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MaaS paradigm: insights of innovative MaaS4Mi project and application at Linate Airport

TESI DI LAUREA MAGISTRALE IN
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Abstract

In 2014 the first event dedicated to MaaS was organized in Finland [1] to present the new business model to the world for the first time. What could have seemed only an idea based on a new technology has become a trend that has changed the way of experiencing mobility.

New technologies have allowed the development and integration of transport services up to a single platform where users can plan, buy and monitor their journey using multiple modes of transport. In addition to the availability of technologies, one of the key factors that is pushing towards the MaaS is the greater attention to the environment. The environmental problem has been known for years and the COP 27 held in November 2022 reaffirmed the need for immediate action to keep global warming below 2° C [2]. The transport sector, responsible for almost a quarter of greenhouse gases in Europe [3], needs to reduce its environmental impact. In addition to promoting alternative fuels to those of fossil origin, the MaaS encourage the use of shared transport modes and public transport.

This revolution is about to happen also in Italy with the MaaS4Italy project. Among the cities chosen as a test site there is Milan, a metropolitan city, open to change and with a wide range of public transport and sharing mobility. The project includes an experimentation phase in which multiple MaaS platforms will be available to users, in which it will be possible to find the various transport operators and services present in the area according to user's needs.

The project will also concern accessibility to Linate airport, which will be not only an access terminal for air services, but it will be included in the context of the "Linate system", a wider territorial area, characterized by new production sites, oriented to leisure, entertainment, shopping. Accessibility to the airport can be managed with a user-centric paradigm, typical of MaaS, integrating all the systems associated with mobility services, as well as useful services for the airport user.

Keywords: MaaS, integration, sustainability, accessibility

Abstract in italiano

Nel 2014 è stato organizzato il primo evento dedicato al MaaS in Finlandia [1] per presentare per la prima volta al mondo il nuovo modello di business. Quella che poteva sembrare solo un'idea basata su una nuova tecnologia è diventata un trend che ha cambiato il modo di vivere la mobilità.

Le nuove tecnologie hanno permesso lo sviluppo e l'integrazione dei servizi di trasporto fino ad arrivare a un'unica piattaforma, dove gli utenti possono pianificare, comprare e monitorare il proprio viaggio utilizzando più mezzi di trasporto. Oltre alla disponibilità di tecnologie, uno dei fattori che sta spingendo verso il MaaS è la maggiore attenzione all'ambiente. Il problema ambientale è noto da anni e il COP 27 tenutosi a novembre 2022 ha ribadito la necessità di azioni immediate per mantenere il riscaldamento globale al di sotto dei 2° C [2]. Il settore dei trasporti, responsabile di quasi un quarto dei gas serra in Europa [3], deve diminuire il suo impatto ambientale. Oltre a promuovere carburanti alternativi a quelli di origine fossile, con il MaaS si incentiva l'uso delle modalità di trasporto condivise e il trasporto pubblico.

Tale cambiamento sta per avvenire anche in Italia con il progetto MaaS4Italy. Tra le città scelte come luogo di prova c'è Milano, città metropolitana, aperta ai cambiamenti e con un'ampia offerta di trasporto pubblico e di sharing mobility.
Il progetto prevede una fase di sperimentazione in cui saranno disponibili agli utenti più piattaforme MaaS, in cui sarà possibile trovare i vari operatori di trasporto e altri servizi della zona in base alle esigenze dell'utente.

Il progetto riguarderà anche l'accessibilità all'aeroporto di Linate, che non sarà solamente un terminal di accesso ai servizi aerei, ma sarà inserito nel contesto del "sistema Linate", un ambito territoriale più ampio, caratterizzato da nuovi insediamenti produttivi, nuovi poli orientati al tempo libero, al divertimento e allo shopping. L'accessibilità all'aeroporto potrà essere gestita con un approccio incentrato sulle esigenze dell'utente, caratteristico del MaaS, integrando tutti i sistemi associati a servizi di mobilità, oltre a servizi utili per l'utente dell'aeroporto.

Parole chiave: MaaS, integrazione, sostenibilità, accessibilità

Contents

Introduction

The objective of the thesis is to present the MaaS model that is spreading faster and faster in Europe and to investigate the paradigm applied to a nearby and known territorial reality, that of the city of Milan.

The first part of the thesis is dedicated to the literature review to identify the main features that characterize the model, the benefits and the actors involved in the business. The main European initiatives that have led to experiments and functioning businesses in some cities are also presented, including Helsinki considered the birthplace of MaaS.

Among one of the projects funded by the EU there is the LAirA project, aimed at improving accessibility to airports and making it more sustainable. Milan airports were also involved in the project and the initiatives that have been undertaken to better manage the accessibility can be considered a first step toward MaaS.

In the second part it is presented the case study of Milan, where the MaaS4Mi project is born and, even if not yet in the experimental phase, it will be soon, realistically in the second half of 2023. The context of the city of Milan is therefore analyzed, the travel demand that gravitates around the city and the transport offer.
Lastly, accessibility to Linate airport is examined, starting from the effects that the LAirA project has had on the management of the airport and from a MaaS perspective the future actions that will be undertaken.

The thesis was carried out in collaboration with the SEA Group, which is now briefly introduced.

SEA S.p.A.

SEA Group is the company that manages the Malpensa and Linate airports, based on the agreement signed between SEA and ENAC in 2001 and valid until 2043 [4]. The structure of the SEA group on 31 December 2021 is presented in the Figure 1.
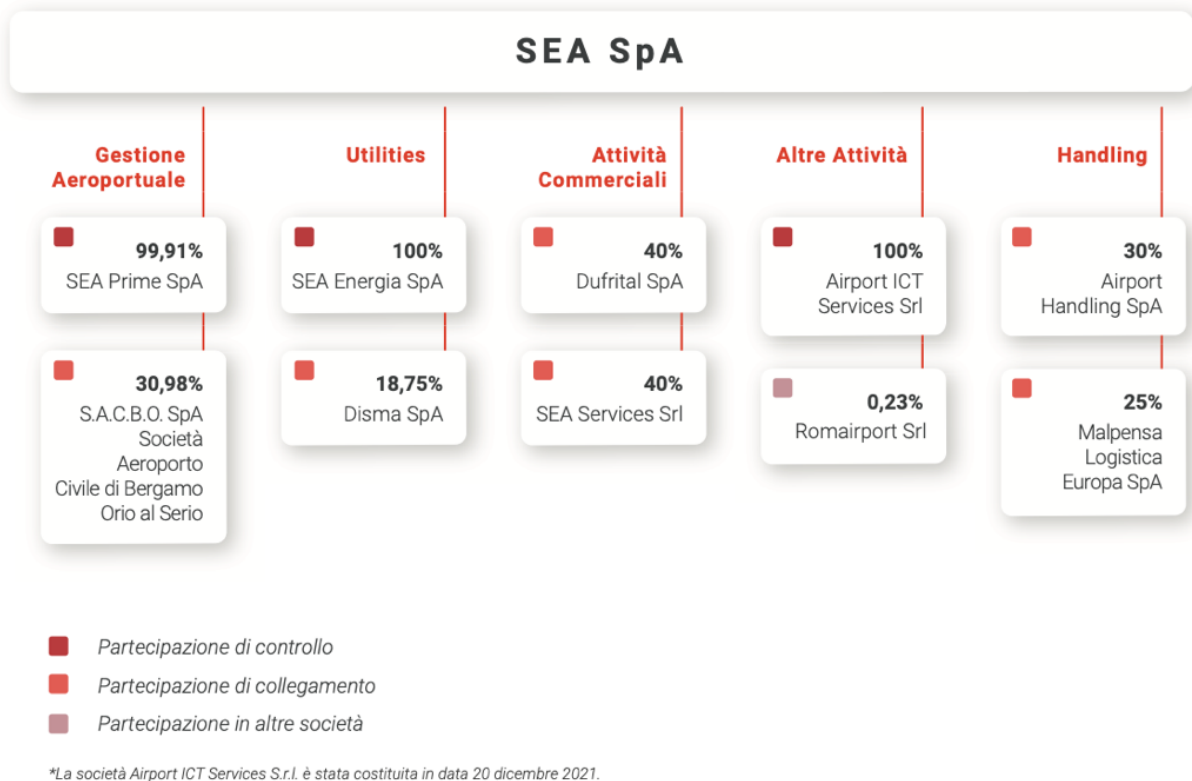
Figure 1: SEA S.p.A. organization [4]

The Milan airport system managed by SEA, which includes Milan Malpensa, Milan Malpensa cargo, Milan Linate, Milan Linate prime and Milan Malpensa prime, served in 2021 a total of 13,9 million commercial and general aviation passengers. The pre-pandemic data is much higher and the Milan airport system in 2019 records 35,3 million passengers.

In details the Figure 2 shows traffic data for 2021, including commercial aviation and general aviation for the two airports, compared with the years 2019 and 2020. The decrease in passengers and movements is due to Covid-19.

The effects of the pandemic manifested especially in the first six months of 2020. The new pandemic wave of the first months of 2021 and the consequent travel restrictions contributed to delaying the recovery of traffic. A partial recovery of movements took place only starting from May, a trend which then consolidated in the summer and lasted until November.

The spread of the new variant in December 2021 had a negative impact on the recovery of the air transport sector, which already showed signs of a slowdown in the operations of the Milan airports as early as the second half of the month. Even in this context, commercial aviation traffic recorded a recovery: if compared to 2020, the

annual growth of movements in 2021 was equal to +34.5% (data which also includes cargo activity) while that of passengers +46.8% (+4,4 million passengers).

On the contrary, freight transport continued also in 2021 to be conditioned by the spread of the pandemic, and cargo sector recorded record results, even higher than in 2019, with around 743 thousand tons of goods transported (+45,1%). The result confirms the role of the Cargo City of Malpensa as a primary center for the exchange of goods in import and export at a national level and as a logistics base for DHL. [5]
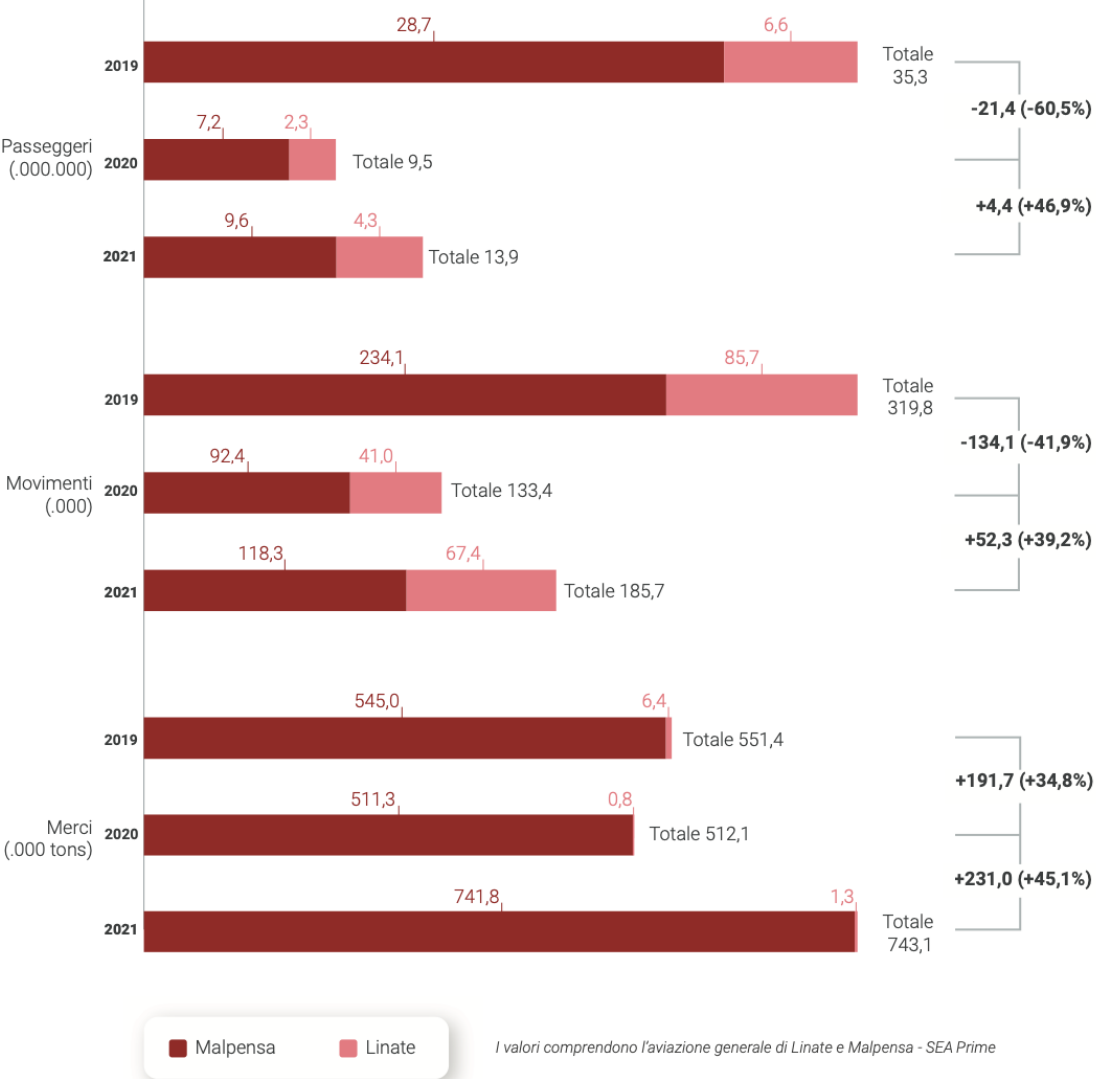
Figure 2: Passengers, movements and goods transported [5]

Regarding the environmental commitment of SEA, it is demonstrated by its involvement in various local and international projects for sustainable development. These include the creation of the *Milan Smart City Alliance* [6], founded in 2021 with A2A Smart City, Accenture, ATM, Cisco, Coima, Dassault Systems, Enel X, Fastweb, IBM, Siemens, Signify, TIM and Assolombarda.

Milano Smart City Alliance wants to create a new model of urban development based on three pillars: technological innovation, sustainable development and active collaboration between companies, institutions and all the players in the city and the local area. The objective is to co-design the city of the future leveraging the opportunities and challenges of the present through the development and testing of shared and innovative initiatives between the public and private sectors, capable of generating tangible benefits for the city, its citizens and all businesses.

Between the goals there is also the integration of all transport services to create a seamless intermodal experience for the end user. For Linate airport in particular, SEA, with the collaboration of NET Engineering, undertook a study with the aim of defining a strategy to make Linate a *Smart Hub* [7] dedicated to intramodality, with a reorganization of spaces and to welcome the new metro station of line 4.

1 MaaS: an introduction

Today transport sector, that employs around 10 million people and accounts for about 5% of gross domestic product in EU [8], is going through a phase of continuous and rapid development. At the basis of this change there are different macro-trends.

Firstly, the demographic growth and the urbanisation. It is estimated that the world population in 2050 will be 9,7 billion and that 70% of these will live in cities [9]. It leads to a growing demand of transport and to a need to review the mobility system of cities and that of public transport.

Another issue is related to sustainability. To safeguard the planet and achieve the objectives of the UN [10], it is necessary to review the traditional concept of mobility based mainly on private cars. The common objective is to encourage public transport and make it an alternative chose by everyone, even by the wealthiest.

The breadth of new technologies available must be also considered: internet of things, artificial intelligence, big data analytics and autonomous driving led to the possibility to manage public transport in a new and more efficient way.

Another aspect concerns the spread of the sharing economy, which allowed users to choose from the numerous means available. The number of vehicles in sharing in Italy has been growing in recent years reaching 100.000 vehicles in 2020 [11], despite a slowdown due to the covid pandemic. There are more and more companies offering these services and with the introduction of electric scooters, which in 2020 recorded 7.4 million rentals with 35.500 scooters in Italy. [11]

All these macro-trends have led to review the transport business model with the consequent rise of Mobility-as-a-Service.

1.1. MaaS: a new way of thinking mobility

MaaS has become the main topic of conferences and events in the field of mobility, in which international experts confront each other by analysing the infinite interpretations to understand the phenomenon of MaaS and how our mobility will change. Over time, the topic has expanded and now it regards no longer only app and

digital platforms, but it regards the rules, business models, or governance models that can favour effective development of MaaS.

A definition of MaaS is presented by *MaaS Alliance* [12], a public-private partnership developed by the European Union to support the identification of a common knowledge over the new transport paradigm. MaaS is defined as the integration of different forms of transport services into a single mobility service, accessible on demand.

For the passenger, MaaS offers added value using a single application to provide access to mobility services, with one unique payment channel instead of multiple ticketing and payment operations. MaaS allows to improve passenger travel experience and reduced journey times thanks to optimal travel solutions and planning. The Figure 3 shows from the user's perspective how it is changed the interface with the public transport sector.

Figure 3: with and without MaaS from user's perspective [13]
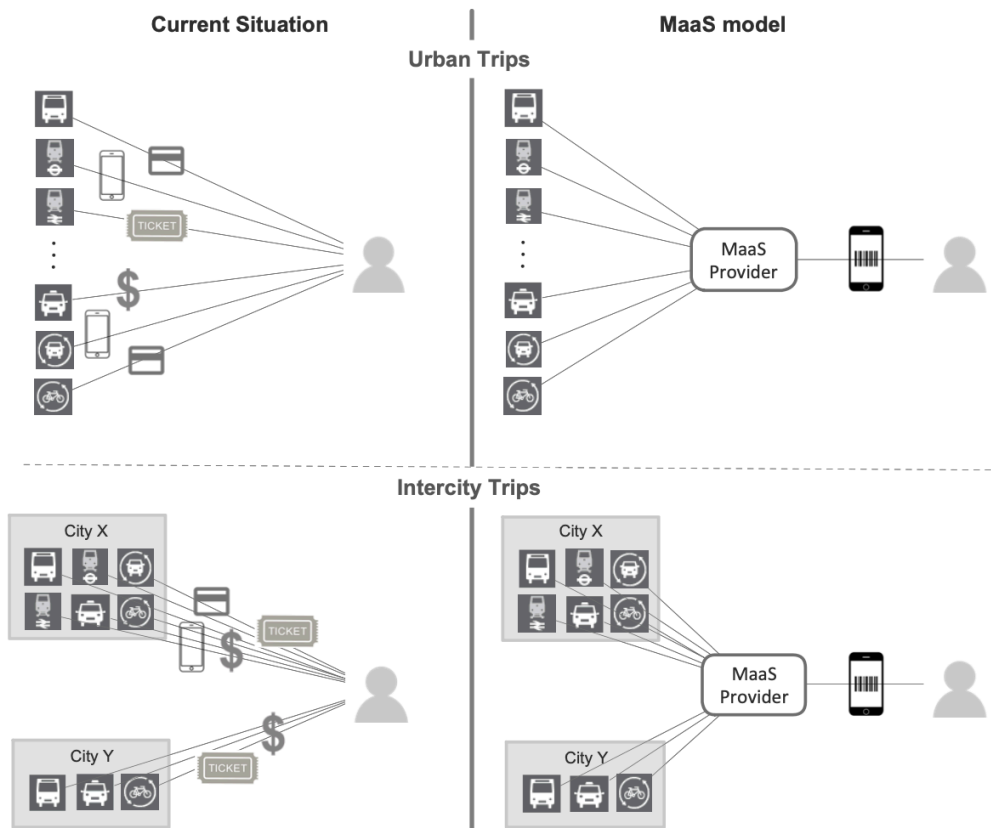
1.1.1. One platform

The first feature of MaaS is to be based on a single platform. Today for every need there is an application made specifically to solve the problem. This also applies to the world of transport. The use of applications to plan, buy and manage a trip by public transport is nothing innovative anymore. Users, in the last decade, have downloaded

and used more and more innovative mobility apps. These types of apps have existed for years, and they are used daily. However, one problem noticed is the amount of these apps necessary to use the different service available.

