop, using Artificial Intelligence [Cirianni et al., 2023] and predictive analysis techniques, models for processing user behaviour to intercept mobility demand and provide high-value planning functions for Public Administrations;
- develop and validate innovative business models for MaaS systems;
- identify and promote the regulatory and legal context for the development and implementation of MaaS schemes at the national level;
- develop and implement strategies to facilitate behavioural change among citizens towards the concept of sustainable mobility.

MyPasS was based on the importance of evaluating the level of acceptance of a transportation service to understand how users perceive and adopt the service. There are various methods used to evaluate the acceptance of a service, which allow for the collection of valuable information about user experience and overall satisfaction. One of the project's objectives was to extract key relevant information from the collected data to estimate the performance of transportation systems, identify issues and opportunities, assess the impacts of transportation planning and policy decisions, and pre-evaluate effective solutions to enhance sustainable mobility before their implementation.

The methodology employed two approaches: the Technology Acceptance Model (TAM) and Revealed Preference/Intended Preference (RP/IP). The TAM approach [24] assesses behavioural intentions and provides an effective framework for understanding the acceptance choices of users regarding technology. The model suggests that users interacting with new technology are influenced by certain factors that determine how and when they use new tools. In its original formulation, the TAM approach is based on two classes of variables commonly defined [24]: perceived usefulness (PU) and perceived ease of use (PEU).

PU represents the user's belief that using the technology will yield benefits in terms of improved efficiency, productivity, or satisfaction. If a user perceives the technology as useful for achieving their goals, they are more likely to adopt it. PEU represents the user's perception of the ease and comfort of using the technology. If a user finds the technology easy to use, requiring little effort or technical skill, they are more likely to adopt it. The evaluation was then conducted by integrating TAM and RP/IP to measure the level of acceptance of transportation technologies and services.

3.1. Experimentation

The Project was developed through an experimental phase that included two pilot tests (Section 3.1.1) and an extended test (Section 3.1.2), (Fig. 1).

The experimentation just provides a survey consistent with the TAM approach, but the attitudinal data have not been analysed through a behavioural model.

3.1.1. Pilot test

The two pilot tests in the *Strait of Messina* and *Gioia Tauro* were carried out before the execution of the extended test in Cagliari. The analysis of data collected from the pilots allowed to obtain preliminary information and statistics about user choices, which were useful to the design of the extended survey.

Data from pilot samples have the advantage that can be collected with lower monetary costs and easily evaluated. The pilot samples of the Strait of Messina and the Gioia Tauro areas are respectively composed by 47 and 21 users. Table 1 shows the main characteristics of the two study areas.

Hypothetical MaaS scenarios are proposed to each traveller belonging to the samples: 4 scenarios for the Strait of Messina and 3 scenarios for Gioia Tauro. Each scenario presents 3 options (named A, B, C). The amount of available transport services and price in the bundle increases (not-linearly) from A to B to C.

The questionnaire is subdivided into three sections:

- First (or ex-ante): characteristics of the users and the current transport services;
- Second (or en-route): users' choice in the current transport configuration;
- Third (or ex-post): users' choice in a hypothetical MaaS configuration.

The questionnaire contains RP, IP and TAM questions.

Strait of Messina

The area of the Strait of Messina includes the two metropolitan cities of Messina, in Sicily, and Reggio Calabria, in Calabria, both in Italy. Some characteristics of the area are reported in Table 1. The overall mobility of people in the area is approximately 216,000 users in a day and about 60 % travel by car. All types of transportation services are available in the region and there is no fare integration that can reduce the fare for users.

Four scenarios are proposed to users: two are related to trips carried out on the mainland (without or with parking fees in the current configuration) and are related to trips made crossing the Strait of Messina (without or with a car on board the ship).

The 60 % of users in the sample travel for work and the 30 % for study purpose. The level of acceptance of MaaS increases as the generalized travel cost of existing alternatives increases. Further information can be found in [25].

Gioia Tauro area

The other basic pilot experiment was performed in the Gioia Tauro area, which is part of the Metropolitan City of Reggio Calabria (Italy). Some characteristics of the area are reported in Table 1. The public transport in the area is characterized by low-frequency service and there is not fare integration among public transport operators.

Three scenarios were proposed to users, one is related to short and medium distance trips, two are related to long distance trip (without or with parking cost in the current configuration).

Today the 60 % of the users belonging to the sample travel by car; among these, the 43 % of users travel for work and the 33 % for study

Table 2
Main characteristics of Cagliari study area.

Land and transport characteristics
Continuous area
Inhabitants 420,117
Surface area 1248.71 km^2
Density 336.63 inhabitants/km^2
Motorization rate 66.4 vehicles/100 inhabitants
Modal split private car 67 %, public transport 13.4 %, walking 16.5 %, motorcycle 2.8 %, other 0.6 %
Transport services
CTM urban bus services 306 km of network, 30 lines, 270 vehicles, 989 stops of which 207 with poles, BusFinder App (service included in the MyPass app)
ARST tram service 2 lines, 12.3 km, 12 stops (service included in the MyPass app)
Railway services 118 daily trains arriving at the railway station and airport (service included in the MyPass app)
Car sharing PLAYCAR 108 vehicles, 60 round trips, 58 free floating (service included in the app)
Bike sharing (service included in the MyPass app)
Sharing scooters (service not included in the MyPass app)
Taxi (service not included in the MyPass app)

Fig. 2. Project phases.

purpose. The level of acceptance of MaaS increases, also in this case, as the generalized travel cost of existing alternatives increases. More details are reported in [26].

3.1.2. The extended test: the case study of Cagliari

The extended test was carried out in the city of Cagliari. The objective of the experimentation was to test, following the experiences of the Strait of Messina and Gioia Tauro, the effectiveness of a mobile application specifically implemented to promote the development of a MaaS, i.e. a technology that allows the integration of planning, pricing, booking and payment systems of the various services to be integrated. It is important to point out that this is an experiment involving simulated functions, in the sense that the trip solution eventually chosen by the users does not include the real purchase of tickets via the mobile application (MyPasS app).

The metropolitan city of Cagliari is located on the southern coast of the island of Sardinia (Italy). The metropolitan city has a population of over 420,117 inhabitants spread across 17 municipalities and covers an area of 1248.71 km2 with a population density of 336.63 inhabitants/km2. In addition to the capital (Cagliari), it consists of sixteen municipalities.

The most populous municipality is Cagliari with 149,474 inhabitants, while the second one is Quartu Sant'Elena with 67,831 inhabitants, located just a few kilometres from the capital. From a geographical point of view, the city is located in the southern part of Sardinia, on the eponymous Gulf of Cagliari, which overlooks the Mediterranean Sea. Table 2 shows a summary of the spatial characteristics and transport services for the metropolitan city of Cagliari.

Please also note that there are currently 14 digital solutions in the Metropolitan City of Cagliari offering heterogeneous services for travel booking and/or payment, parking payment, or vehicle rental.

4. Methodology of the extended test in Cagliari

The extended test in Cagliari unfolded through five main phases (Fig. 2). Following the approach of Jittrapirom et al. (2020) and Polydoropoulou et al. (2020), our study employed a mixed quantitative-qualitative approach to gather data from MaaS stakeholders.

The initial two phases, named "Platform/System Requirements Analysis" and "Context Analysis" respectively, aimed to provide an overview of the current state of Mobility as a Service (MaaS) and the study area. The first phase involved a thorough literature review on MaaS to understand existing case studies and emerging issues, leading to the formulation of an action plan with specific technical and functional requirements for the experimentation. During the "Context Analysis" phase, an in-depth analysis of the study context was conducted, focusing on understanding transportation offerings, mobility demands, and sharing this knowledge with project partners. The analysis highlighted the limited modal integration due to a lack of coordination among different operators, not only in terms of fares but also service management.

From the third phase onwards, a highly participatory approach was adopted to engage stakeholders and citizens, gather feedback, discuss expectations, and ensure alignment among involved parties. A first workshop held in December 2021 with key stakeholders, both public and private (15 participants: public authorities (5 individuals), public transport operators (3 individuals), sharing mobility transport operators (3 individuals), academic partners (1 individual), consultancy firms (1 individual), IT companies (1 individual), and ticketing and payment service providers (1 individual), of the Metropolitan City of Cagliari, emphasized the importance of public governance for MaaS success at the metropolitan level (see Piras et al. [27] for more details). Balancing the interests of various stakeholders should stem from a detailed analysis of societal and private benefits depending on the adopted model. Consensus was reached on the role of MaaS in facilitating citizens' trip planning by providing comprehensive information on available transportation modes for both outbound and return journeys. Attention was also drawn to tourists, especially in urban tourist hubs, stressing the need for tailored services in terms of language and service type. Another highlighted aspect was the necessity of implementing an intuitive MaaS platform, easily understood and applied by all user categories. Following the workshop, participants were invited to fill out an online questionnaire on the WUFOO platform. Analysis of responses revealed that, particularly for public entities, local public transport should play a central role in MaaS, while other services such as taxi and parking were considered important but not crucial. Sharing services were also deemed important but not indispensable.

The approach involved the implementation of a mixed quantitative-qualitative method to collect data from stakeholders. Through a workshop held in December 2021, which involved public authorities, public

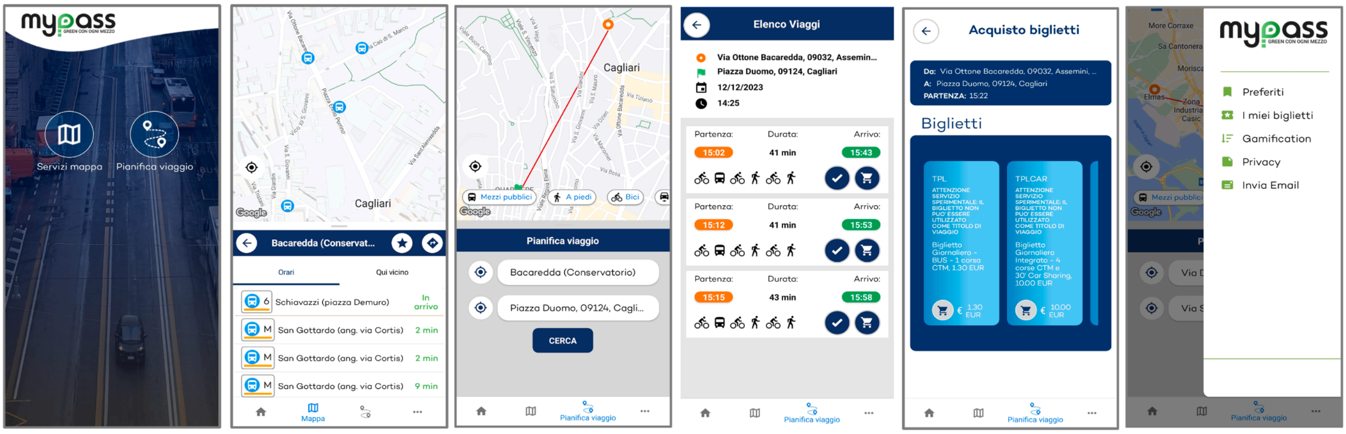

Fig. 3. Main features of the app developed by Algowatt (travel planner), Engineering (middleware), and Municipia (tariff part).

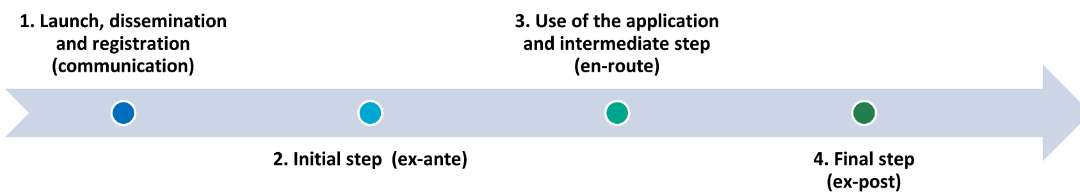

Fig. 4. Steps for the implementation MyPasS app.

transport operators, sharing mobility operators, academic partners, consulting firms, IT companies, and ticketing and payment service providers, an introduction to the MyPaaS project and its objectives was first provided, followed by the start of an initial discussion session. At the end of the discussion, a first questionnaire on the concept of MaaS was administered. A second discussion session was then initiated, where stakeholders discussed the potential benefits and barriers of MaaS for the Metropolitan City of Cagliari, with the aim of identifying possible solutions to remove the barriers. At the end of the second session, a second closed questionnaire on the topics just discussed was administered.