MaaS aims to simplify this process aggregating all mobility options in a single application, to provide a simple and intuitive procedure. It is not just a matter of having to use multiple applications, but also of registering and providing personal data for each of them. With a single application the user, by registering and providing their personal data with third parties for profit. [14]

1.1.2. Spread of public transport

Transport represents almost a quarter of Europe's greenhouse gas emissions, and it is the main source of air pollution in cities [3]. Combining new mobility modes with traditional services such as public transport, the MaaS concept clearly supports a paradigm shift in urban mobility. This goal is consistent with Sustainable Development Goal 11 of the United Nations is to "Make cities inclusive, safe, resilient and sustainable". [10]

A goal of MaaS schemes is to encourage the choice of collective transport services, by bringing together multi-modal transportation and allowing the users to choose and facilitating them in their intermodal trips. Urban modes may be included: public transport, taxi, car-sharing, ridesharing, bike-sharing, car-rental, on-demand bus services; but also, long-distance buses and trains, flights, and ferries. [15]

MaaS can have a positive contribution to reducing air pollution and congestion. The possibility of having a wide choice of shared transport vehicles at their disposal will increase the propensity of users' choice and to a greater multimodal choice. [16]

Moreover, with the introduction of greener options (alternative fuelled vehicles or electric vehicles) among the potential means of transport accessible on the MaaS platform, there will be the chance to further decarbonize urban cities.

An example of MaaS effect is shown by *UbiGo* project trial, a MaaS project realized in city of Gothenburg (Sweden) [17]. The package of mobility offered to households have led to a net reduction of the private car use among 44% of participants and a net increase of the reliance upon bus and tram service among 46% of participants

1.1.3. Demand-driven transport

Furthermore, it is not only a problem of shift from individual car to public transport. A further implication that contributes positively to the environmental dimension is represented by the better use of the existing resources. The traditional transport system has been designed based on a fixed demand, while the new mobility service, thanks to

the real time information, can distribute dynamically individuals to boost the resource efficiency of each transport vehicle. [18]

MaaS is defined as a user-centric paradigm [19]. Indeed, one strategy to reduce congestion and emissions is to make the transport system efficient and demand oriented.

The importance of a flexible transport offer was evident during the pandemic period. Covid-19 has had a very strong impact on consolidated mobility models and behaviours. The impacts on post-pandemic mobility choices have been the subject of multiple studies, all of which agree that the "*Next Normal*" phase [20] will require the introduction of tools for the management and monitoring of transport and mobility systems increasingly flexible and dynamic to ensure the necessary effectiveness and efficiency.

Traditionally public transport is based on fixed collection points and schedules along the entire planned journey for reaching the destination. In every field of the market, customization and personalization are increasingly importance, that is also happening in the transportation field [21]. MaaS is born to match with the recent changes in consumption that characterized the new digital era.

Better management of match between offer and demand results in improvement of quality of life due to reduced total time spent travelling thanks to more efficiency of the network.

1.1.4. Other MaaS benefits

Another dimension where MaaS could be beneficial is represented by the social perspective.

For example, the geographic exclusion perceived by people living in rural areas, could be tackled with the accessibility concept embedded in the MaaS solution [22]. Moreover, the on-demand vehicles available in the service could help better connect to the main corridors of the city those urban residents living in contexts not properly covered by the transport system.

Another important MaaS implication to the social dimension involves the economic inclusion. Theoretically, the new service could be used as a mobility solution by those individuals that have not enough financial support to cover the upfront expenditure for acquiring a private vehicle and the related maintenance costs. This does not hold true in all the MaaS configurations. [23]

1.2.   MaaS levels

Over the years, different taxonomies have been provided based on terms of the presence or absence of recurring integrated services. The usage of combined information for multimodal journeys, the integration of the payment systems of different transport actors, the ticketing and booking functionalities for the access and validation of door-to-door journeys have all been always represented as criteria to distinguish different MaaS levels.

1.2.1.   Sochor et al. (2018) taxonomy

A proposed classification provided by Sochor et al. (2018) and it defines levels from level 0 to level 4 [24]. This type of classification has also been used to draw up the Guidelines for the development of MaaS services in Italy. [25]

- Level 0 – No Integration. It represents the reference case. Information, payment systems, reservation and validation instruments are mode specific, and no type of integration is available.

- Level 1 – Integration of information. At level 1, travel information is provided through multi-modal travel planners, which may or may not include information about routes and costs. The advantage for users in this case is given by the possibility of selecting the time of day, the route, or the mode of transport to be used to make the journey. The added value of level 1 is the support function it offers to help the user in finding the best trip. In this type of service, transport service operators contribute to enriching the travel planner by providing data according to open and free standards. Travel planner service providers are not responsible for the quality of the service and information provided, and users may decide not to use the service again if they find the information untrue or difficult to understand.

  The most suitable case to be cited for this level is represented by *Google Maps* [26]. *Google Maps* was used to provide updated travel information for reaching a pre-defined destination point based on the specific transport mean selected. In fact, users could decide to travel by proprietary car or bike, walking or choosing the available public transport offer.

- Level 2 – Integration of booking and payment. At level 2, travel planner services are complemented by "search, book and pay" functions for single trips. The added value of the level 2 integration is that users can search, book and pay for their trips directly through a single platform, which includes an app, a payment system and a credit card. In this case, therefore, the service is focused on the single trip and can be considered as the natural evolution of the travel planner

(level 1), with the addition of public transport tickets, taxis and other transport services (where possible). At this level, users can take advantage of easier access to available transport services, but the offer is not sufficiently comprehensive of all transport services to ensure that citizens can decide to abandon their private car and consequently Guidelines for the development of MaaS services in Italy become exclusively MaaS customers.

MaaS operators are responsible for the booking, purchase and validity of the ticket, while they are not responsible for the transport service provided. Regarding the business model, MaaS operators get an economic return from the commissions deriving from reservations and / or sales commissions.

- Level 3 – Integration of the service offer. A level 3 mobility service provides an offer that, compared to the previous layers, is more valuable from a customer perspective. In fact, in addition to the information and transaction integration, the service provider will potentially take care of the mobility needs of an entire household. The service will not only cover the need of integration for a single trip, but it will potentially offer the same value for longer periods.

  More specifically, the users will be able to register and potentially subscribe to the mobility service, paying monthly fee to access bundles of transport solutions customized to the specific movement's necessities. In this way, the service will represent a valuable substitute product to the private car, capable of potentially mitigating the need of an automobile. Consequently, important environmental implications could be generated from this level of mobility service.

- Level 4 – Integration of societal goals. This last level is particularly focused on the environmental perspective. In fact, the authors envision a level 4 that could be reached from any other layers whenever public authorities influence the MaaS offer to explicitly address the congestion and pollution issues of densely metropolitan areas, increasing the quality life of their inhabitants.

  For example, this objective could be reached with the city or government's imposition of clear criteria to be respected by the service provider, which will consequently result into incentives capable of fostering a more environmentally friendly behavior among travelers. Consequently, at this level it is essential a strong cooperation between the city and the public transport authorities with the mobility service provider.

1.2.2. X. Zhao, C. Andruetto, B. Vaddadi et al. (2021) taxonomy

Another taxonomy proposed in 2021 by X. Zhao, C. Andruetto, B. Vaddadi et al., it defines 4 levels of integration [27]. Each of the levels is based on the presence or absence of the following features: Service coverage, Online and app platforms, Multimodal, Information, plan, book and pay. Figure 4 summarizes the presence of the various functions at the different levels.

- Level 1-Partial info. Common information includes transport modes and timetables, while price information is only available for a few transport modes included in the service. At this level, all transport modes are independent of each other, and only one trans- port mode can be chosen at a time (for example, e-bike, e-scooter, car rental, taxi or public transport). Planning, booking and paying for a journey combining different modes is not possible at this level.

- Level 2-Multimodal planner: The services aggregate different information regarding multiple transport modes through an app or online platform and offer full coverage of both urban and rural areas. Multimodal plans can be offered, including information on transfer time, wait times and cost. However, the number of transport modes that are integrated in the service is still limited. Users can choose between different optimization schemes when planning their trips: e.g., fastest or cheapest route.

- Level 3-Planning, booking and paying with partial service coverage: The services allow users to plan, book and pay for a whole trip through one app. Payment options such as ticketing schemes, subscriptions and travel cards can be also included in the app. Multimodal options are available for users to choose from. However, the services are accessible only in a certain area, which means that geographical coverage is limited to an area such as a city center, a specific work hub or designated rural areas.

- Level 4-Planning, booking and paying, with full-service coverage: The same services as in Level 3 are provided. In this level, the provided services are more adaptable to different scales of on-demand needs, from city center to suburbs to certain rural areas. The services fulfil various transport needs at the highest coverage level, including both urban and rural areas.
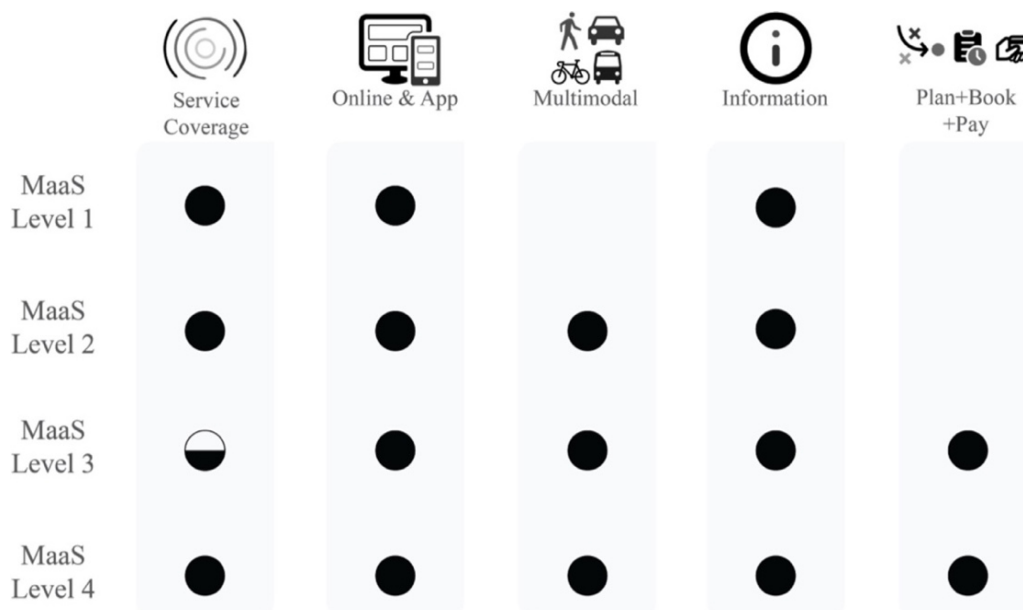
Figure 4: MaaS levels with different features [27]

1.3. MaaS ecosystem

Since MaaS is a new business model, the role of the various traditional players is redefined, and new roles are introduced.

1.3.1. MaaS Provider

MaaS Provider is the intermediate between the transport operators and the users. It collects data about the customer preferences and information, it provides a unique interface to the final users, displaying different journeys combinations that can fit their mobility needs. [28]

It manages the platform that represents the unique point of convergence for the different transport service operators' offers. Additionally, it manages the collaboration with all those companies that provide technological services for the platform management and the analysis of data.

A distinction can be made within the role of MaaS provider, identifying two key roles, namely MaaS Operator and MaaS Integrator.

1.3.2. MaaS Operators

The MaaS Operator is the entity that aims to offer end users digital mobility solutions. it is responsible for the user's journey as it acts as the user's main interlocutor. Its job therefore consists in the dissemination and sale of all mobility services, present in each territory and of interest to a specific target of users.

The MaaS Operator therefore operates as an "intermediary" whose main objective is to offer value-added services to the end user. Taking as a reference a local mobility

system (at urban, metropolitan or regional level), it is possible that there are several MaaS Operators, which provide mobility services, each according to its own business rules. These in turn can refer to one or more MaaS Integrators, from which they receive the enabling data and services.

The MaaS operator, depending on the various business models, can be public or private. It offers the transport solution that integrates at least all public transport and digital ticketing solutions. integrates different public and private transport operators through the MaaS integrator and shop a priori the purchase of a volume of travel or minutes of transport.

1.3.3. MaaS Integrators

The MaaS Integrator has the objective of aggregating together the information of the different transport services existing in each territory, in terms of collection and homogenization of the available data (static or dynamic), playing a role of aggregation and intermodal synthesis (from various transport to a single digital mobility meta-product). It therefore interfaces on the one hand with the individual transport service operators, and on the other with the MaaS Operators. It mainly deals with the processing of data, including transaction and payment data, and presents itself as a collector of information. It does not have direct exchanges with individual users but offers digital and technological services to MaaS Operators. The information it collects can be used to carry out specific analyzes on supply and demand.

The MaaS Integrator is generally a private entity and offers a technological solution for the integration of data from the various actors who carry out the transport. provides the data to the MaaS operator to allow the provision of services and provides information and data for analysis to policy makers.

1.3.4. Transport Operators

It can be public or private and physically carries out transport. The public companies offer tram, bus, metro, and train services, while the private ones offer usually sharing services.

To have an effective MaaS it is necessary that both parties, both private and public, are present to widen the choice. Again, for this reason it is easier for this new project to be successful in cities, given the greater presence of means of transport and alternatives available. Indeed, the existing projects started from urban areas, where there are more road and rail infrastructures. [29]

Both the public and private transport providers have the role to sell their capacity to the MaaS Provider, which will be coherently used to present the offer to the final user.

The main advantage for the transport operators is represented by a higher visibility on the final customer. During peak hours, the MaaS Provider could redirect the demand to those transport operators that present available capacity, increasing their revenue stream from previously unreachable market and even avoiding potential issues related to the customer dissatisfaction. [18]

With this business model for the transport operator is to have more information on the demand for transport and therefore also reposition the vehicles in the fleet or make changes to the service offer dynamically. [30]

1.3.5. Data Providers

The importance of data is obvious and data providers deal with managing the exchange of data between the parties involved. they offer the service of processing and repackaging data, by collecting them from both the transport provider's APIs and other sources, such as customers' mobile phones. In addition, they make the data available in interoperable formats, which, is the fundamental condition that enables the integration of the information captured by each single transport service provider. [31]

1.3.6. Regulators and policy makers

Another fundamental actor consists in the public and regulatory actor [30], which have the role to incentivize the MaaS paradigm. The role of public authorities is to allow radical innovation to be adopted by society.

There are four scenarios representative of the political positioning undertaken to the MaaS development: [32]

- governing by authority, it is the strongest way to enforce the introduction of MaaS into the society as it consists in the approval of laws that favor the growth of the paradigm. An example is the case of Whim, for which the Finnish public authority has developed in 2017 a specific legislation, the Transport Code, to coerce all the transport providers to open their datasets; [32]

- governing by enabling, it is the case where regulators create a shared vision to ensure a learning process between all the stakeholders involved;

- governing by doing, in which the public authorities are in charge of developing and managing internally a MaaS solution;

- self-governing and governing by laissez-faire, where regulators do not participate in any development of MaaS by adopting a wait and see approach, as they are not interested in a radical change, or due to bureaucracy.

According to the guidelines for the development of MaaS services in Italy defined by TTS [25], the policy maker must have the role of regulator and creator of policies, determining a framework of rules and establishing relationships between transport service operators, MaaS operators and users. the definition and implementation of adequate policies can favor a diffusion of MaaS services on a large scale, with incentive logics towards sustainable modes of transport.

1.3.7. Customers

Finally, there are the end users of the services. The decisive role of consumers is underlined by the fact that MaaS is defined as a customer-centric approach.

The offer of MaaS Provider is not always directly to commuters, but even to companies and governments. In case of companies the MaaS service is experienced by those employees whose organization wants to reduce the private car usage and encourage business trips with intermodal mobility. [33]

In addition, MaaS could be even a valuable solution to encourage visitors to experience the efficient public transport of a foreign city, discouraging them from relying upon the most conventional and expensive options, like car rental or taxi.

According to the study realized for the testing the likelihood for MaaS to emerge in Netherland, it resulted that those residents who were more interested in the new transport service do not evaluate car ownership as fundamental during their travel habits, rely upon public transport regularly and are more responsive to environmental issues. [34]

Another international study [29], showed how users who were already inclined to use transport applications were even more in favor of introducing MaaS. The same study also showed that younger generations are the first to choose this new paradigm. this is partly since young people are more inclined to new technologies, and it is registered, especially in western countries, a decrease in the number of owned cars and for new generation.

1.3.8. Other actors

To make such a complex transport system work, there are many other players:

- Technical backend providers (responsible to the introduction of technological breakthroughs such as big data and cloud computing services and IT infrastructure);

- ICT infrastructure providers (they allow the customer to access in real time, through the high band connectivity enabled by 4G and 5G technologies, to the TSPs data concerning the transport information of their vehicles);

- Third party technology and service providers those companies which offer to the MaaS Provider technical services necessary to integrate planning,

booking, mobile ticketing and payment functionalities together with data analytical capabilities;

- Dynamic multiservice journey planner providers (MaaS Provider has the possibility to collaborate with those "journey planner providers" already available on the market);

- Ticket and payment solution providers (The possibility of having a single payment platform is one of the key points of the MaaS. to make this possible, the MaaS provider must coordinate and collaborate with the companies that allow payments. [13]);

- Insurance companies;

- Research institutes (that works on new theories and measure the impacts of MaaS on society).

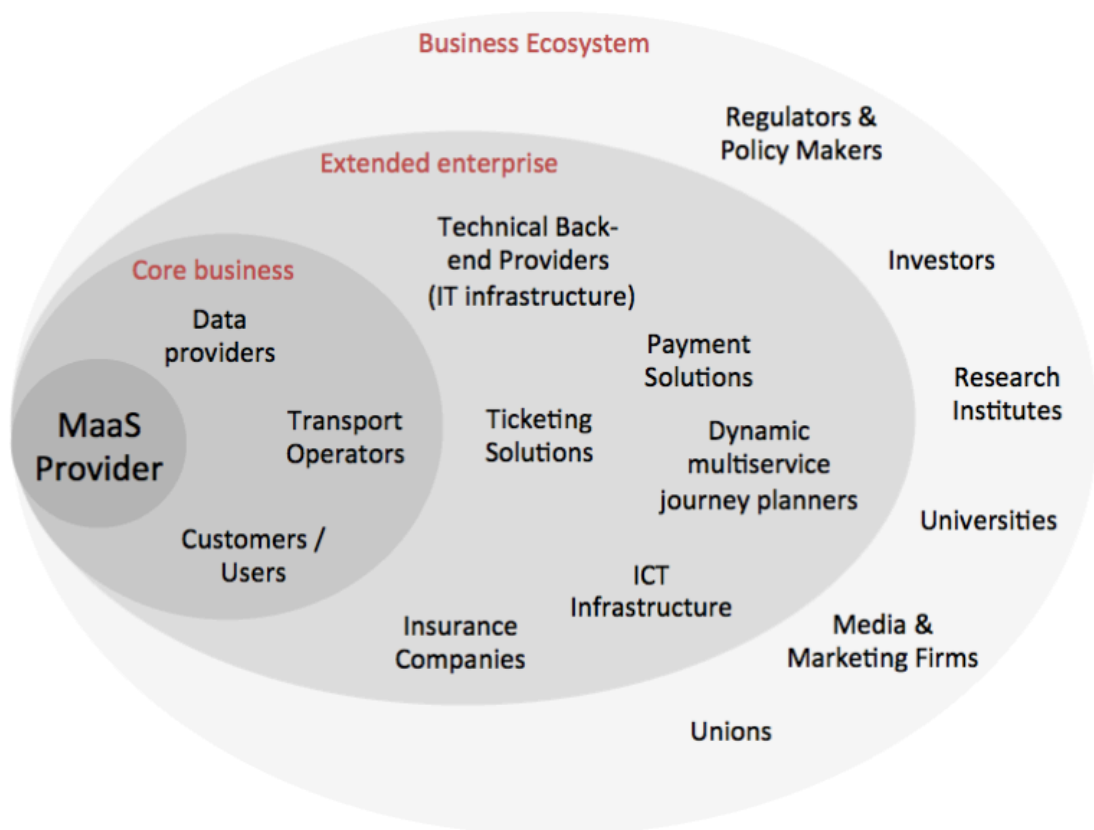In the Figure 5 there are summarized all the actors presented above.