4.1. Software platform design

The MyPass application is a Level 2 MaaS application *developed by Algowatt, Engineering, and Municipia*. The main features of the application are twofold: 1) map services that allow users to view public transport stops and set one or more stops as favourites for origin and destination; 2) the Travel Planner, which enables users to plan their trips efficiently and pay for the trips. By entering origin and destination addresses, managed through an auto-complete system, the app provides various mobility solutions based on the transportation options the user has chosen to view as modal alternatives. For each proposed solution, departure and arrival times, as well as trip duration, are displayed. By clicking on a specific option, the user can view additional details such as the route on the map and any interchange points. Once the user selects their preferred single or multi-modal alternative, they can confirm and proceed with purchasing the travel ticket, choosing from several available options. The ticket cost and the remaining balance relative to the initial amount recharged by the user are displayed. After purchasing, all tickets are accessible from the main menu, with the option to view a QR code for simulated access to the purchased services. Additionally, the app offers other features such as managing a favourites list, including bus stops, and a gamification section that shows a leaderboard of the top service users, (Fig. 3).

As previously mentioned, the app simulates a MaaS service that is not currently offered in the study context. Specifically, while all the mobility alternatives proposed in the app are real, the travel tickets offered are not. In fact, once the selection is made, the user is informed that the chosen ticket does not constitute a valid travel pass. The choice of a simulated app was a necessary decision due to the limited resources available, both in terms of budget and time. A real ticketing solution would have required more resources, as well as a commitment from the regional authorities and service providers to quickly implement a MaaS solution. However, thanks to the real alternatives presented, users receive information about the different travel options available for each O/D pair, which may differ from their usual choices, and they are implicitly encouraged to reconsider their mobility preferences. A final questionnaire reveals that approximately 40 % of respondents, following their participation in the trial, changed their travel habits, with about 20 % reporting a reduction in their use of private cars.

4.2. MyPasS app implementation

The app implementation targeted a specific population segment with potential interest in using MaaS (Mobility as a Service). This segment included individuals who used to travel to the metropolitan city of Cagliari, were 18 years of age or older at the time of registration, owned an Android smartphone. The trial started on January 26, 2024 and ended on February 29, 2024.

The experimentation followed a multi-step process (Fig. 4). The data were collected anonymously and processed by the project partners only for scientific purposes, according to the current regulations regarding the protection of personal data. Participation incentives were offered and, in particular, the users that participated in all steps of the experimentation and used the app for at least 14 consecutive days in Cagliari, took part in the final draw of 100 Amazon vouchers worth €50.00/each.

After the launch and communication phase of the initiative, which included a press conference, a descriptive seminar on the experimentation and a social media presence, participants needed to register on the project website whose link was widely disseminated through various channels (https://www.progettomypass.it/sperimentazione/). After registration, participants received all necessary instructions via email to the email address they provided during registration.

Option A	Option B	Option C
Integrated public transport pass (Urban, extra urban, Train)	Integrated public transport pass (Urban, extra urban, Train)	Integrated public transport pass (Urban, extra urban, Train)
Car sharing 90 min	Car sharing 60 min	Car sharing 30 min
Bike sharing 50 min	Bike sharing 40 min	Bike sharing 20 min
Scooter sharing 50 min	Scooter sharing 40 min	Scooter sharing 20 min
Car parking 4 hours	Car parking 2 hours	Car parking 1 hour
Standard: € 80 per month Student/Over 60: € 50 per month	**Standard: € 60 per month Student/Over 60: € 35 per month**	**Standard: € 40 per month Student/Over 60: € 20 per month**

Fig. 5. MaaS options for Cagliari study area and costs.

4.2.1. *Ex-ante and en-route*

The first step for participants is to complete an initial "entry" questionnaire. After completing the questionnaire, it was possible to download and use the MyPasS mobile application and then receive an invitation to complete an ex-post questionnaire to obtain information about the experience of the trial carried out.

The ex-ante questionnaire, inspired by the ones implemented in the Strait of Messina and Gioia Tauro areas, was structured to collect information on participants' socio-economic characteristics, including details on private vehicle ownership and use of mobility services. It includes a section dedicated to describing the home-work or home-study trip, with specific questions about the modes of transport used and the duration of the trip. Furthermore, the questionnaire included questions about the patterns and characteristics of the activities carried out by the participants, as well as psycho-social variables that could influence their mobility choices. Finally, it included a section on information and consent to ensure that participants are fully informed and aware of the purposes of the research and the processing of their personal data.

In the test phase, the participants used the MyPasS application and could access the map services and plan their trips. In particular, they could:

1. use services Map allowing to display the available Public Transport stops in the metropolitan city of Cagliari, with the transit forecasts of the TPL service vehicles;
2. plan trips using a Trip Planner;
3. purchase the tickets offered based on the selected modal alternative.

4.2.2. *Ex-post*

After the test with the application MyPasS, the users were requested to fill an ex-post questionnaire. This final questionnaire was divided into different sections. The first section concerned the choice of monthly subscriptions between different options, with the possibility of expressing preferences and the importance attributed to various choice attributes. Next, users were asked to evaluate their overall experience with the trial program, followed by questions on how participation impacted their mobility style and use of the MyPasS mobile application. In the third section questions about the usage and impressions of the mobile application, as well as the evaluation of the services offered, were included. Finally, psycho-social variables related to sustainable mobility were explored, with questions covering a wide range of opinions and attitudes. Specifically, respondents were asked questions for TAM with a 5 points Likert scale (1=strongly disagree; 5=strongly agree).

The final section allowed participants to provide any additional suggestions or comments useful for improving the app.

A more detailed description of on how the first part of the questionnaire was constructed is needed.

Based on the experience from pilot tests conducted in the Strait of Messina and Gioia Tauro and the analysis of the current situation of the metropolitan city of Cagliari, both in terms of supply and demand, a hypothetical scenario was defined and then proposed to the user. This scenario contemplated the modal and tariff integration that characterizes a MaaS service.

The identified scenario consists of a single package containing an integrated service of mobility services that includes public transport by rail and road, car sharing, bike sharing, scooter sharing and finally paid parking zones (either in structures or on the road).

3 options were defined (A, B, C) in which the types of service remain fixed, but the "quantity" of services offered to the user and the price of the package (bundle) vary. The reference scenario is the B scenario. Concerning costs of scenario B, they were set equal to the real costs of the services available in metropolitan city of Cagliari (public transport, car sharing, bike sharing, scooter sharing, parking) after a discount of 20 %. Note that transit costs also included the local government incentives provided in 2023 and valid until June 2024 by the municipality of Cagliari. The transit costs for students and people over 65 were corresponded to 70 % of the standard costs without incentives. Costs for option A were obtained by increasing the cost of the bundle by 25 % compared to option B. The cost of the bundle for option C was obtained by reducing the cost of the bundle by 25 % compared to option B.

Regarding the quantity of services offered to the user, option B was considered as a basic reference. Option A was obtained by increasing the quantity of services by 50 % compared to options B; option C was obtained by reducing the quantity of services by 50 % compared to option B. In this way it was possible to capture the threshold of price that the user is willing to pay to use a possible MaaS service.

Fig. 5*Figure 5* describes in detail the three defined options, as proposed to the sample of users participating in the experiment.

In this context, respondents were asked to make a choice in pairs of one of the three options (A versus B, B versus C, C versus A) and then make a choice by comparing all three at the same time.

5. Results in the extended test in Cagliari

The results are reported in two sections in relation to the ex-ante and ex-post variables.

Table 3
Percentage preference frequency of each scenario divided by age groups.

Age	*A*	*B*	*C*	*None*
All	14 %	36 %	32 %	18 %
18–30	24 %	38 %	24 %	14 %
31–40	12 %	38 %	44 %	6 %
41–50	0 %	44 %	44 %	12 %
>50	16 %	29 %	26 %	29 %

Table 4
Percentage preference frequency of each scenario divided by professional status.

Professional status	*A*	*B*	*C*	*None*
All	14 %	36 %	32 %	18 %
Self employed	21 %	37 %	32 %	10 %
Employee	11 %	35 %	38 %	16 %
Undergraduate	38 %	38 %	0 %	24 %
Specializing/PhD	0 %	33 %	50 %	17 %
Retired	0 %	25 %	25 %	50 %
Other	25 %	50 %	0 %	25 %

5.1. *Ex-ante*

The ex-ante questionnaire was completed by 123 participants. Among them only 92 questionnaires were filled out completely and will be used for the ex-ante analysis.

The survey sample was relatively homogeneous regarding gender distribution (50 %). In terms of occupational status, nearly half of the respondents were employees.

Regarding the modal split, more than a third of the interviewees (37.04 %) reported using a car (as a driver) as a primary mode, while 28.4 % relied on the urban bus and the remaining part is distributed across other transportation modes. The aggregate modal distribution shows a preference of 43.84 % for the car mode and 38.36 % for the PT.

The analysis of the survey revealed that 65.43 % of respondents use only one vehicle for their transportation needs. From the analysis of the prevalent mode, almost 90 % of those who use PT use only one means of transport, it does not involve transfers. Regarding season tickets, Public Transport users demonstrated a high ownership rate (64.20), while those who prefer other modes of transport showed very low ownership percentages. The high proportion of subscribers may be due to the incentives available for purchasing subscriptions during the survey period. The survey also found a strong correlation between travel frequency and work commutes. Those who travel to their workplace tend to do so at least once a day, suggesting that work is the main factor driving travel

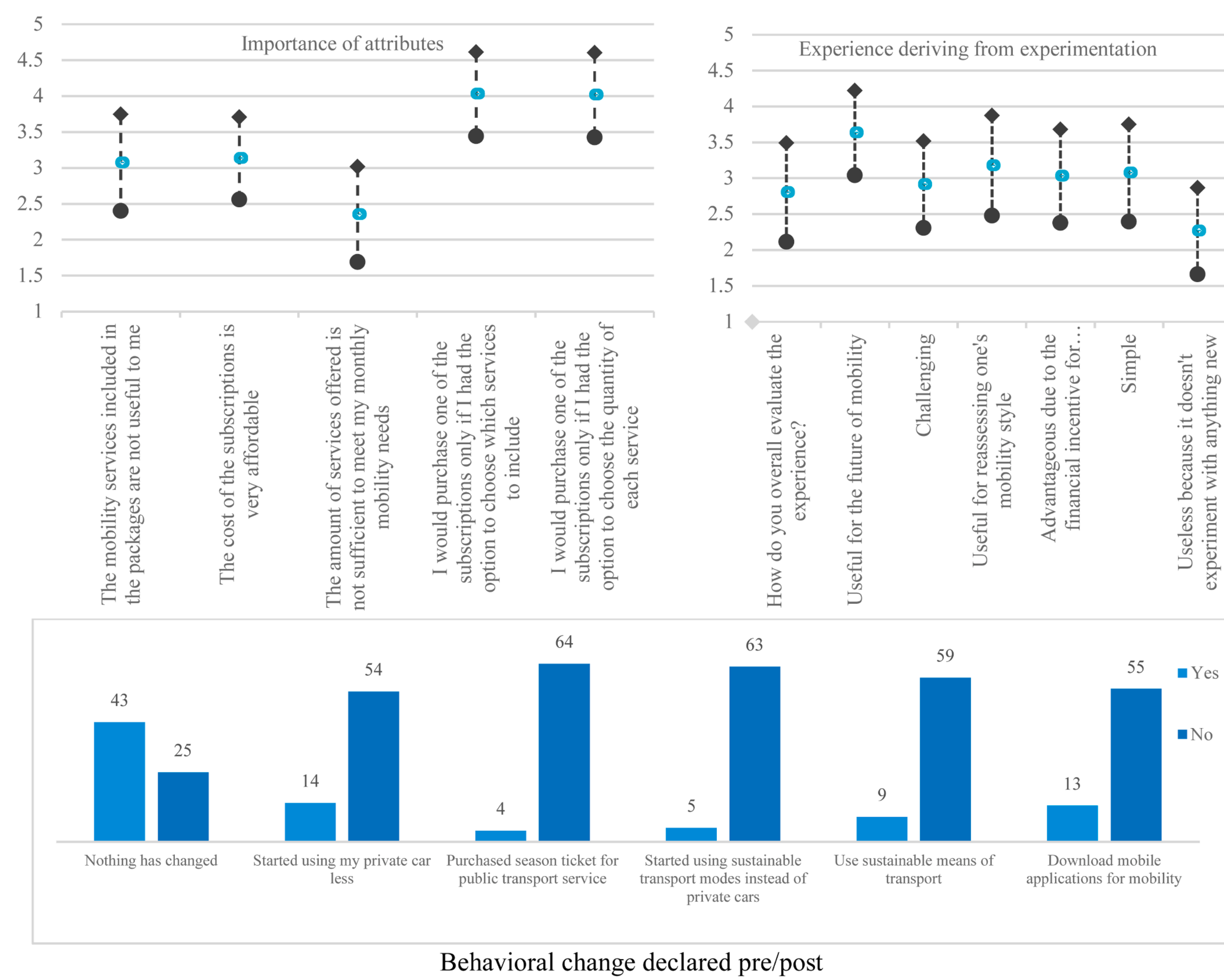

Fig. 6. MaaS options preferences with respect to scenario preferences
(Note: the first two graphs show the average value, and the values obtained by adding and subtracting the standard deviation)