Figure 5: MaaS ecosystem [28]

1.4. MaaS challenges and future growth

1.4.1. Challenges

One of the barriers to achieve the final objective of the MaaS is that related to the integration. It is necessary a high level of collaboration and coordination between the parties involved. The coordination is not easy because of the lack of regulations, uncertainties of roles and business model [35]. This also applies to the payment integration. The complexity lies in involving multiple parties, fix the tariffs and then redistributing the gains.

Another issue that could be trivial is that of ticket validation. There are often physical barriers present in train and metro stations and which require validation of a ticket. There are not always devices to scan QR from smartphones and this can only be solved with a modernization of the devices in public transport.

To be efficient and effective MaaS needs data, provided by consumers, such as their travel preferences and their movements. It is therefore a question of building consumer trust. In accordance with the general data protection regulation (GDPR) [36] companies are responsible for the processing of user data and must comply with their obligations (i.e. indicating the purpose of the use of data and facilitating an intelligible privacy policy). Relating to the management of personal data, there is also the problem of cybersecurity.

Lastly, it should not be forgotten that a project can become reality only if citizens decide to use the service. The challenge is to change the habits of consumers, in particular those not so young, who are more reluctant to new technologies.

1.4.2. Future growth

According to the latest estimates by *Markets and Markets12*, the world market of Mobility as a Service, understood as a whole in terms of public and private transport systems, vehicle sharing services, technologies used (from infrastructures to payment systems / reservation, from applications to insurance), could in fact be worth more than 106 billion dollars in 2030, compared to the 6.8 billion dollars estimated for 2020, with an annual growth rate of 31.7% from 2020 to 2030. [37]

The growth of MaaS is also confirmed by more recent *research13* which states that in 2027 the revenues generated using MaaS platforms will exceed 52 billion dollars, compared to 405 million dollars in 2020. [38]

In addition, the study credits Europe as the most developed and innovative market, [25] with some companies already global leaders in the MaaS offer, such as the Finnish *Whim*. Existing and emerging MaaS platform will be presented in the next chapter.

1.4.3. European projects

The topic of MaaS is addressed at a European level with the various project founded by EU and with different objective

MyCorridor [31] is a 3-and-a-half-year project, funded by the EU's Horizon 2020 programme, with the goal to achieve sustainable travel in urban and interurban areas and across borders. The project investigates connecting services from various service providers and providing the traveler with alternatives to replace their own vehicle trip with combined shared vehicles and multimodal transport solutions. The project is part of MaaS concept that puts users at the core of transport services.

The conventional MaaS concept is mostly focused on public transport and sharing mobility services within a certain locality; *MyCorridor* focus is to bring together different MaaS issuers of various cities and regions which are connected by corridors.

The project looked into connecting services from various service providers and provide the traveler with alternatives to replace their own vehicle trip with combined shared vehicles and multimodal transport solutions, incorporating in addition Traffic Management and added value services.

After a first phase of pilot tests conducted in 2019, the five pilot sites of the project (Amsterdam, Athens, Prague, Rome and Salzburg) tested the newly developed *MyCorridor App* from summer to autumn 2020 with real users in real life conditions. During the second phase, during COVID-19, *MyCorridor* was used in 934 trips in total with 160 users participating.

MyCorridor paves the way for cross-border MaaS by setting an important example of how transport services can be integrated into a single mobile application and the initiative was also welcomed by another MaaS projects, called *MaaS4EU*.

MaaS4EU, founded by EU, provide frameworks and tools, to remove barriers and promote a cooperative and interconnected EU single transport market for MaaS. As already mentioned, one of the barriers of MaaS development is the lack of regulation. The European project aims to define sustainable business models that support the cooperation across transport stakeholders, implementing the required technological infrastructure and identifying the enabling policy and regulatory frameworks. [19]

The objectives of the project can be summarized as follows, in 11 areas:

- Management - there is the need to establish a strong project management scheme, processes, a common understanding of goals and maximize impact; ensure day-to-day coordination and successful achievement of project objectives on time and within budget; ensure efficient scientific and technical coordination; implement and maintain procedures for quality and risk management to ensure the quality of the final results and deliverables and to promptly identify, assess and efficiently manage any related risks;

- Definition of MaaS ecosystem - The objective is to work with the stakeholders involved in the MaaS ecosystem to identify and analyze their requirements, concerns, barriers, and opportunities regarding this concept;

- Design of MaaS business ecosystem and organizational structures in regard to whom is the MaaS operator, including the cooperation agreements needed with the MaaS ecosystem actors; examine the financing schemes for the MaaS concept and design revenue allocation models between the MaaS operators and their "suppliers"; study the current legal and regulatory barriers that hinder the MaaS market;

- Analysis of the needs, preferences, and demand for MaaS services of various end users' groups, assesses MaaS acceptance rate, and identifies changes in travel decisions given the MaaS concept;

- Enterprise data framework - The aim is to develop the data infrastructure (models and physical) that will underpin the operation of the *MaaS4EU* platform; Develop the adaptors and APIs for the integration of heterogeneous data sources and services as part of the technology platform; Develop models and algorithms that will support data analytics; Develop services focused on the portability, management and security of data with special attention to user privacy;

- Dynamic & customized MaaS services - The goal is to develop a suite of algorithms that supports the dynamicity and personalization of the MaaS services;

- Integration towards a single *MaaS4EU* open platform and development of the Personal Mobility Assistant, a mobile and a web application that will facilitate the interaction of the users with the MaaS4EU services;

- Demonstration and proof of concept. In this phase the aim is to design the MaaS Living Labs for each pilot area that will be used to recruit participants for the development and testing of the *MaaS4EU* solution; after collecting data about

end-users MaaS demand and travel behavior and feedback it is possible to evaluate the pilots and the impact of MaaS;

- Identification of the different target groups, key messages, communication channels and activities and implement a communications program in alignment with exploitation actions in order to maximize impact; Blend different channels and tools to reach the widest possible audience, including business stakeholders and the public, through the effective flow of information and publicity about the project's open architecture and tools;

- Exploitation and business development. In this phase the project monitors the MaaS market and identify other MaaS initiatives;

- Determination of ethics requirements that the project must comply with.

2   LAirA project and later developments

In this chapter it is presented the LAirA project, a European project that addresses the issue of multimodal, smart and low carbon integration of airports in the mobility systems of Central European Functional Urban Areas (FUAs). [39] This project is mentioned because it can be considered a precursor of MaaS and it shows how some airports have been working to reach this goal for years.

Subsequently, examples of airports and cities with interesting developments in MaaS platform are presented with their key features.

2.1.   LAirA project

The Landside Airport Accessibility (LAirA) project was a European Union's *Interreg central Europe program* which aimed to improve landside mobility planning for airports.

It lasted 30 months between May 2017 and October 2019 and it was financially supported by EU with a total budget of € 2,3 million. [39] The goal was to review the accessibility to airports, reducing the environmental impact of the movement of passengers and workers to reach the airports.

Indeed, given the rapid growth of the air passenger market and increased competition, airport accessibility is widely recognized as an enabling and stimulating factor for airport development and to gain a competitive advantage over neighbouring airports. [40]

The eight airports involved were Budapest, Dubrovnik, Milan, Poznan, Stuttgart, Vienna and Warsaw, for a total of 56 million passengers and 39.000 employees, but in addition more airports were analyzed to create a benchmarking study. [39]
The opportunity of the project was to promote transnational cooperation between policy makers and communities to create modern and environmentally conscious options which will ease the travel between airports and city centers.

It can be considered a precursor of MaaS since the following short-term steps are all prerequisites for the realization of MaaS:
- Pre-trip and on-trip information for arriving passengers on low carbon ways of leaving the airport;

- Employee awareness-raising on low carbon mobility;

- Shared mobility hubs in the functional area of the airport for passengers and employees;

- Application with real-time data on different modes of transport and their schedule for passenger.

The project comprehensive approach integrates seven key thematic areas: electric mobility, air-rail links, active travel, shared mobility, wayfinding, road public transport and ITS.

2.1.1. Electric mobility

Nowadays electric mobility is increasingly practical in terms of range, availability, cost and specification. Charging infrastructures are more and more common at airports for convenience for customers and to support low carbon travel.

LAirA research has shown, as reported in Figure 6, that a significant proportion of airport passengers and employees are accessing or leaving the airport by car. Given the high preference for cars, it is necessary to encourage electric mobility to decarbonise the sector and reduce the environmental impact.
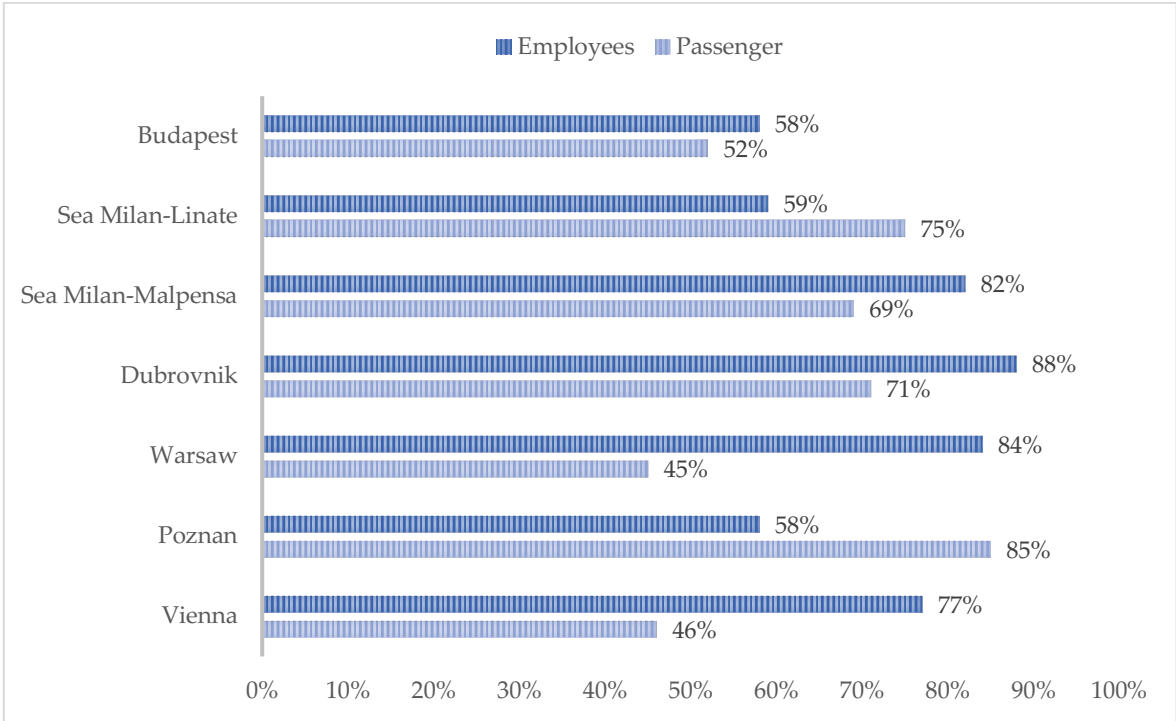

Figure 6: use of private cars to reach and leave airports [41]

To encourage the shift to electric mobility, every airport needs parking spaces with charging stations.

Considering the Italian case in 2022 there are more than 30.000 charging stations for cars [42]. As regards the case of the Milan airports, an alliance was signed between *Free To X*, an *Autostrade per l'Italia Group*, and SEA, the management company of the Milan Linate and Malpensa airports, which recently led to the inauguration of the first Superfast Charging Station at Milan Linate airport, one of the largest charging stations in an international airport [43]. This alliance demonstrates the importance of the topic.

2.1.2. Air-Rail links

Easy access to a fast, frequent rail link to the local city centre is an attractive alternative to road-based transport to and from airports. Rail services generally provides fast connections particularly at peak time when road congestion is more penalizing.

To reach Budapest airport terminal 2 it has available a railway connection with the city in less than half an hour, with 100 trains per day. [44]

In Milan, to connect Malpensa airport with the city centre, the *Malpensa Express* was introduced, a service managed by the Trenord railway company, with 146 daily trips and over 3 million of passenger every year [45].

Figure 7 : *Malpensa Express* stops [45]

2.1.3. Active travel

Active travel, cycling and walking, can represent an alternative way for employees to reach some airports, depending to their layout and locations. To encourage cycling to the airport, good supporting facilities are required.

According to LAirA output in general the average active travel share is very low (Figure 8) with exception of Poznan airport where 6% of employees use bicycle. In this case the city centre is connected with the Airport by a bicycle lane with a total length of 6.1 km. [46]
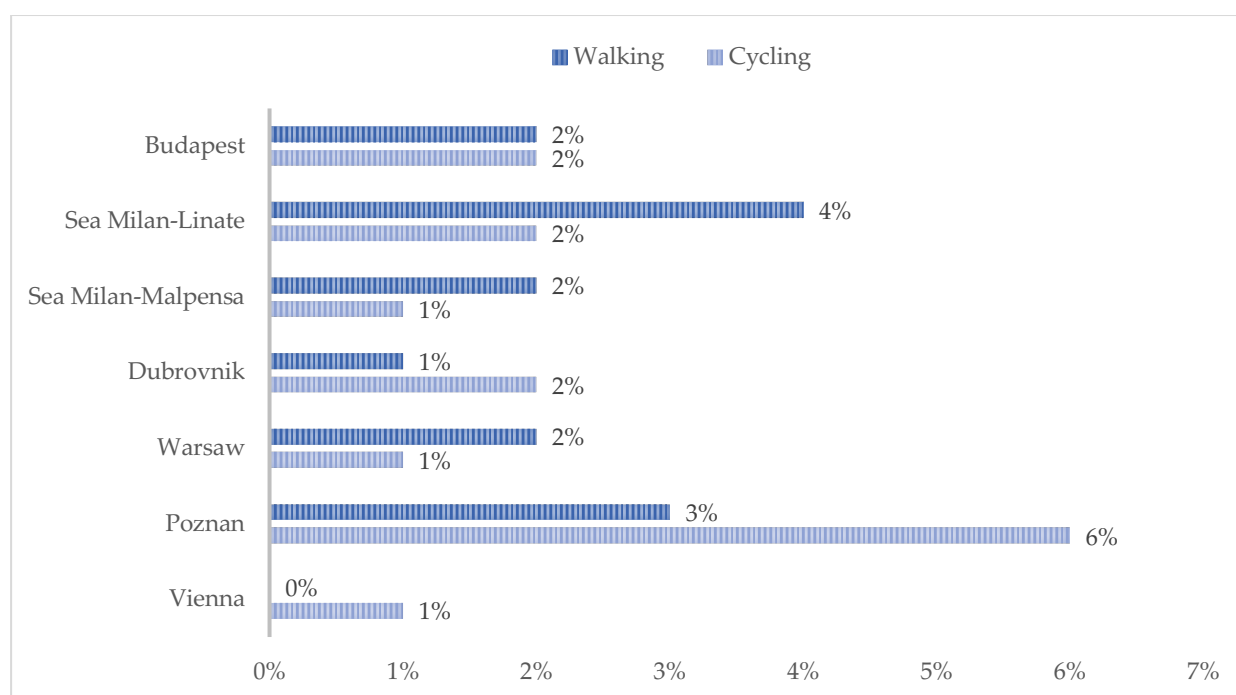
Figure 8: % share of active travel by employees [41]

After the end of the LAirA Project, the Vienna airport created a new cycle route to connect the airport with the centre of the city for the 35.000 people which live close to the airport and the 20.000 workers in the area. [47]

2.1.4. Shared mobility

As mentioned, the trend towards sharing mobility is spreading. Car sharing is very common on cities with several different providers operating in the same area. In addition, lower emission vehicles and electric vehicles are now becoming a common option for sharing mobility.

This also applies to reaching airports, since it can be a more economical solution than a taxi for travellers. During LAirA project observation car sharing was not very common, or it was totally absent in airports.

An example is Budapest, that didn't have any car sharing operating in airport area. Nowadays *ShareNow*, a popular car sharing present in all Europe, it is also available at Budapest airport with reserved parking spaces.

At Linate airport there are 3 different car sharing options available 24 hours a day and with reserved parking spaces: *Enjoy*, *E-Vai* and *ShareNow* [48].

2.1.5. Wayfinding

Innovative services in the airport are not enough, to be effective they need clear wayfinding.

In airports the provision of effective wayfinding provide passenger to have more control over their journey, know where they are and increasing overall satisfaction level. LAirA report has defined principles of wayfinding at airport [49]:

- Begin wayfinding before they leave the arrivals area;

- Provide simple information and targeted at people unfamiliar with the area;

- Use standardized visual markers;

- Provide consistent wayfinding style in all airport area;

- Lead the passenger the whole way;

- Confirm passenger that they have reached their destination.

To make a place more understandable it is necessary to think of it from the point of view of the public and the difficulty that can arise in signage at the airport arises from the fact that it is an international place and therefore means making local customs and codes understandable to everyone. The goal is to connect people's sense of trust and safety with their satisfaction and the impression they have of a place. as if a traveler feels lost, the probability that they will revisit the place decreases. [50]

2.1.6. Road Public Transport

LAirA main goal is to reduce the carbon footprint of transport activities related to the airport's landside connectivity in FUAs, developing a common new low carbon mobility strategy involving local authorities, other organizations and stakeholders.

To reach that objective it is analysed also road-based public service, that provide direct connections between airports and the landside.

LAirA output survey (Figure 9) shows about 25-54% of the passengers use public transport, bus and train, coach, regional, international and airline transfer buses, to access and exit the airport. By comparison, the airport' employees appreciated less the public transport (3-40%) than the passengers. [41]
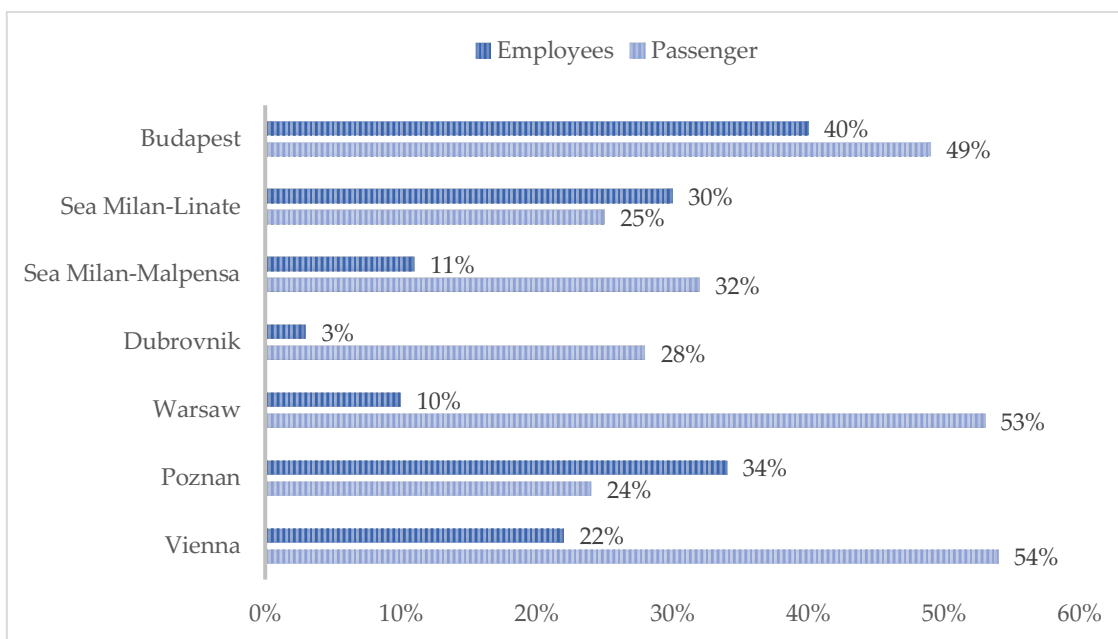
Figure 9: % share of public transport users among passengers and employees [41]

For Milano case, from and to the Linate/Malpensa Airport are multiple road-based public services offered: Provinces outside Milan Metropolitan area are connected to Malpensa Airport both by regular and seasonal or on-demand services; Services are operated by local public buses, or by coach services, which connect Malpensa also to central Italy; there is also a connection between Linate and Malpensa airport; The central Milan area is connected to Linate Airport by local public bus and coach services. Accessibility to Linate Airport will be detailed in the dedicated chapter. Regarding the low percentage of employees who use public transport In Malpensa, it is probably because the bus services are mainly aimed at tourists and travellers. therefore, both the areas covered by the buses and the timetables better satisfy the tourist user.

2.1.7. Information Technology Systems (ITS)

People are increasingly relying on digital channels to search for information, and real time information are even more relevant in the airport environment: airport apps must provide real time information on flights, delay, cancellations, shopping opportunities, car parking and info on accessibility to airport.

A LAirA's goal was to investigate the solutions already available on the market and define the desired and must-have functions for a platform for planning travel to / from airports. The application needs to be consistent with the MaaS logic, opting for integrated, intermodal and transport solutions.

During the project it was carried out a benchmarking study between the different platform available in airports. Below some examples are reported:

- Budapest – Budapest airport has an official app, *BUD*, that let to compare and choose a transportation option to leave or reach the airport, as an alternative to bus shuttle. The same application developed by Bolt is available in more than 100 airports around the world [51];

- Warsaw - *Warsaw Chopin Airport* app, provides info on flight, parking, food and shopping area and map of airport [52];

- London Gatwick – The *Gatwick Airport Official* was acclaimed 'Mobile Innovation of the Year' at the National Technology Awards 2018, with live flight information, intuitive wayfinding with interactive airport maps, and great offers and tips [53];

- Milan - *Milan airports* application (Figure 10), which brings together all the information useful for traveling (flight tracking, assistance, paperless shopping experience, viamilano program, promotions, planning of trip, shop&food) [54]. I t focused on improving surface access functionalities and passenger interfaces by integrating third-party tools.
  The app has been downloaded from over 100.000 and it is very popular with users, who give it 4.5 points out of 5 according to the reviews on Google Play [55];
  In 2018, studies were carried out within the LAirA project to learn about customer satisfaction relating to the quality of information at the Linate and Malpensa airports. As regards the Linate case, 95,0% of the interviewees proved to be satisfied with the clarity, comprehensiveness and efficiency of the wayfinding term and 91.2% proved satisfied with the up-to-date and user-friendly web site.
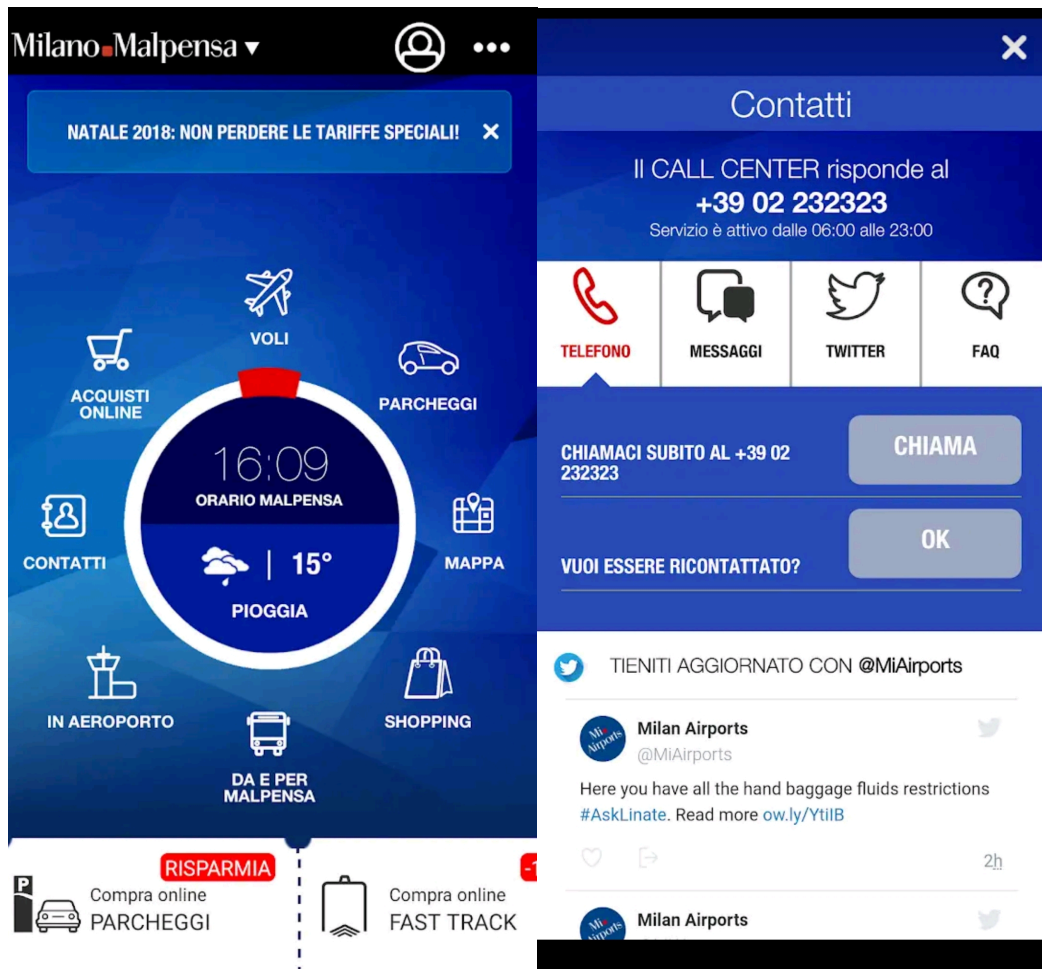
Figure 10: *Milan airports* app layout [54]

2.2. Existing MaaS project

Before focusing on the *MaaS4Mi* case study, explored in the next chapter, MaaS platform available and functioning in Europe are now presented. Some of these platforms are available in more than one city or area, other created for particular needs of one city.

2.2.1. Munich – *Passngr, MVGO*

Munich airport is located 38 km northeast of Munich, has seen a significant increase in passengers in the last 30 years and in 2019, pre-covid situation, it had 47.9 million commercial passengers. The alternatives to reach the airport are the following [56]:

- Deutsche Bahn;
- Airport service by s-Bahn lines S1 and S8/MVV;
- Lufthansa express bus;
- Flixbus;
- Regional bus lines/MVV;
- Car;

- Car sharing;
- Taxi.

Munich airport has been collaborating strongly with industries for years with the aim of developing its own digital hub and together with the Hamburg and Dusseldorf airport, was involved in the development of an app, *Passngr* [57] launched in 2017. *Passngr* is an integrated platform that allows to have all travel information on a single app, information on the flight, delays, gate changes, boarding time and other relevant information. The platform also allows for reserve parking displacement.

Passngr is not the only integrated platform available for the inhabitants of Munich.
MVG [58], the Munich's public transport authority, launched the *MVGO* platform in February 2021. *MVGO* is a MaaS platform with corresponding app created in collaboration with *Trafi* [59], that allows users find, book and pay for a variety of shared mobility services from one place.
This innovative platform presents within it all the characteristics of the MaaS, presented in the previous chapter. Users can see real-time moving vehicle on the map, the payment are simple and directly on the app, no third-party providers required.
The planning technology adjusts to real-time traffic conditions checking schedules, finding stops or mapping trips. The platform includes all operators in the city Bird, BOND Mobility, Circ, CleverShuttle, Dott, emmy, IsarFunk, Taxi Zentrale, münchner taxizentrum, SHARE NOW, Sixt, STATTAUTO München, Taxi München eG, TIER Mobility, and VOI .
Additionally, *MVGO* also integrates *M-login*, an innovative Munich's portal that lets access a wide range of digital serves around the city (i.e utility bills, parking tickets and more from a single account). [60]
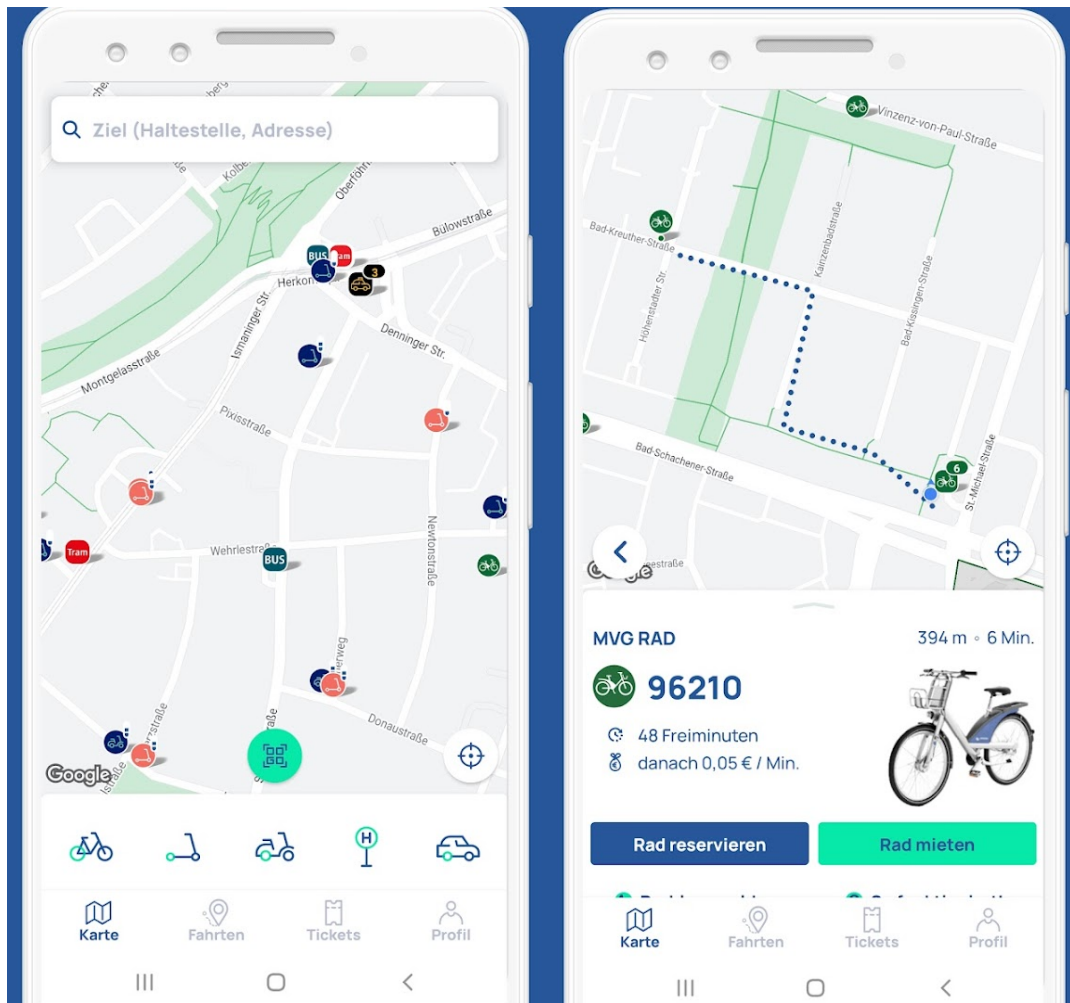
Figure 11: *MVGO* application layout [58]

2.2.2. Trafi

Trafi [59] is one of the world's leading MaaS technology company. It is present in several cities: in Berlin with *BVG* application from September 2019, in Munich with *MVGO*, in Vilnius with *Trafi* app sine 2017, in Zurich, Basel and Bern creating the world's first regional MaaS sing august 2020.

Last launch was in UK in august 2022 with a multi-city MaaS platform to connects the Uk's Solent region. The app features routing for buses, trains, ferries, and bike and e-scooter sharing and carsharing services and deeper ticket integration are coming soon.

2.2.3. Whim

One of the most advanced examples of MaaS is represented by *Whim* [61], a MaaS global application born in Finland. It is currently available in Austria (Vienna), Belgium (Antwerp), Finland (Helsinki, Turku), Japan (Tokyo), Switzerland (nationwide), United Kingdom (Birmingham). The offer provides intuitive mobility experience where customers can choose between a wide spectrum of transport packages.

Through Whim application, it is given the possibility to combine, plan, book and pay many modal options: taxis, car-sharing, bike-sharing, public transport and car rental services. As an example, it is reported the Vienna *Whim* application.

2.2.4. Vienna – *Whim, WienMobil*

At the end of October 2019, *Whim* platform was introduced in Vienna. It marked the beginning of a new era in local transport in Vienna, that was the first metropolis in Central Europe where the Finnish company MaaS Global launched the mobility app. The *Whim* mobility app was launched in Vienna with three initial partners: the public transport provider Wiener Linien (5 subway lines, 28 tram lines, 129 bus lines and 5,390 stations), the taxi company Taxi 31300 and the City Airport Train (CAT). [61]

Figure 12: *Whim* app layout [61]

In addition to *Whim* platform, the local administration has created *WienMobil* which presents itself as a digital enabler for MaaS solution providers. Now, *WienMobil* provides an open digital infrastructure that exposes data on transport services for:

- Transport operators, for data and information, payment gateways, travel planning applications and any other customizable applications;

- IT systems integrators, software houses or third parties for front-end applications.

It constitutes a sort of hub for info mobility and aims to evolve by also offering payment services for Vienna's transport and mobility services to MaaS operators in the future. [62]

2.2.5. Moovit

Moovit [63], born in 2012 operates worldwide and is the world's leading MaaS solutions company and app maker. Since 2017 it has introduced a series of MaaS tools, which use artificial intelligence for planning, management and data analysis. *Moovit*'s solutions reduce traffic, increase the number of passengers and increase the efficiency of the service, ensuring that more people use public transport and shared mobility. *Moovit* allows also to create customized, co-branded applications to reach local public transport users, build loyalty and increase satisfaction for the service.

Moovit is present in Italy in several cities, and also in Milan where it is possible to plan the trip by comparing travel alternatives, public transport, call a taxi, look at offline maps of public transport, stay update on the news.
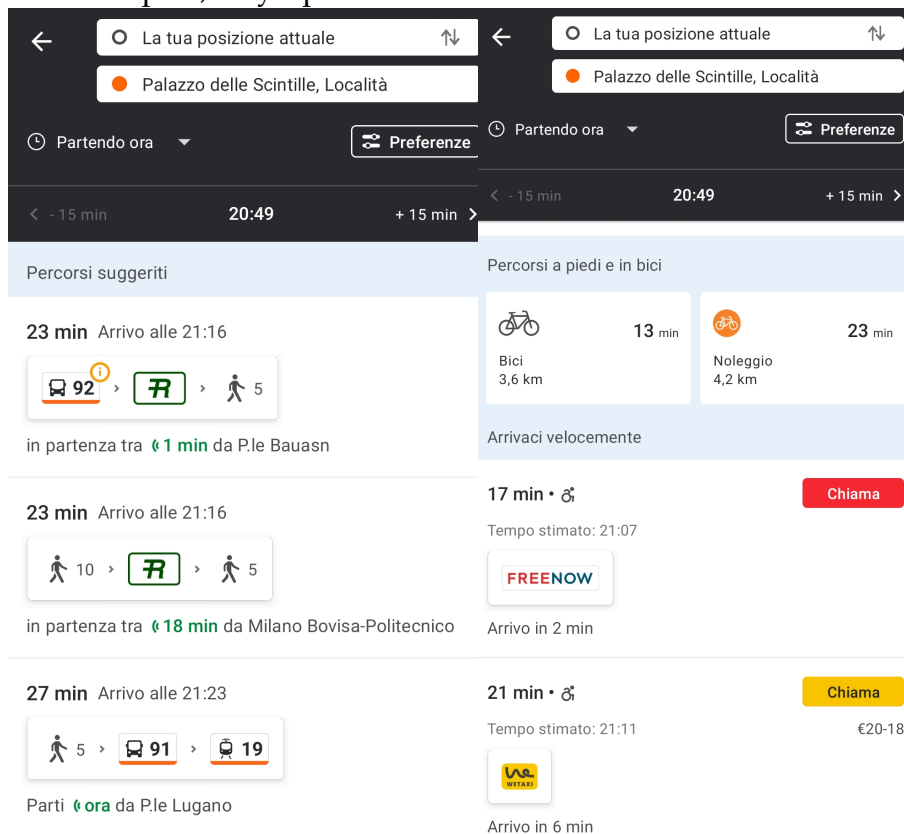

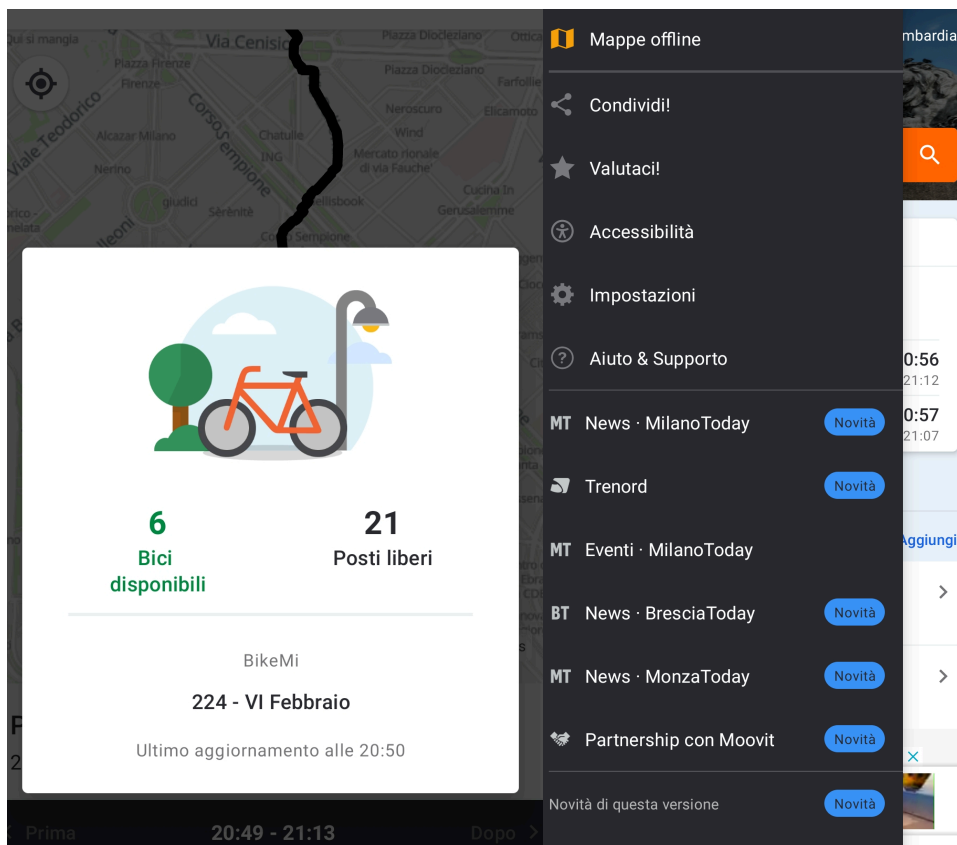Figure 13: *Moovit* app – choose the best transport solution and plan the trip [63]

Figure 14: *Moovit* app – check parking availability at destination and news update: [63]
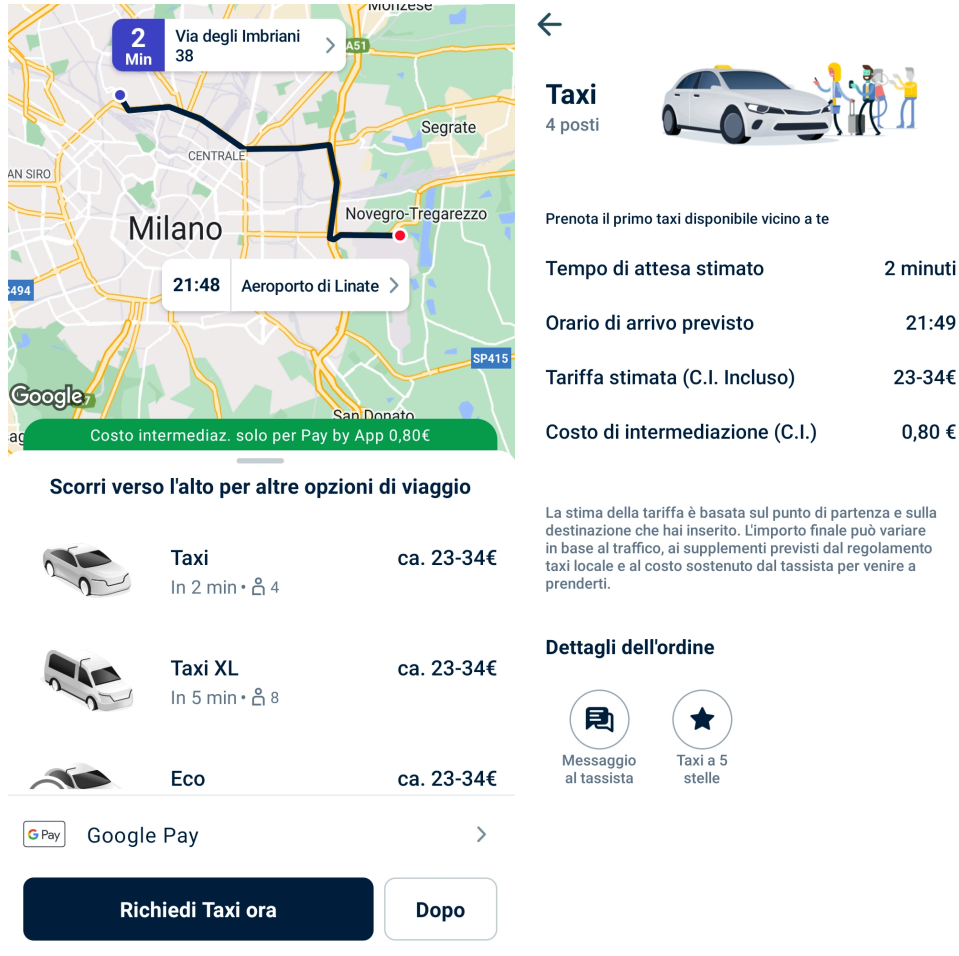
2.2.6. FREE NOW

FREE NOW [64] was born as an application to book a taxi, but it is become a multiservice platform for urban mobility that operates in over 100 European cities with 14 million passengers and over 100,000 licensed taxi drivers.