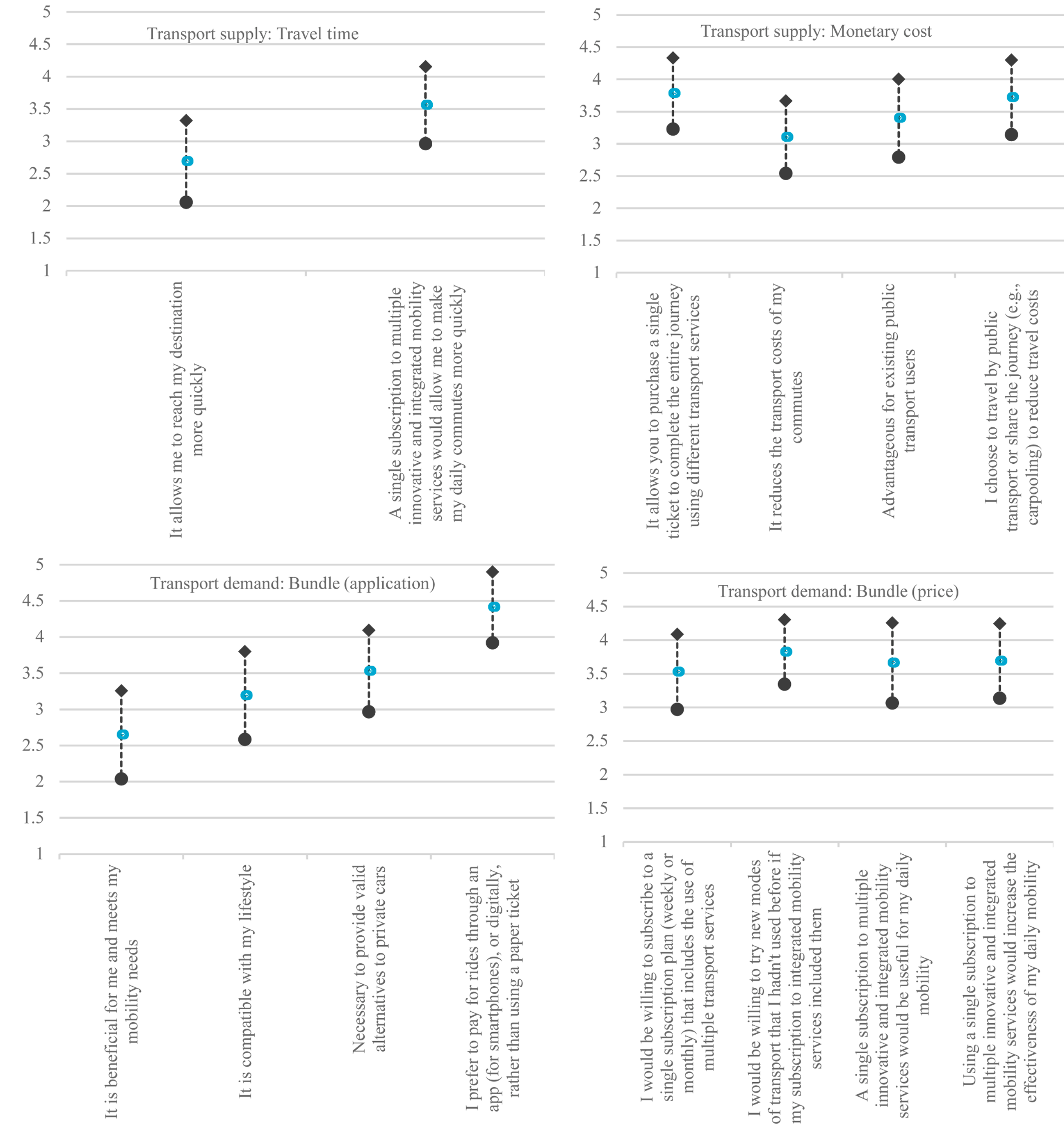

Fig. 7. MaaS options preferences with respect to transport services preferences
(Note: the graphs show the average value, and the values obtained by adding and subtracting the standard deviation)

frequency (55 % travel once a day, and about 20 % more than once a day). In-store shopping was also identified as a significant factor in vehicle usage (<20 % of the sample travels to stores less than once a week), while other activities resulted in less frequent travel.

5.2. *Ex-post*

Of the 92 users who completed the ex-ante questionnaire, 68 participated in the follow-up survey. Compared to the 68 users who provided answers in the ex-post questionnaire:

- 60 users (compared to 68 users) provided responses with respect to the proposed subscription scenario packages;
- for 53 users (compared to 68 users) it was possible to combine the answers provided in the ex-ante and ex-post questionnaire;
- for 42 users (compared to 53 users) it was possible to correctly calculate the attributes referring to the origin and destination of the trip.