FREE NOW is part of the BMW and Daimler mobility joint venture, established in February 2019 and it is the first mobility platform in Europe to implement the "Net-Zero Emissions" project.

Nowadays FREE NOW is becoming a MaaS platform, that integrates different options of transport: e- scooters, bicycles, taxis and car sharing. It is also available at many airports, including Linate and Malpensa.

Figure 15: Alternative transport available in *FREE NOW* platform [64]

Figure 16: *FREE NOW* app - booking a taxi for the airport [64]

The summary table below shows the applications mentioned above with the respective geographical areas of use, the year in which the app began operating, the number of downloads and the score attributed by users to each app (with a score from 1 to 5). [65]

Table 1: MaaS app summary

App	Geographic area	Launch	N° download (more than)[1]	Score (up to 5)
Passngr	Munich , Hamburg, Dusseldorf	2017	50.000	3,9
MVGO	Munich	2021	100.000	3,9
BVG	Berlin	2019	1.000.000	4,2
Trafi	Vilnius	2017	5.000.000	4,7
Whim	Vienna, Antwerp, Finland, Switzerland,UK	2017	100.000	4,6
WienMobil	Vienna	2016	1.000.000	2,8
Moovit	More than 2500 cities	2012 (MaaS from 2017)	100.000.000	3,9
FREE NOW	More than 150 cities	2010 (MaaS from 2019)	10.000.000	4,1

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[1] The number of downloads refers only to downloads from Google Play

3   Milan context overview

In this chapter the focus is on the city of Milan and on the developments in mobility management that are leading to the birth of the MaaS model.

The interest to focus on the metropolitan city of Milan as a case study for the application of the MaaS paradigm is sustained by the variety of transport options already present in the territory and the openness of its inhabitants to alternative and sustainable means of transportation.

Before entering into details about the transport context in the Milan area, some conditions that are currently putting pressure on the traditional configuration of the transport system, e.g. the urbanization and pollution issues, are presented.

3.1.   Demographic growth and urbanisation

Milan represents the most important economic pole of the country; the presence of many industries and businesses and consequently the variety of job places opportunities generated have acted as real magnet, attracting people to live or daily commute in the direction of these centres.

The metropolitan city of Milan is the third most populated European area, just after the city of London and Paris and the wealthier city of Italy, registering GDP equal to 368 billion, that is around the 22% of total Italian GDP [66].

Its prosperity has contributed to incentivize even foreign people to move inside the city, further amplifying the urbanization trend.

Indeed, 14.5% of the overall population living in the metropolitan city is currently constituted by foreign citizens [66].

Lombardy has recorded an increase in the population in recent years, going from a resident population of 9.033.602 in 2001 to 9.965.046 in 2021 and it is confirmed as the most populated region in Italy for population density with 417,9 residents/km^2. [67] Figure 17 shows the variation of Lombardy population over the years with a decrease in the last two years due to the Covid-19 pandemic.
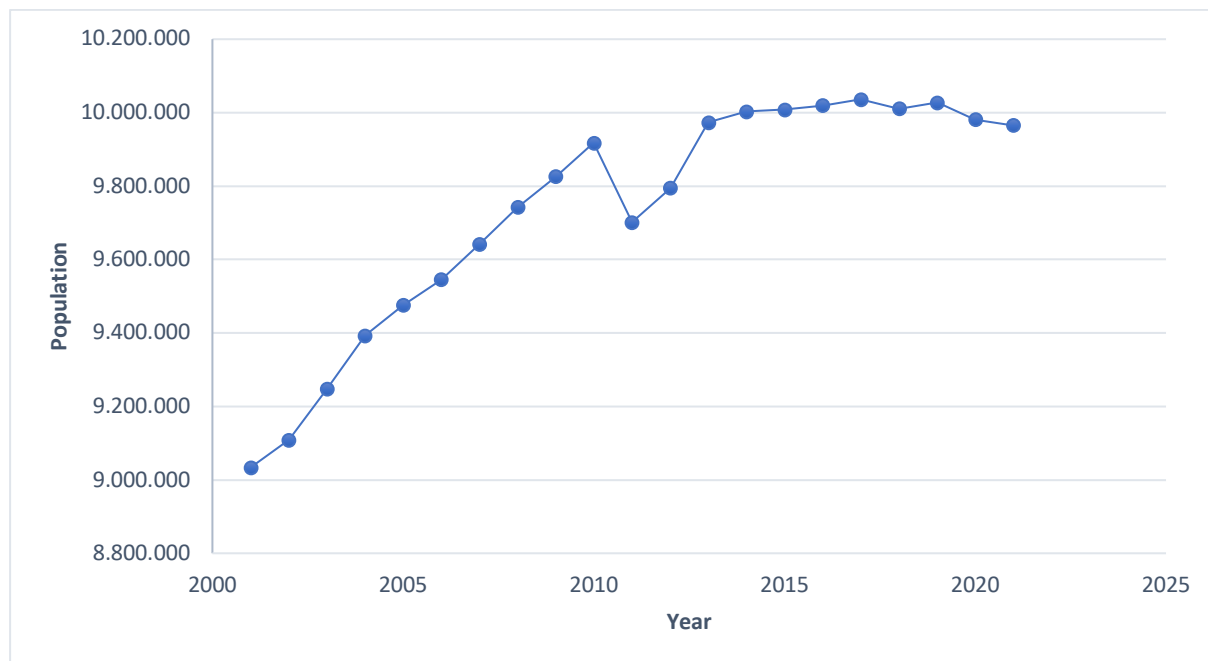
Figure 17: Lombardy demographic population [68][2]

Considering in particular the metropolitan city of Milan in 2021, it recorded 3.241.813 residents with 1.371.498 only in the municipality of Milan [69]. The municipal population density (equal to approximately 7.520 inhab/km²) is very high, in absolute terms, if compared with the average of the Municipalities in the territory of the Metropolitan City of Milan (2.000 inhab/km²). [70]

Figure 18 shows the trend of resident population over the years:a rise from 2003 to 2005 and then a decrease up to 2008 where there was a substantial increase up to 2012 (+5.5%) when the trend returns to fluctuating; from 2014 to 2019 there was constant growth (+ 55,562 inhabitants). In 2020 there was a significant caused by the Covid 19 pandemic, confirmed in 2021. [66]

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[2] The graph shows a decrease in population in 2011 because the data reported refers to the post-census population of 9 October 2011. The census population and the registered population differ. In fact, 1.338.8242 people were registered in the municipal registers on 9 October 2011, in line with the number of residents in previous years. [68]
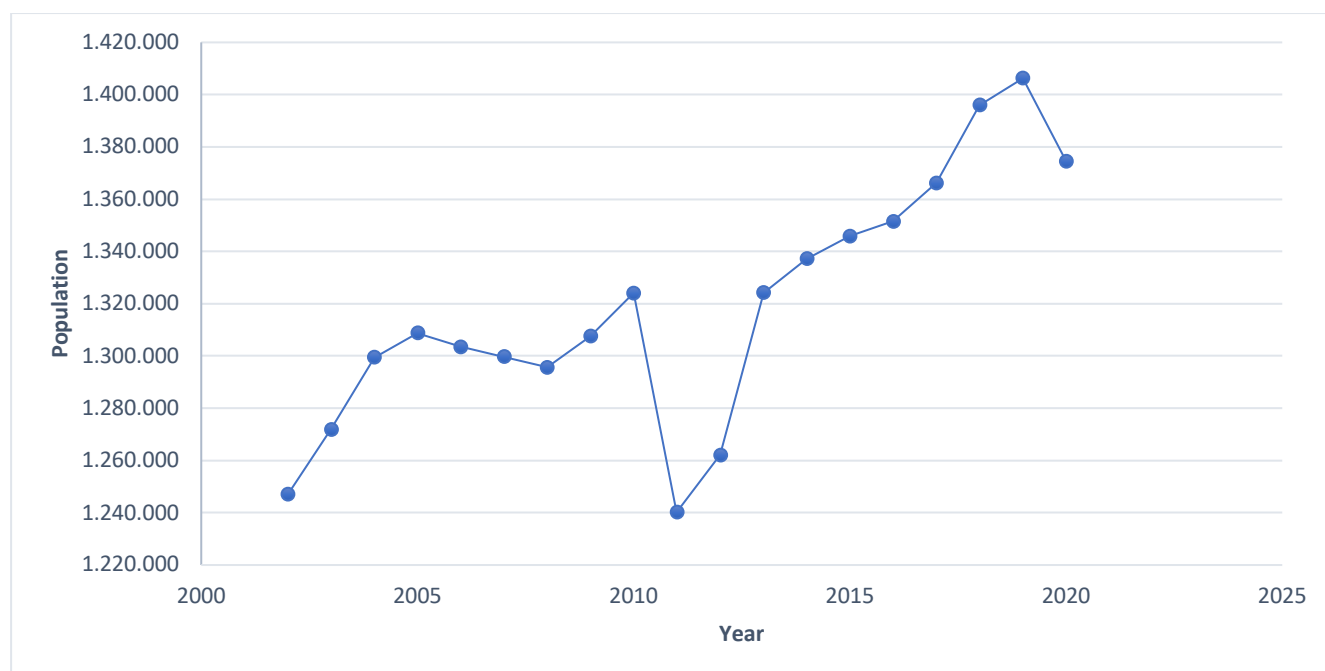
Figure 18: Milan resident population [66][3]

The consequence of being an attractive pole is that of imposing high pressure on the transport system and it makes it even more necessary to have an efficient mobility system.

3.2. Environmental pollution

Another aspect mentioned in the introduction as a determining factor for the advent of MaaS is the environmental issue.

By referring to the metropolitan city of Milan the pollution has repeatedly represented an open challenge. In addition to having negative consequences on the problem of global warming, it has direct consequences on the health of residents.

Pollution is the cause of more than 467.000 people in Europe every year, with external costs to society, linked to health, which are estimated at between €330 and €940 billion per year [71], according to the recent report on the air quality published by the European Environment Agency. Italy appears to be the first country in the European Union for deaths due to pollution with over 67.000 deaths every year. The Po valley and the Milan area appear to be the area that records the most deaths due to pollution [72].

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[3] The graph shows a decrease in population in 2011 because the data reported refers to the post-census population of 9 October 2011. The census population and the registered population differ. The number of people registered in the municipal registers on 9 October 2011 are in line with the number of residents in previous years. [66]

In the Milan urban agglomeration, the main emission source of pollutants is represented by road transport, precisely 40% of PM 2.5 and 68% of NOx have been generated by road traffic alone. [73]

To better describe the difficult picture that the north of Italy is facing in terms of air pollution, it is provided in the Figure 17 a representation of the indicator IQA recorderd from ARPA the 15 november 2022. The air quality index (IQA [74]) is an indicator that allows you to provide an immediate and synthetic estimate of the state of the air, considering critical thresholds for the various types of pollutants (PM10, PM2.5, nitrogen dioxide, ozone, sulfur dioxide). In Figure 19 the municipality of Milan is in the red area, that is the one with the worst air quality.
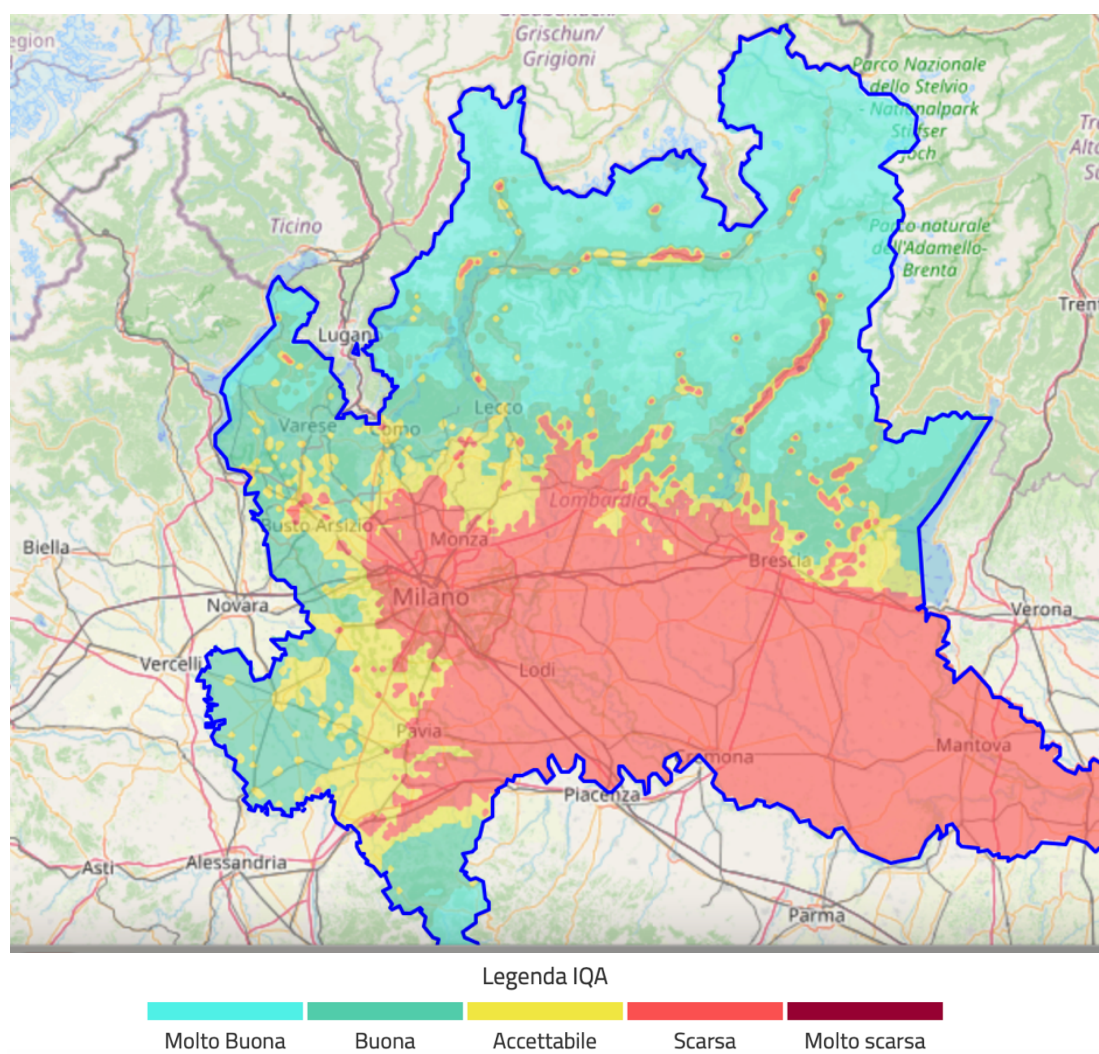

Figure 19: IQA in Lombardy (15/11/2022) [74]

Despite the downward trend relative to both the annual average of pollutants concentration and the number of days with a concentration overcoming the daily limits, the threshold values have been constantly violated [70].

By recognizing the tough situation, many sustainable policies have been adopted to reduce pollution related to transport sector.

In Lombardy, the traffic restrictions for the most polluting vehicles are in force all year - diesel Euro from 0 to 3 - in many municipalities and other more stringent ones from 1 October 2022 they are in force in winter season; there are also circulation restrictions for Euro 4 vehicles in other municipalities and municipalities with over 30.000 inhabitants.

In October 2019, the *MoVe-In* project (Monitoring of Polluting Vehicles) was launched, which provides for the possibility of monitoring vehicle journeys by installing a device on board (the so-called "black box") capable of providing the Lombardy Region with real journey. This makes it possible to introduce new control methods to limit the actual emissions produced by the vehicles themselves [75].

Furthermore, Area B is in force in Milan, a restricted traffic area with a ban on access and circulation for the most polluting vehicles.

In addition to policies previously cited, other initiatives have been adopted to pursue a more sustainable condition: From 2008 to 2014 it is recorded an increment in the size of pedestrian areas, in the length of cycle paths and in the coverage of limited traffic zones to disincentivize the car's usage; the wide proliferation of sharing transport operators; the replacement of old and polluting public fleet with electric modes. [76]

Consequently, given the high focus of regulations in the research for a more environmentally friendly transport system, the premise of Mobility-as-a-Service to reduce car ownership offers an innovative mobility solution that could theoretically find support even at a political level.

3.3. Demand analysis

To estimate the demand of mobility *Regione Lombardia* has produced in 2014 the regional Origin-Destination (O/D) matrix [77] with the objective of depicting as precise as possible the actual representation of the transport reality. It consists in a publicly accessible dataset. One relevant characteristic that emerged is, indeed, the great number of daily mobility movements affecting the metropolitan city of Milan, reaching nearly the 30% of the overall trips realized in the Lombardy region. it is possible to notice how the Lombardy's capital is interested every day by more than 4,6 million internal trips.