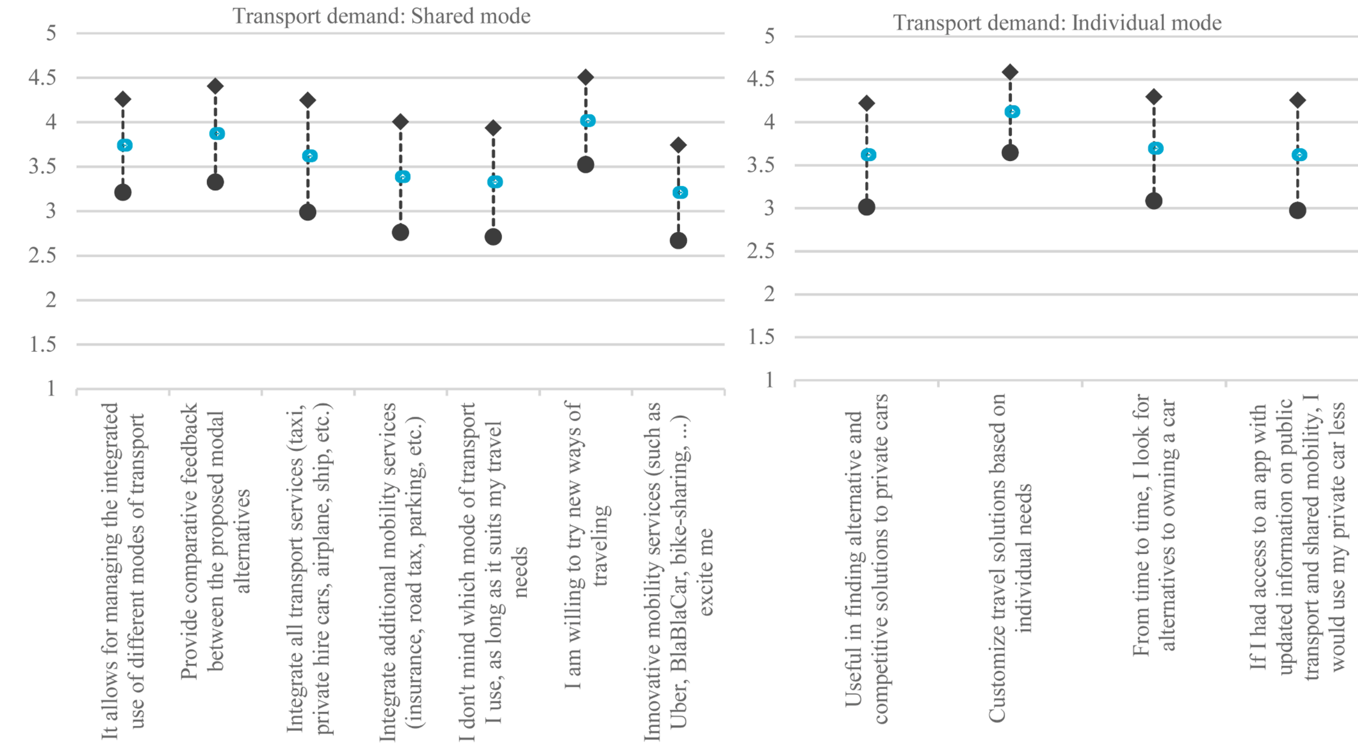

Fig. 7. (*continued*).

Therefore, ex-post statistical analyses were calculated using the sample of 68 users; the statistical analyses relating to the subscription scenarios were calculated based on the sample of 60 users; the statistical analyses requiring cross-referencing of ex-ante and ex-post data were calculated using the sample of 53 users; the statistical analyses which also require data on origin and destination locations were calculated considering the sample of 44 users.

The ex-post preference analyses were divided according to the proposed subscription scenarios, the acceptance of transport services, and the acceptance of technologies.

Scenario preferences

The analysis of preferences regarding the scenarios was divided into two parts: the first part presents the statistics regarding the choices of the scenarios; the second contains statistics relating to the preference variables of the scenarios. The question about choosing between three subscription scenarios (A, B and C) was structured so that users could directly compare the characteristics of each scenario and express their preferences. By presenting the options in pairs (AB, BC and AC), respondents were able to evaluate the trade-offs between the different solutions and weigh their advantages and disadvantages. The results show a clear trend towards scenarios B and C, with a slight preference for the latter. 19 % of participants chose not to select any choice in the four proposed scenarios.

This data suggests that some users may not have found the presented options appealing, might prefer alternative transportation modes or payment methods not included in the scenarios, or simply lacked interest in participating further. Considering the sub-sample of 53 users, the percentage of preference for each scenario was calculated by age group (Table 3) and professional status (Table 4). The preference for at least one scenario is higher among those belonging to the age groups under 50 and for workers and students. Furthermore, scenarios B and C are more preferred than scenario A. For the preferences declared by users, two indicators were used for each question asked: the average value and standard deviation of the preference value indicated by the users.

Fig. 6 shows the results grouped into three different components. For each component, the results obtained in each question asked are reported. In terms of the importance of the attributes, the proposed mobility services and the cost of the packages are, on average, well received by users. On average, the degree of satisfaction with the services offered is low. Regarding the experiences from the experimentation, the indicators show a variety of perceptions on the part of the users. The most preferred indicators include the usefulness of the service and its simplicity. Regarding the behavior change reported before and after the experimentation, it appears that around 40% of users indicated a change in their behavior. In particular, the most significant results concern a reduction in car usage.

Transport services preferences

The analysis of user preferences with respect to the acceptance of the transport service focused on two aspects: service offerings and user demand for mobility. Fig. 7 details the results for each component based on the individual questions asked. Regarding the provision of transport services, the results show that the system has not achieved much success in terms of users' perception of time savings. Instead, the users feel the convenience in terms of the cost of the subscription. With regards to the user behaviour (demand), there is clearly a differentiated perception in relation to the usefulness of an application. Users' feedback on the Bundle shows a high degree of homogeneity, with above average ratings. This indicates that the use of a single subscription is widely considered advantageous by users who participated in the survey, both for the convenience of using a single app and for the economic benefit compared to purchasing non-integrated tickets. The preferences regarding changing the service towards shared and individual transport modes highlight the desire to try new travel modes, even if not uniform with respect to the different questions asked to users.

App use preferences

The preference analysis with respect to the use of the application was divided into the following components: compatibility; complexity; perceived utility; perceived ease of use; attitude towards use; behavioural intention to use. For each component, Fig. 8 shows the results for each question asked. The compatibility of the application in managing various modes of transport received an excellent response from users.