Table 2: O/D Matrix of Lombardy's province (2014) [77]

	BG	BS	CO	CR	LC	LO	MB	MI	MN	PV	SO	VA	Tot, Riga
BG	1.547.574	72.016	3.858	12.252	17.897	666	13.015	64.376	659	1.490	682	1.863	1.736.347
BS	64.370	1.926.364	684	14.963	632	1.045	2.123	15.336	21.817	1.098	824	1.092	2.050.349
CO	3.738	678	711.362	294	17.024	407	46.160	41.078	173	948	4.431	34.852	861.145
CR	12.287	15.571	336	501.052	226	13.933	958	18.252	12.380	1.544	59	327	576.927
LC	18.802	656	17.511	230	406.438	207	42.873	20.927	24	403	4.502	1.533	514.107
LO	667	1.014	399	14.434	205	258.343	493	51.614	218	9.376	47	399	337.210
MB	12.622	2.133	44.105	946	39.946	479	931.920	247.695	241	1.452	542	10.555	1.292.635
MI	60.007	14.866	37.579	16.989	18.817	49.218	234.655	4.652.334	654	74.868	811	121.810	5.282.608
MN	720	22.060	192	12.039	41	245	241	669	634.112	720	48	350	671.439
PV	1.537	1.046	1.019	1.612	439	9.792	1.443	77.152	659	719.164	103	2.045	816.012
SO	702	790	3.915	58	4.246	48	496	837	34	92	279.384	310	290.910
VA	1.943	1.166	33.547	329	1.487	425	10.425	126.759	322	2.093	284	1.190.280	1.369.059
Tot, Colonna	1.724.970	2.058.361	854.506	575.198	507.397	334.810	1.284.802	5.317.029	671.292	813.249	291.718	1.365.416	15.798.748

More recent estimates are calculated by *Agenzia Mobilità Ambiente e Territorio*, (AMAT), the agency of the Municipality of Milan which carries out traffic analysis, monitoring, processes data and cartographies, develops models and simulations.

According to the pre-Covid 2019 period there the overall demand for mobility gravitating to Milan in the 7:00-20:00 time slot, was around 4,3 million trips. In details:
- 2.460.000 internal journeys in Milan;
- 1.860.000 journeys to and from the Milan border.

This estimate, which refers to an average working day in 2019, was carried out, as part of the update of the *Piano Generale del Traffico Urbano*, starting from the elaborations supporting the preparation of the Sustainable Urban Mobility Plan, integrated and refined with the available data, relating to the monitoring of vehicular traffic flows and passengers transported by the different public transport services [70].

The data on the choice of means of transport for the year 2019 is also available in Figure 20, where it is noted that the share of journeys made by public transport, within Milan, covers 47% of the total journeys. Considering only the transfer journeys between Milan and the outside world, the percentage of journeys by private motorized vehicle rises to 63%, indicating the need to improve accessibility to the public transport network in the urban and extra-urban area [70].
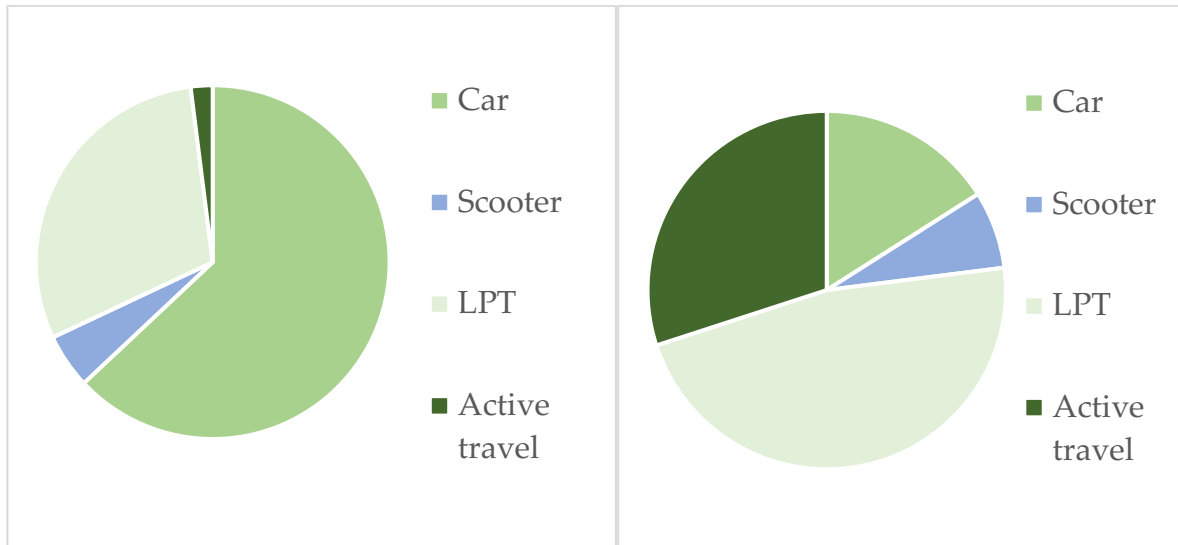
Figure 20: Modal choice from/to Milan (left) and for internal trips (right) [70]

In the previous analysis, the change in demand induced by the pandemic was not considered. The demand for mobility on the local public transport services of the Municipality of Milan suffered a significant drop first due to the Covid-19 emergency and then to the new working structure which introduced an important share of smart working. The scenario at the end of the emergency in May 2022 still shows a significant drop in demand on public transport (-30%) and is still very dynamic, assuming further growth in 2022 and 2023 also induced by the new opening of Metro 4 in November 2022. [70]
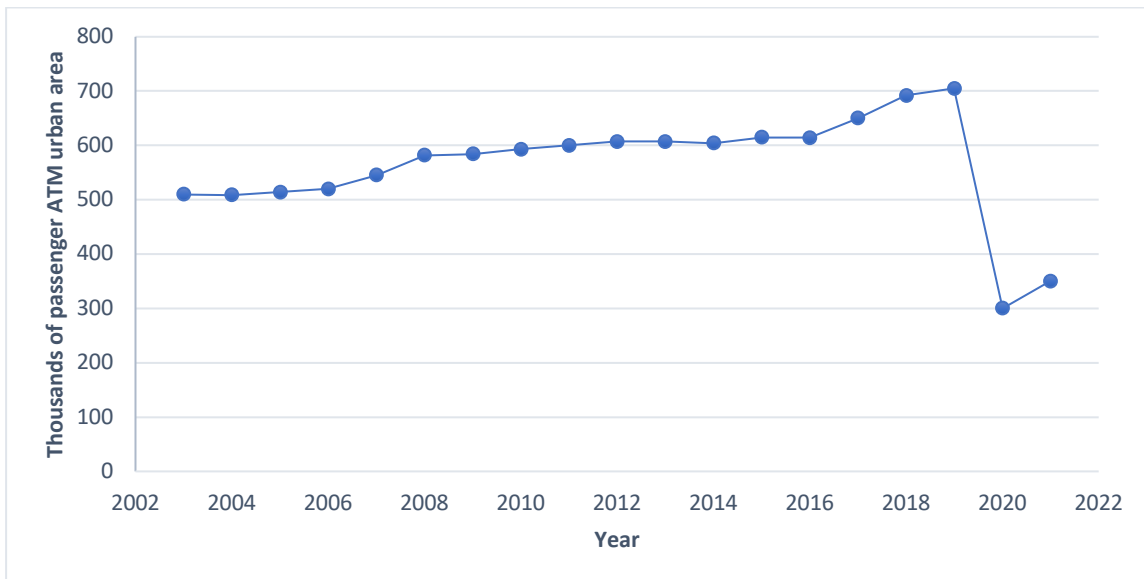

Figure 21: Thousands of passenger ATM in urban area [70]

3.4. Transport system in Milan

After an overview of the quantity of transport demand to be satisfied, the transport offer available to users is now reported.

The great variety of transport operators present in the city of Milan represents a fertile ground where to implement the Mobility-as-a-Service paradigm. Indeed, the wide public transport coverage together with the increasing amount of sharing mobility actors are fundamental conditions to the creation of a MaaS initiative, capable of adapting to the variety of citizen mobility needs. Milan has most of the typical means of local public transport, surface and underground, various types of car, motorcycle, scooter and bicycle sharing and the taxi system in the area is also mentioned.

3.4.1. Private car

The analysis of the vehicles used in Milan starts with the private car, which is chosen in 16% of trips in the urban area and in 63% of intercity trips. The motorization rate can be considered an indicator of the propensity to use the car and of the overall state of the mobility system. According to the *ACI* (Automobile Club d'Italia) [78], at the end of 2020, the vehicle fleet in Milan amounted to 958.203 vehicles, of which 71,8% were cars and the remainder were motorcycles. The consistency of the car fleet in Milan is decreasing, there was a decrease of 7% from 2004 to 2020 and the relative motorization index also decreased by 13%. While there is a growth in the number of motorcycles of 55% from 2004 to 2020 [70].

3.4.2. Public transport service

The offer of local public transport services in Milan is provided mainly by ATM S.p.A (Agenzia dei Trasporti Milanesi) [79]. ATM is a company founded in 1931 to manage the Milan transport network, 100% controlled by the Municipality of Milan. Over the years it has currently facing a long-lasting period of growth and has also been operating abroad since 2008. Sustainability has been fundamental for years for ATM which, according to the 2021-2025 strategic plan, has among its priorities the transition to a zero-impact fleet in 2030 with the full electric plan.

The company offers the following services: [80]

- 5 operating metro lines with overall length of 102 km;
- 134 bus lines and 4 trolleybus lines with overall length of 1500 km;
- 19 tramway lines with overall length of 180 km;
- on-demand Radiobus service;
- 24 park spaces implemented in crucial areas for modal shift;
- street parking system;
- bike-sharing service *BikeMi*.

The second public transport provider operating in Milan and the entire Lombardy region is Trenord S.r.l, a railway company founded in 2011 and equally owned by Trenitalia and FNM S.p.a. Trenord with a network of over 2000 km and 460 stations

reached, serves over 550.000 travelers/day [81]. In addition to suburban and regional lines covering the entire Lombardy area, Trenord also offers a railway line to connect Malpensa airport to the center of Milan called *Malpensa Express*.
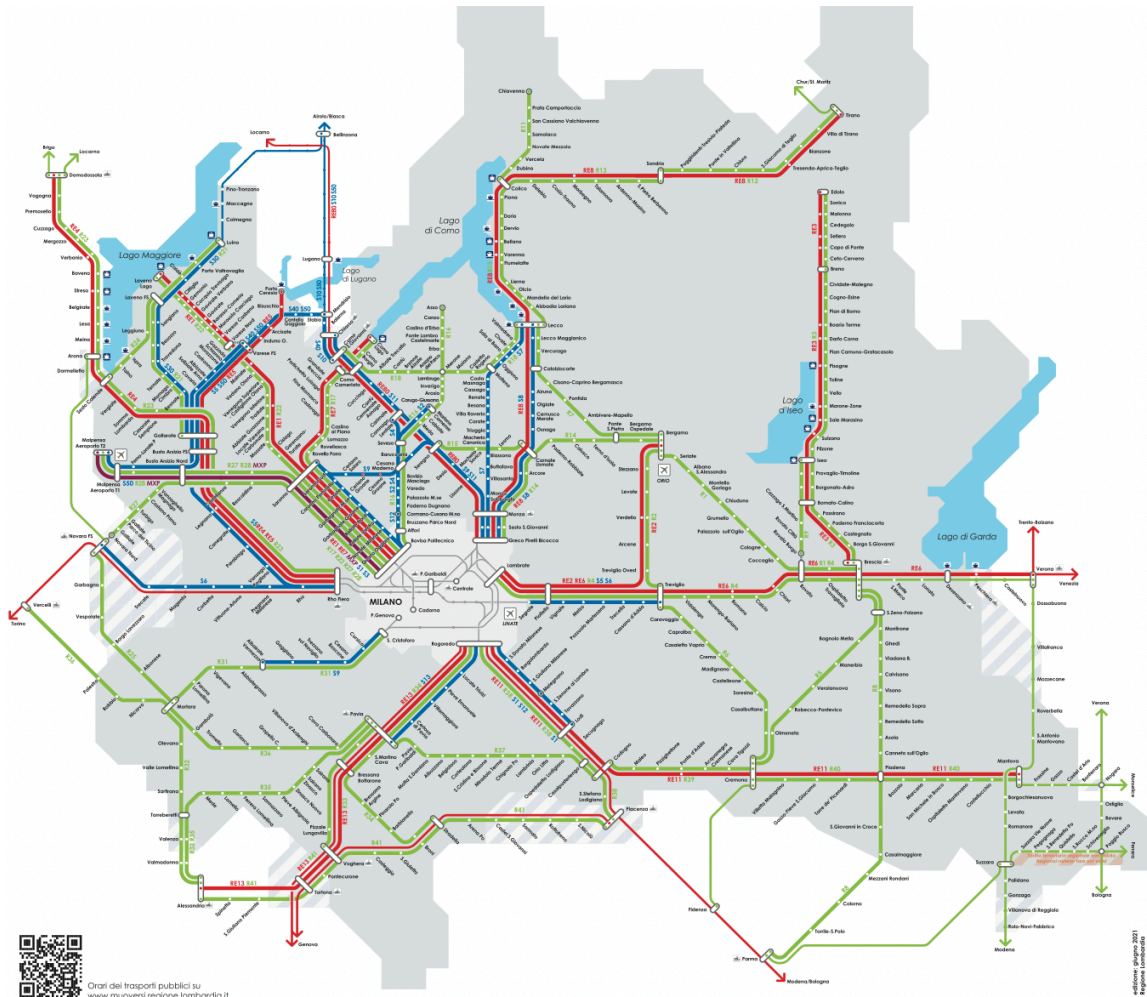

Figure 22: *Malpensa Express*, regional and suburban lines in Lombardy [81]

In the municipality of Milan Trenord also manages 12 urban railway lines.
Figure 23 shows the metro lines managed by ATM and Trenord urban railways lines.
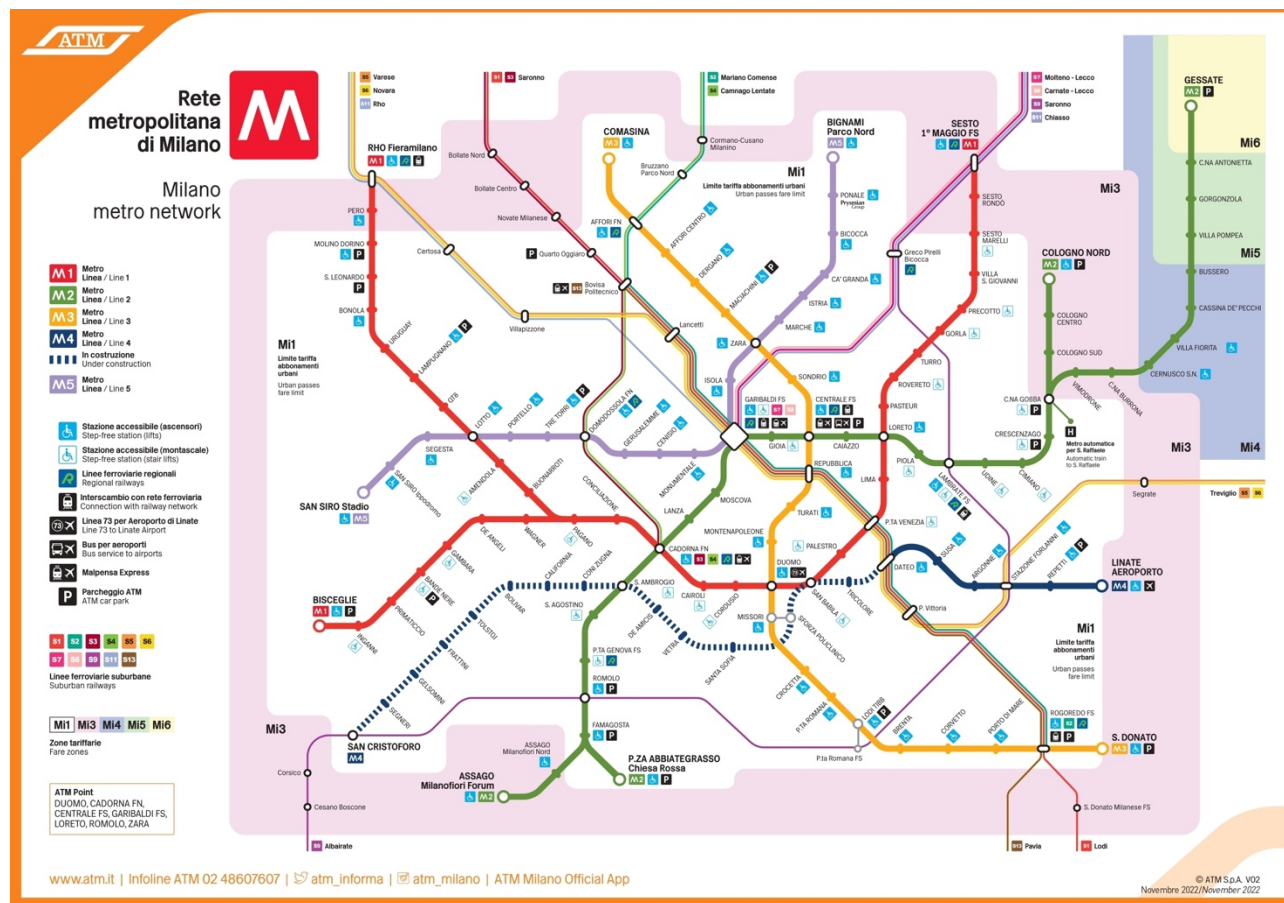
Figure 23: Metro and railway offer in Milan [82]

To complete the illustration of the public transport operators, it should be mentioned the presence of other transport actors, offering bus lines within the Milan metropolitan city in 6 different areas. Here is presented an overview of the companies with the number of bus lines and the specific area of responsibility: [83]

- *Autoguidovie* with 16 lines in the south-east area [84]
- *Net* with 5 lines in the north-east area [85]
- *Air Pullman* with 23 lines in the north-east area [86]
- *PMT* with 5 lines in the south-west area 5/B [87]
- *STAV* with 9 lines in the south-west area 5/A [88]
- *Movibus* with 25 lines in the west area [89]

To improve the integration of the various modes of transport present, also from a MaaS perspective, *Sistema tariffario del bacino di mobilità* (STIBM) [90] was introduced in 2019. It extends to all the municipalities that are part of the metropolitan city of Milan, the Province of Milan and Monza and Brianza as well as some municipalities outside the province. The fare between two locations does not depend on the means of transport used and is calculated simply on the basis of the number of zones within which one travels. The STIBM tickets allow, within the time validity and the areas purchased, to

travel along several routes and combining several vehicles, both continuously and with several intermediate stops [91].

3.4.3. Sharing mobility

The importance of shared mobility vehicles is recognized by MaaS practitioners and also in the program "Mobility as a Service for Linking Europe" (*MaaSiFiE*) [92], where it is recognized as one among the three key components that constitute the MaaS paradigm.

Thanks to the coverage of a wide and capillary area, car-sharing, bike-sharing, scooter-sharing, and e-hailing services are all capable to further increase the attractiveness of the traditional inflexible public transport offer [93]. This effect is mainly driven by the possibility to combine along the journey to the public vehicles different sharing mobility solutions and consequently enabling the resolution of the first and last mile problem.

Thus, the wider is the range of mobility solutions that could be combined, the higher the variety of seamless trips satisfying different user's needs offered by the service. Consequently, it will be generally reduced the sense of urgency to own and use proprietary vehicles.

Within sharing mobility, each company offers services with specific features. A first distinction that can be made is between station-based and free floating. in the first case, sharing is based on fixed pick-up and drop-off stations for the vehicle. Instead, the free-floating configuration is the most flexible solution enabled for carsharing services, since there will be the possibility to pick-up and drop-off the car in any predefined park area within the boundaries.

Starting with the carsharing, in Milan the offer of sharing is very wide, so that the city of Milan won the prestigious "International Carsharing City Award" in the metropolitan category in 2020, a global competition that rewarded the cities that stood out most for having introduced and maintained a car sharing system in their city over time [94].

The mobility service providers operating in the urban area are summarized in the following Table 3: with the principal features. Among the common elements there is the propensity for electric vehicles, to provide an alternative to public transport that is as sustainable as possible; in addition, the various companies provide flexibility for parking also with dedicated parking spaces.

Table 3: sharing companies in Milan

	Minimum Tariff	Configuration	App score (up to 5) [95]	N° download app [95]
Enjoy [96]	1€ + 0,19 €/min Daily tariff available	Free Floating	2,1	More than 1 milion
ShareNow [97]	0,19 €/min Tariffs on more days available	Free Floating	4,3	More than 1 milion
e-Vai [98]	7,20 €/hour (min 3 hours) 39 €/day	Station-based	2,2	More than 10.000
Ubeeqo [99]	7 €/hour (min 4 hours) 54 €/day	Free Floating	3,5	More than 100.000
Leasys [100]	0,32 €/min	Free Floating	2,2	More than 10.000

A distinction between free floating and station-based configurations can be made also for bike sharing services. In total, there are 15.400 bicycles of different types in Milan, 3.500 are pedal assisted [101]. Also in this case there are various companies, summarized in Table 4, which offer the service by offering subscriptions of various types and different types of bicycles, traditional or electric. To benefit most of the bike sharing service and in general to encourage the use of the bicycle, even for personal use, it is essential to have a road infrastructure that allows it to be used in complete safety. In Figure 24 the cycle paths present in the area are shown in blue. It is evident that many areas remain without this service, but the city of Milan continues to improve the situation. [102]

50

Table 4: Bike sharing companies in Milan

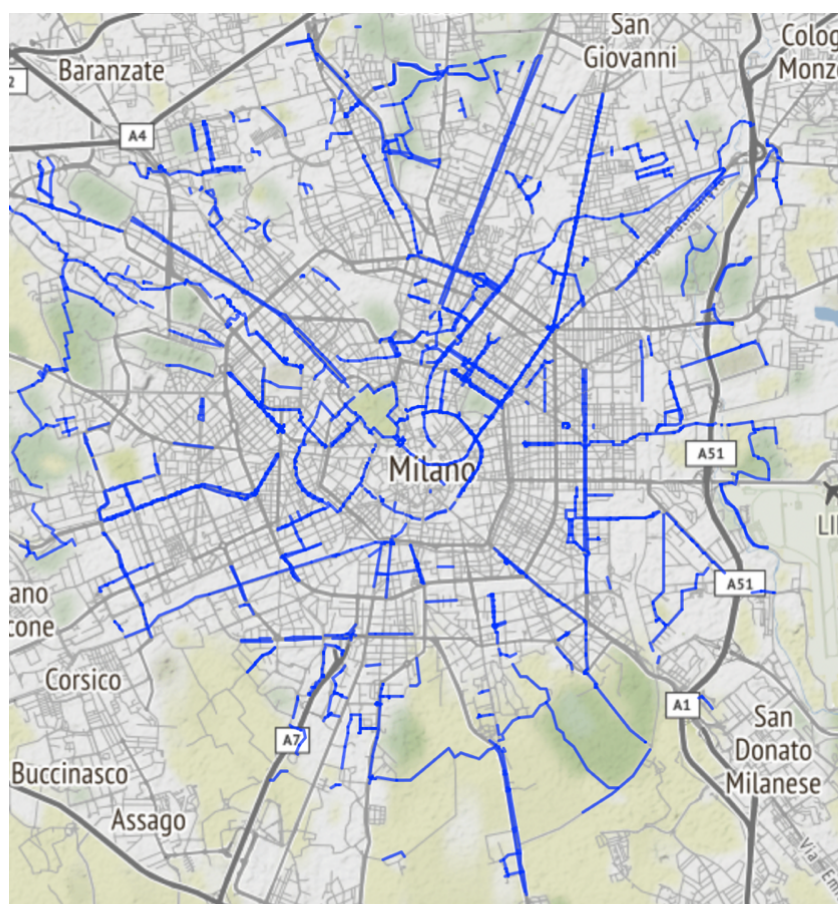|	Configuration	App score (up to 5) [95]	N° download app [95]
Ridemovi [103]	Free Floating	3,5	More than 500.000
Lime [104]	Free Floating	4,7	More than 10 milion
BikeMi [105]	Station-based	2,9	More than 50.000

Figure 24: cycling path in Milan [106]

Concerning scooter sharing, the available methods are similar to those of bicycles and cars, with the possibility to access and leave the scooter in any permitted place within a restricted area. In the city of Milan, the free-flow scooter sharing service has been active since 2015 with a fleet of 100% electric vehicles. The available companies are the following: *MiMoto, ZigZag, GoVolt, Cityscoot, eCooltra, Acciona* [107]

The latest service introduced in the sharing mobility category is the one concerning kick-scooter sharing services. The micromobility service was introduced in February 2020 at the conclusion of a regulatory process which defined the areas of experimentation and which led to the liberalization of electric micromobility by equating the rules of use to those of the bicycle. The number of active companies are seven: *Dott, Bit Mobility,Bird, Helbiz, Lime, Voi, Tier*. [108]

This overview lets understand how sharing mobility is currently a real phenomenon taking place in the city of Milan. Indeed, the metropolitan city is recognized as an open-air laboratory to be exploited to analyze the evolution of this new mobility era.

To quantify the use of the services Figure 25 show how the pandemic has affected the sharing system in Milan. There has been an increasing number of bicycles available and after a decrease of use of the services in December 2021 in the last few months they are increasing the number of rentals. After the pandemic period, the number of rentals registered by sharing mobility services grew by 113% between January and June 2022. [109]
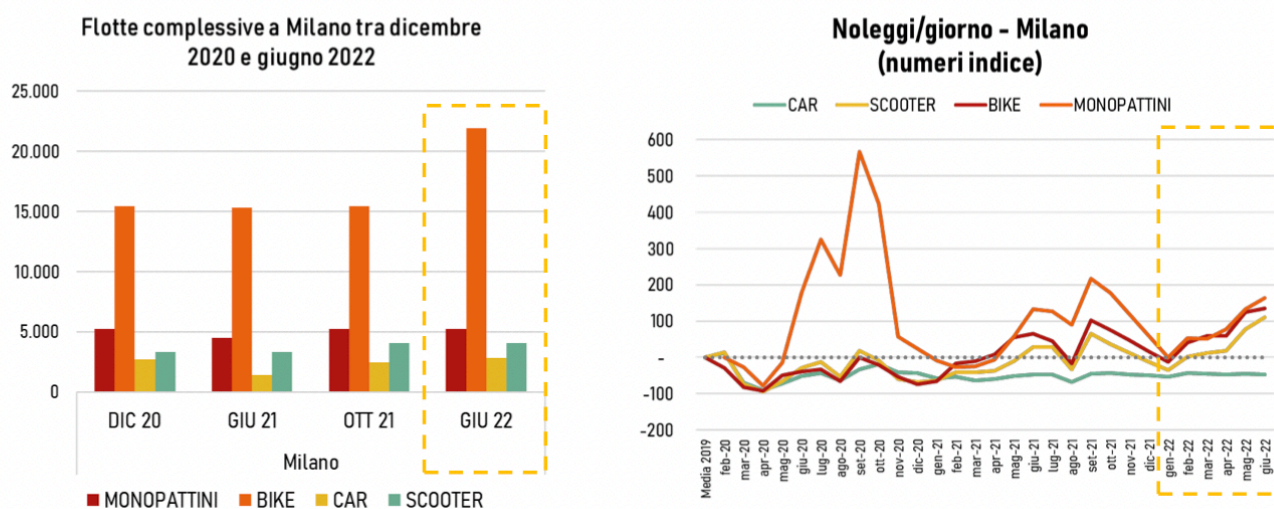
Figure 25: sharing mobility statistics in Milan during and after Covid-19 [109]

3.4.4. E-hailing services

To complete the overview of the transport offer in Milan, we must mention the e-hailing service, which includes mainly the taxi services. In this case, consumers will simply type the point of departure and the one of arrival within the application. Thus, the service will be in charge for sending all the information to the selected taxi driver, enabling the realization of digital economic transaction.

the e-hailing service is another dynamic market present in the city of Milan. According to a Bocconi University study [110] 51% of Italians use a dedicated app to book a taxi, 38% go to a parking lot or stop a car on the street and only 11% use the service call phone. The advantages found are a decrease in the average wait, an increase in the number of trips for taxi drivers, more security with digitally traceable payments, the possibility of booking a trip for third parties and the transparency offered by digital platforms. Among this category could be mentioned *FreeNow, WeTaxi, AppTaxi, inTaxi* and *itTaxi* services, which are all used to let interact the demand side with the supply one.

4   MaaS in Milan

Before the details of the MaaS4Mi project with its objectives and its actors involved, it is presented the MaaS4Italy project which led to the choice of Milan as one of the three leading cities for the MaaS experimentation in Italy.

4.1. MaaS4Italy

The *MaaS4Italy* project is part of the series of projects of the *Italia Digitale 2026* strategy, the investment plan within the *National Recovery and Resilience Plan* (*PNRR*) dedicated to digitization and innovation. [111]

In particular, the project is financed by the investment number 1.4.6 of *PNRR* for a value of € 40 million aimed at the development of new mobility services, based on the MaaS paradigm to promote data sharing, reusability and the interoperability of transport systems. The investment provides for specific public selection procedures aimed at selecting the large metropolitan cities in which test MaaS solutions, where the implementation of MaaS solutions is expected to generate the greatest benefits.

The selection to identify the cities from which to start this project was launched with the public notice of *Dipartimento per la trasformazione digitale* (DTD) and of *Ministero delle Infrastrutture e della Mobilità Sostenibili* (MIMS) on 1 October 2021 with the deadline on 29 October 2021. [112] [113]
The aim was to identify and finance three pilot projects in technologically advanced metropolitan cities, in which a higher probability of success is expected.

The notice also aims to provide a measure of financial support to local transport operators to digitize their systems and services (e.g. electronic ticketing), thus promoting integration with the Data Sharing and Repository Facilities (DS&SRF) [114]. This repository will be the tool for data sharing and the collection/display of the enabling services and data of all the mobility managers involved. Figure 26 shows the DS&SRF and the parties involved in the MaaS platform. A financial support measure will also be provided to local transport operators to digitize their systems. One of the three cities will serve as an experimentation laboratory (Living Lab - "Cooperative, connected and automated mobility") to test innovative local transport solutions (e.g. advanced driver assistance systems, Vehicle-to-X communication technologies etc.).
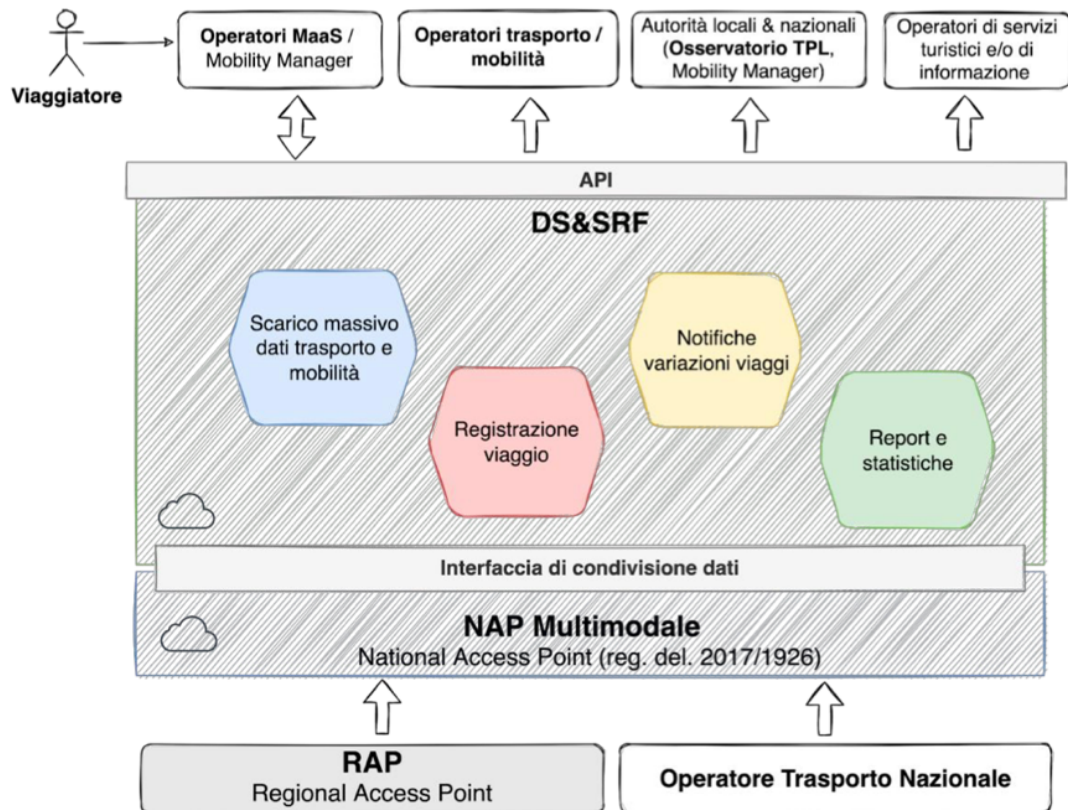
Figure 26: Data Sharing and Repository Facilities [114]

On 28 February 2022, the final ranking was published, and the cities of Milan, Rome and Naples were the three leader cities chosen, out of the 13 participating cities [115] [116]. The Milan project will be detailed in the next paragraph.

Similarly, to the first notice, a second public notice was published on 2 May 2022 to identify three other cities to continue the project with a deadline of 6 June 2022. The results were published on 27 July 2022 with the cities of Bari, Florence and Turin as winners. [117]

Dipartimento per la trasformazione digitale and *Ministero delle Infrastrutture e della Mobilità Sostenibili* are planning to extend the project experimentation to seven other territories in the coming months. [118] The steps of MaaS4Italy are summarized in Figure 27.
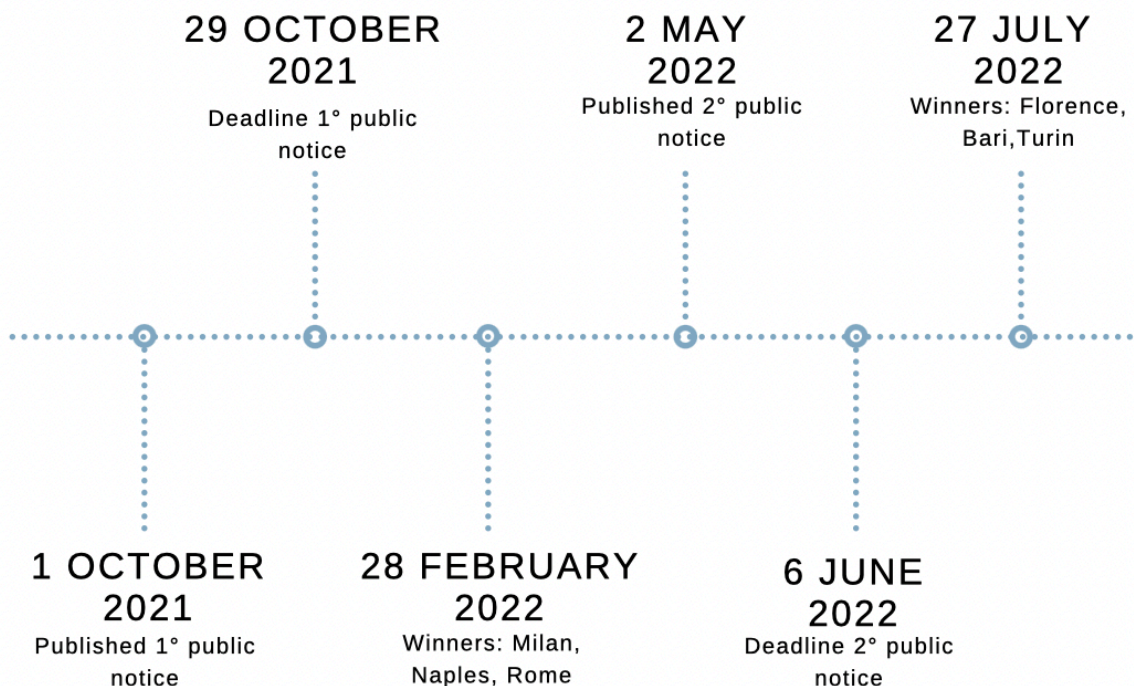
29 OCTOBER 2021
Deadline 1° public notice

2 MAY 2022
Published 2° public notice

27 JULY 2022
Winners: Florence, Bari,Turin

1 OCTOBER 2021
Published 1° public notice

28 FEBRUARY 2022
Winners: Milan, Naples, Rome

6 JUNE 2022
Deadline 2° public notice

Figure 27: MaaS4Italy steps [119]

4.2. MaaS in Milan

MaaS has been a hot topic in Milan for a few years now, even before the decision to dedicate funds from the PNRR to develop this model. In the next paragraph, the l'*Agenzia Mobilità Ambiente e Territorio* of the municipality of Milan, responsible for the development of the project in the city, will be presented and subsequently the steps that led to the approach to MaaS.

4.2.1. AMAT

Agenzia Mobilità Ambiente e Territorio (AMAT) [120] is a technical structure of the Municipality of Milan which, since 2000, has carried out services in support of the municipal functions in the fields of planning, programming, design, management, monitoring and control relating to different topics in the area of Milan. Since 2009 the company has become the exclusive property of the Municipality of Milan, therefore it is an "in house" company.

The area of expertise the development of the territory and green areas, urban planning, mobility and public transport, parking on the road and in structures, road safety, environmental resources such as air, physical agents, water resources, the circular economy, energy and the climate.

The work carried out by *AMAT* is aimed at achieving the sustainable development goal 11 of UN Agenda: "Make cities and human settlements inclusive, safe, resilient and sustainable" [121]. Relevance in this context has all the activities related to the evolution of mobility systems, green areas and the quality of public spaces as well as attention to air quality and the management of resources contained in waste, and with particular attention to support of new technologies for the search for sustainable solutions.

Among these initiatives there is also the attempt to have a mobility based on the MaaS model.

4.2.2. MaaS4Mi

The first step towards an integrated system took place with the world exposition in Milan in 2015. On that occasion the *Ecosistema Digitale E015* [122] was launched, it was an initiative promoted by the Regione Lombardia together with Expo 2015 SpA, Confindustria, Camera di Commercio di Milano Monza Brianza Lodi, Confcommercio Imprese per l'Italia, Assolombarda e Confcommercio Milano Lodi Monza Brianza, and Cefriel.

E015 – Ecosistema Digitale it is an open digital environment of cooperation for the development of integrated software applications and it represents an important opportunity for the development of the territory.