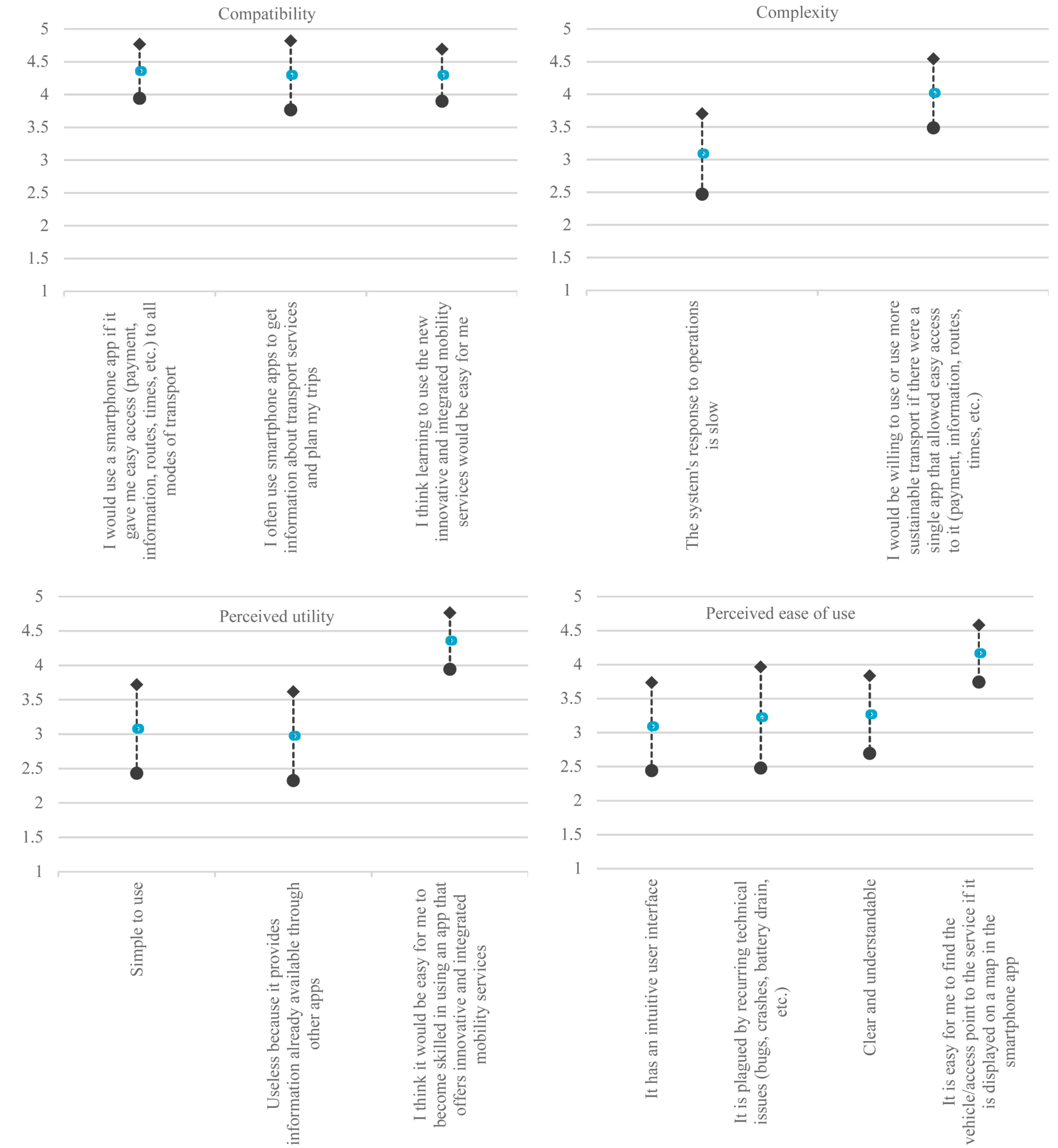

Fig. 8. MaaS options preferences with respect to application use
Note: the graphs show the average value, and the values obtained by adding and subtracting the standard deviation)

The application complexity attributes were rated particularly high because a single application can manage multiple modes of transportation. This suggests that users fin the application adequate and effective for managing a variety of transportation modes. The users perceived usefulness results highlighted a medium to low level of satisfaction regarding the use and services offered by the application. Perceived ease of use was rated as average overall. This suggests that, although there is an interest and propensity towards using innovative services, there are significant differences in users' perceptions and experiences of overall satisfaction with the application and its services. The results on attitude towards use revealed that the sample has little confidence in the implementation of the transport service. The behavioural intention to use the application highlighted that the sample viewed the application and the transport system as useful if widely

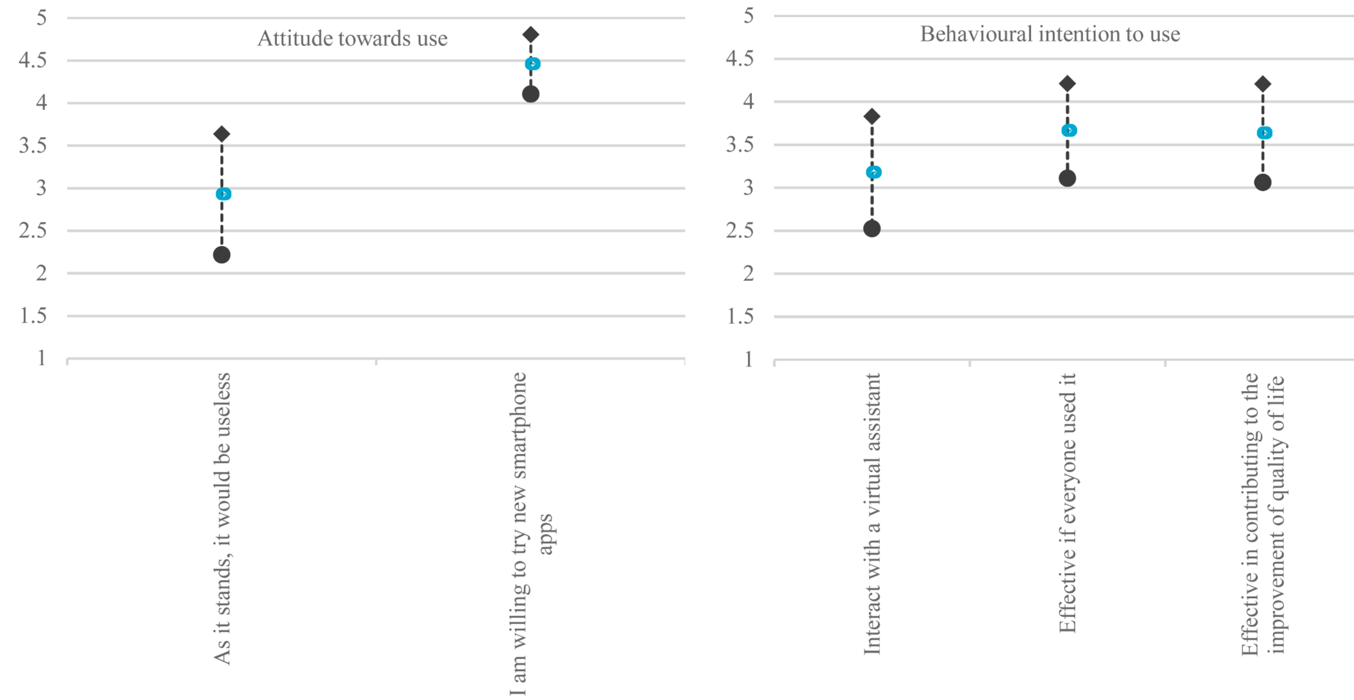

Fig. 8. (*continued*).

adopted and used by the community.

6. Conclusions

This study aims to explore, through the analysis of the mechanisms influencing mobility choices in three distinct territorial contexts, the potential of a Mobility as a Service (MaaS) and its acceptability among potential users and stakeholders. To achieve this objective, diverse and validated analytical methodologies have been adopted, ranging from qualitative to quantitative approaches, as well as more innovative solutions that integrate mobile technologies.

On one hand, focus groups facilitated a participatory approach, essential for exploring a complex project like MaaS, which involves numerous public and private actors with clearly distinct priorities. On the other hand, quantitative surveys on expressed preferences provided a snapshot of current travel habits. The analysis of choice intentions for different bundles, in the context of the Technology Acceptance Model, allowed for the measurement of the intention to use MaaS and the conditions influencing its adoption.

Finally, monitoring decision-making behaviour in a hypothetical MaaS context, simulated through a mobile app, enabled users to experience a service proposal, allowing for a comparison with the intentions expressed through traditional data collection techniques. This approach provided an opportunity to validate and refine declared choices.

Through two initial pilot tests, the methodological approach was outlined and later refined in an extended test conducted in the city of Cagliari. Small-scale experiments are currently necessary given the state of MaaS development at national and international levels, as they provide the level of detail needed for large-scale implementation. The sample surveyed consists of approximately 200 users across the three territories.

The results obtained indicate that the preference for MaaS grows with the increase in travel time and is strongly influenced by the price of the package. The packages proposed in the trial are more attractive for users who make trips characterized by longer travel times. Attractiveness decreases with the cost of the package. The additional cost for parking in the current scenario influences the preference for bundle cost. The analyses conducted have shown the need to pay particular attention to the entire chain of information and mobility services offered to users. A good commercial offer may not be enough to change users' mobility habits.

The results of the analysis of the data obtained from the preference surveys conducted at the Cagliari site highlight some factors to take into consideration when designing a MaaS. Regarding the transport supply, it appears that users are more interested in getting around with a single subscription rather than the time savings obtainable with the use of the app. Users did not perceive the application as an effective tool to reduce travel times or simplify their travel but above all as a tool to travel with a single subscription. Regarding transport demand, the positive influence on user behaviour emerges connected to the use of a digital application that offers information services, digital payments and mobility services. The users interviewed show a certain propensity to use MaaS services as an alternative to the use of private vehicles and appreciate the centralization of transport functions in a single platform, which simplifies travel experiences.

The investigations conducted show the need to integrate the different functions offered by ICT tools with the methods and models of transport systems engineering. In fact, the experiences conducted in the field have shown that the creation of an app, that provides information and sales services to users, is not the solution. It is necessary to take into consideration the complexity of the transport system, especially connected to the travel choices of users influenced by the current and future structure of the transport system in terms of infrastructure and mobility services. For example, the presence of incentives in the case of the Cagliari site, contributed to increasing the involvement of the users involved.

From these considerations emerges the need to integrate skills deriving from different disciplines and scientific sectors. User tracking is essential to determine travel mobility needs in compliance with current privacy regulations.

In conclusion, the policies necessary for the effective and efficient implementation of a Mobility as a Service (MaaS) system must focus on various crucial aspects. First and foremost, it is imperative that the service integrated into the platform adequately meets user needs, ensuring flexibility and integration at competitive prices. It is therefore necessary to develop dynamic pricing models which define attractive packages not only for users of sustainable and integrated transport, but also for car users.

Supporting the ticketing system, it is essential to implement enabling technologies that are intuitively usable and that simultaneously provide real-time information, digital payment solutions, and integration of personalized mobility services. A crucial aspect is the promotion of participation in the experimentation phases, as well as participatory planning that involves all stakeholders. Although the importance of interdisciplinary planning may seem self-evident, in the context of MaaS it is appropriate to emphasize it again, as it constitutes one of the fundamental elements for the success of the system.

The study presents some intrinsic limitations of a pilot test approach: the sample is not numerically consistent and cannot be considered representative of the population, as self-selection processes are inevitable. However, the goal of the research is not to generalize the results or apply them to other contexts, which may, in any case, be characterized by a different service offering, thus making the findings from one context inapplicable elsewhere. Rather, the intent is to provide evidence supporting a specific approach. Additionally, the experiences gathered can serve as a basis for developing broader and more targeted engagement strategies, aimed at attracting a more diverse audience in future implementations of the service.

An additional limitation may lie in the use of surveys to measure intention, which could be influenced by a cognitive dissonance effect, leading user behaviour in different directions. This risk is inherent in the evaluation of hypothetical scenarios during the study. In the future, it will be possible to experiment mixed TAM and TSM approaches, with the aim to use attitudinal data for building a behavioural model. Finally, it is important to emphasize that a simulated mobile app, which implements a theoretical service, may yield different results compared to those observed in the presence of the actual service.

CRediT authorship contribution statement

Italo Meloni: Writing – review & editing, Resources, Project administration, Investigation, Funding acquisition. **Giuseppe Musolino:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Francesco Piras:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Corrado Rindone:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Francesco Russo:** Writing – original draft, Methodology, Formal analysis. **Eleonora Sottile:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Antonino Vitetta:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

There are no conflicts of interest.

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Data availability

The data that has been used is confidential.

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