The aim was to encourage the creation of digital relationships between different subjects, both public and private, interested in enhancing their digital heritage by sharing it or in enriching the software solutions for their users with the functions and information shared by the other participants. [123]

At the beginning of the experimentation of the digital environment, one of the problems that *E015* wanted to solve was that each service manager provided specific and vertical information, without giving the citizen the possibility of having a truly integrated service. This problem was also found in the field of info mobility. Figure 28 shows an example of how the new service aimed to provide information on the traffic conditions of the Milan metropolitan area on the same web page. [124] Obviously, it was not a MaaS platform, but it was a first attempt at integration.
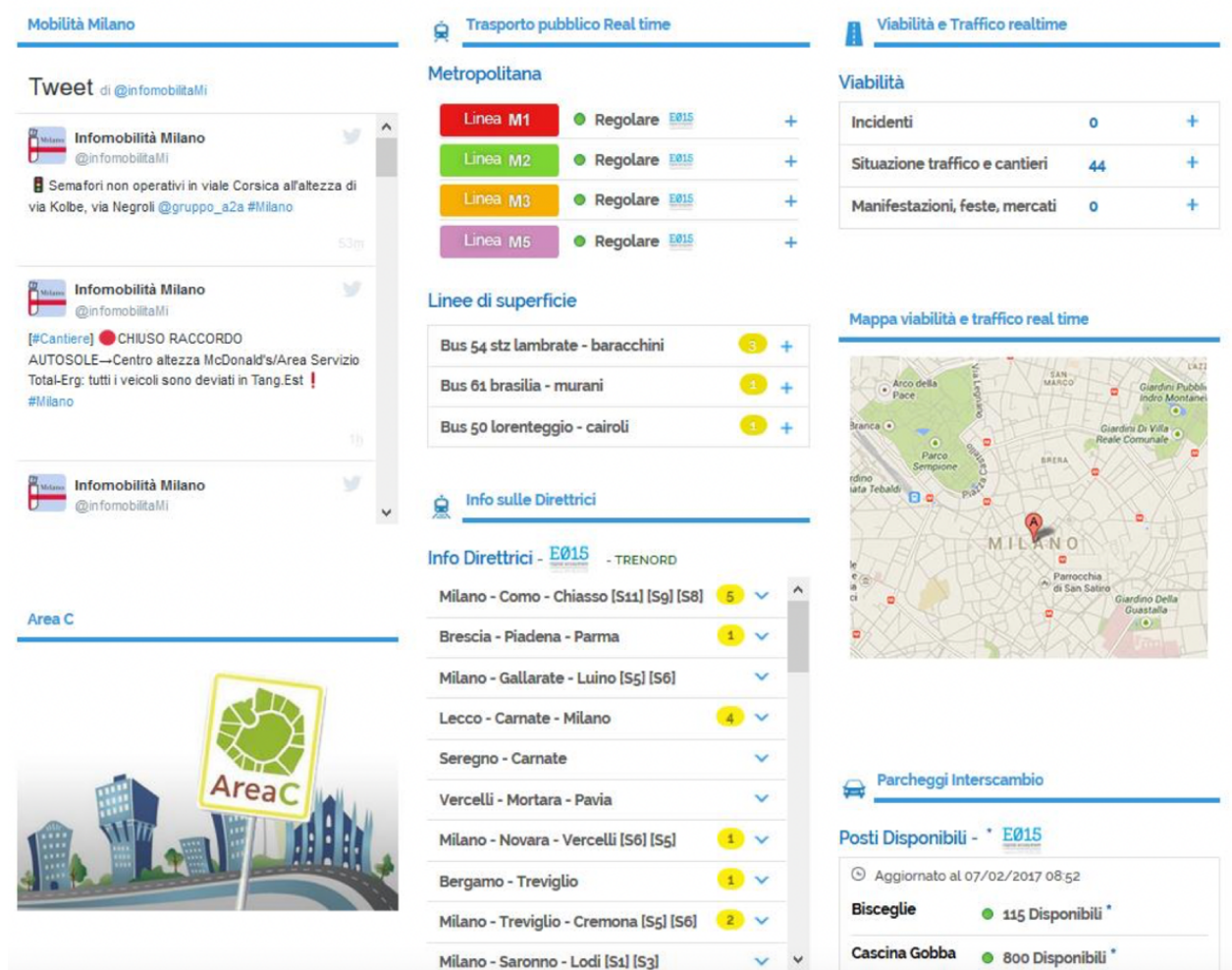
Figure 28: Info mobility provided by *E015* [124]

In the following years thanks to the example of MaaS models that were developing in Europe, the idea of replicating the Finnish example began to spread in Milan too. *AMAT* already in 2018 in the urban mobility plan [125] predicted the need to integrate collective mobility services and in the same years it studied strategies to implement this MaaS model. The opportunity to kick off the project came with the publication of the MaaS4Italy tender.

After the publication of the results of the tender and the choice of Milan as one of the 3 cities to experiment with the pilot project, the municipality published a public notice on July 18 2022 with a deadline of September 9 2022 for [126] the identification of private operators for the role of MaaS Operator. The experimentation phase will be in 2023. Figure 29 summarizes the steps of the development of MaaS in Milan.

The actors involved in the project are the following:

- *Comune di Milano* – with the role of promoter of MaaS services and Guarantor of transparency and guidance of Public Policies. The role of the Municipality is to verify compliance with the project deadlines and compliance of the platform with the integration and interoperability requirements, so as to ensure compliance with the requirements to participate in the experimentation. The Municipality, in compliance with the principle of free competition, favors the development of the MaaS project with initiatives to support users (discounts and travel vouchers aimed at specific groups of users and/or eco-sustainable means of transport) and through a promotional campaign for the service , covering the role of "accelerator" of the MaaS service, using the economic resources made available by the notice to stimulate the adoption of the service through incentive mechanisms aimed at the end user;

- MaaS Operator – service providers that aggregate the various travel and transport options and allow the user to have integrated access to the overall transport offer existing in the area. these interested parties must be willing to create a MaaS proposal that sees the integration of several "Transport Operators" (including the LPT operator) with a multimodal offer that involves at least three different types of transport. The MaaS operators will therefore also be responsible for the technological platforms for the provision of services to users (B2C); [127] [128]

- Transport Operators – as interested parties who, through commercial agreements stipulated exclusively with the MaaS Operators, will see their supply and market opening capacity increase compared to the current individual capacities, in compliance with equal treatment and non-discrimination towards the end user;

- Users – with the role of active participants in the experimentation, also thanks to contributions which, based on specific identified clusters, they will receive from the Municipality of Milan to test the system and encourage its use.
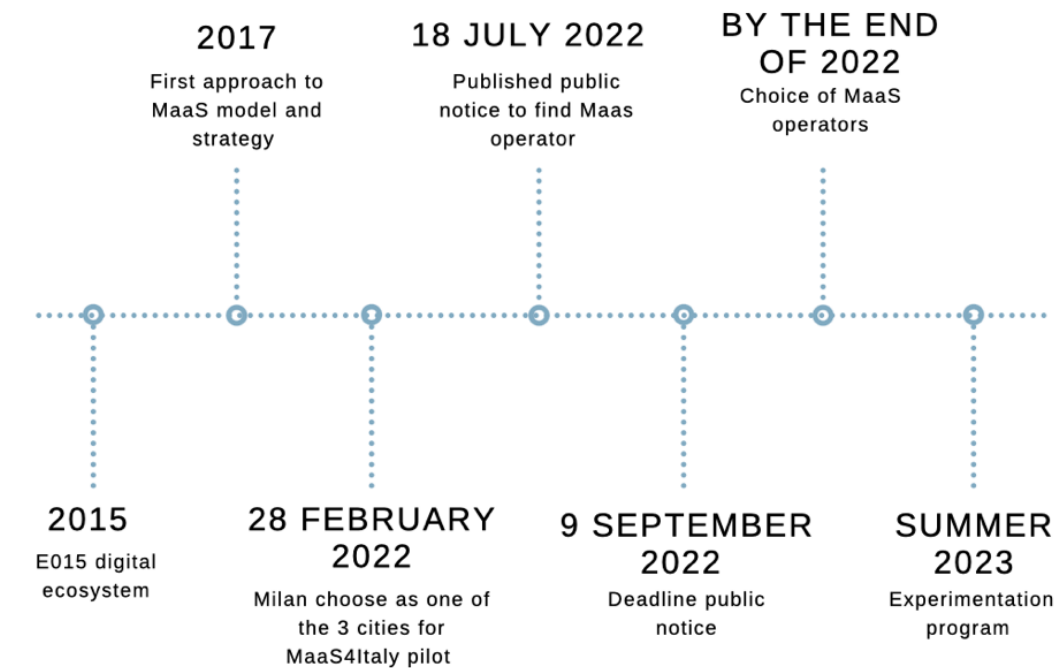
Figure 29: Steps MaaS in Milan

5 Linate airport accessibility

5.1. Linate overview

Linate Airport is the city airport of Milan, located 9 km east of the center of the city. The airport occupies a total area of 350 hectares in the south-eastern part of the Province of Milan, extending into the municipalities of Peschiera Borromeo, Segrate and Milan. [129]

Figure 30: Territorial overview Linate [130]

The airport is aimed at frequent flyer customers on national and international intra-European routes and in 2021 the new Terminal was inaugurated, profoundly renovated according to an avant-garde design.

In 2021, Linate airport handled 4.3 million passengers, equal to 65.9% of the traffic operated in 2019, and equal to 91.3% of the traffic operated in 2020, when Linate airport was closed from 16 March to 15 July for Covid-19 pandemic. The new pandemic wave recorded in the first months of 2021 and the consequent travel restrictions contributed to delaying the recovery of traffic. A partial recovery in volumes took place only starting from the month of May, a trend which consolidated in the summer months and lasted until November. The spread of the new Omicron variant starting from December 2021 had a negative impact on the recovery of the air transport sector, which

already showed signs of a slowdown also in the operations of the Milan airports in the second half of the month. Even in this context, commercial aviation traffic recorded a recovery: if compared to 2020, the annual growth of movements in 2021 was equal to +34.5% (data which also includes cargo activity) while that of passengers +46.8%.

The best performance in terms of passengers transported was recorded in August 2021 with 2 million passengers, equal to 56% of pre-pandemic traffic (3,6 million passengers in August 2019). In the first four months of the year, traffic stood at a level equal to 14% of the pre-pandemic level and then gradually recovered until it reached 61% in December 2021.

The load factor was 63%, up 5 percentage points compared to 2020 and consists of 70% on domestic routes and 58% on international routes, testifying to an uneven recovery on the various traffic segments.

Table 5: Movements, passengers and goods at Linate Airport [131]

	2021	%vs 2020	% vs 2019
Movements	45.362	+59,1 %	-35,0%
Passengers	4.307.100	+91,3%	-34,1%
Goods (tons)	1.320	+72,6%	-79,3%

The Airport offers a wide range of short and medium-haul flights, including European Schengen and extra-Schengen destinations, operated by 25 airlines [132].
As regards the composition of passenger traffic for Linate airport, there are 2.8 million passengers on domestic flights and the remainder on European flights.

The traffic trend was characterized by the cessation of operations by Alitalia which took place on 14 October 2022 with the simultaneous launch of the flying activity by ITA Airways starting the following day. Among the main carriers operating at the airport in terms of number of passengers served, we also find easyJet (320,000), Iberia (210,000), Wizzair (207,000), Lufthansa (184,000), Volotea (178,000), Air France (153 thousand), KLM (137 thousand), British Airways (127 thousand), Blue Air (60 thousand), Austrian Airlines (49 thousand), Brussels Airlines (44 thousand),

Scandinavian Airlines (40 thousand), Vueling Airlines (32 thousand), Air Malta (22 thousand) and Aer Lingus (17 thousand).
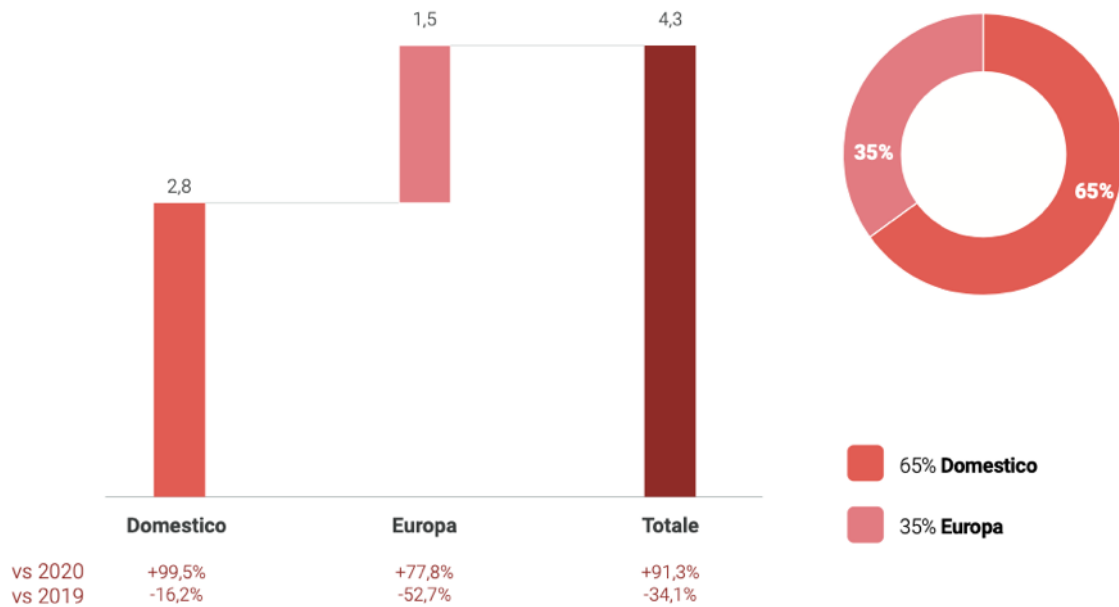

Figure 31: millions of passengers according to geographic area for Linate airport in 2022 [131]

5.2. Linate accessibility

Linate Airport is located 9 km east of the center of Milan and its is well integrated into the road transport network. The main access road axes are the following [133]:

- Highways A51 (Tangenziale Est Milano),A52 (Tangenziale Nord Milano), A58 (Tangenziale Esterna Est Milano);
- State Road ;
- Padana Superiore SS11;
- Provincial Roads SP103, SP14, SP415, SP15b;
- Viale Forlanini, which connects the airport to Milan ring road system and the city center;
- Via Circonvallazione Idroscalo (north-east of the Airport).

Figure 32 shows the main rail and road connection between the airport of Linate and Malpensa and the area around.

Figure 32: Main roads and rail connections [134]

Regarding the province of origin of passengers which choose Linate, a study was carried out during the LAirA project. Linate Airport's catchment area is primarily centered around Milan Metropolitan area, which accounts for 63.7% of all passengers. Other Lombardy provinces account together for 18.6% of the passenger traffics. Further 10.3% of travellers come from the provinces of Turin, Genoa, Alessandria, Lecco, Lodi, Cremona, Piacenza, and Parma. [131]

Figure 33: Linate Airport passengers' distribution by originating province [131]

For the accessibility of travellers by car there are 3 official parking spaces at the airport for private cars (P1 top class xl, P2 executive ,P3 smart), shown in Figure 34. The parking spaces can also be booked online and accessible with a QR code received with the booking.
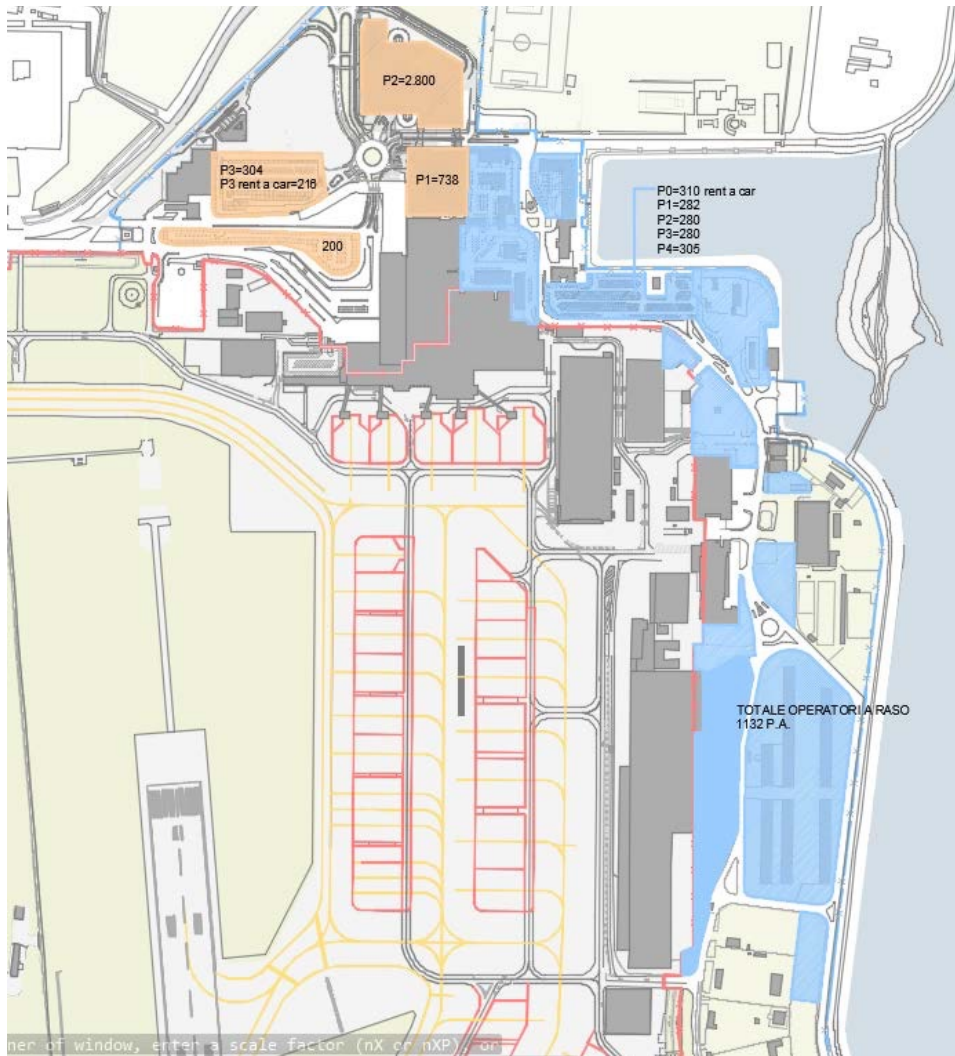

Figure 34: Parking area in Linate

The importance of electric mobility and the increase in circulating electric cars has already been underlined. This trend is also confirmed by a study carried out in 2018 by *KPMG* for SEA to evaluate the need to install charging stations near the airport. The study predicts that in 2030 over 1.300 electric vehicles will pass through Linate a day and foresees the installation of a total of 47 recharging points by 2030. [135]

To meet this need, the ultrafast charging station was inaugurated in 2022 in collaboration between *FreeToX* and SEA, equipped with 5 ultrafast charging columns to recharge 10 vehicles simultaneously. [43]

The following paragraphs show the possible modes of transport to reach the airport, and the Figure 35reports the level of saturation in 2017 of the various transport modes available.
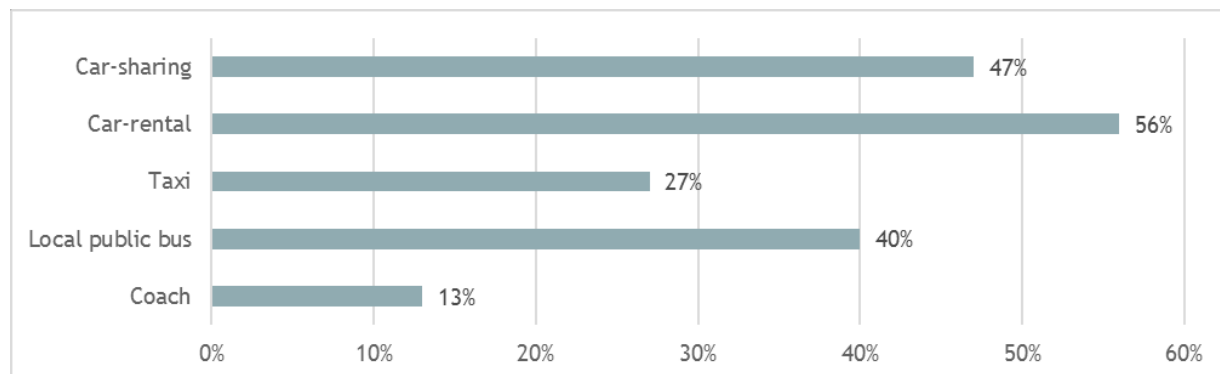

Figure 35: Mobility services saturation at Linate Airport in 2017 [136]

5.2.1. Car sharing and car rental

LAirA project has also underlined the importance of car sharing to improve accessibility at the airport and it is also one of the factors on which the MaaS is based. At Linate airport there are 3 different car sharing options available 24 hours a day and with reserved parking spaces: Enjoy, E-Vai and ShareNow [48].

Numerous traditional car rental companies are also present at the airport, with a wide range of cars depending on the time of year and level of demand.

5.2.2. Linate by Taxi

In addition to the previously mentioned FREENOW service for booking taxis, there are various taxi companies operating in Linate: Radiotaxi 6969, Radio taxi Freccia, Taxi Blu, Radio Taxi la Martesana, taxi 8585 Autoradiotassi e ETAXI Radio Taxi Milano. [137]

5.2.3. Linate by bus [138]

Linate airport is easily reachable from the city center and from the main towns in Lombardy, as shown in Figure 36, thanks to the following bus services in the table. There is also the service managed by *Flixbus* to connect the airport with the main Italian cities [139].
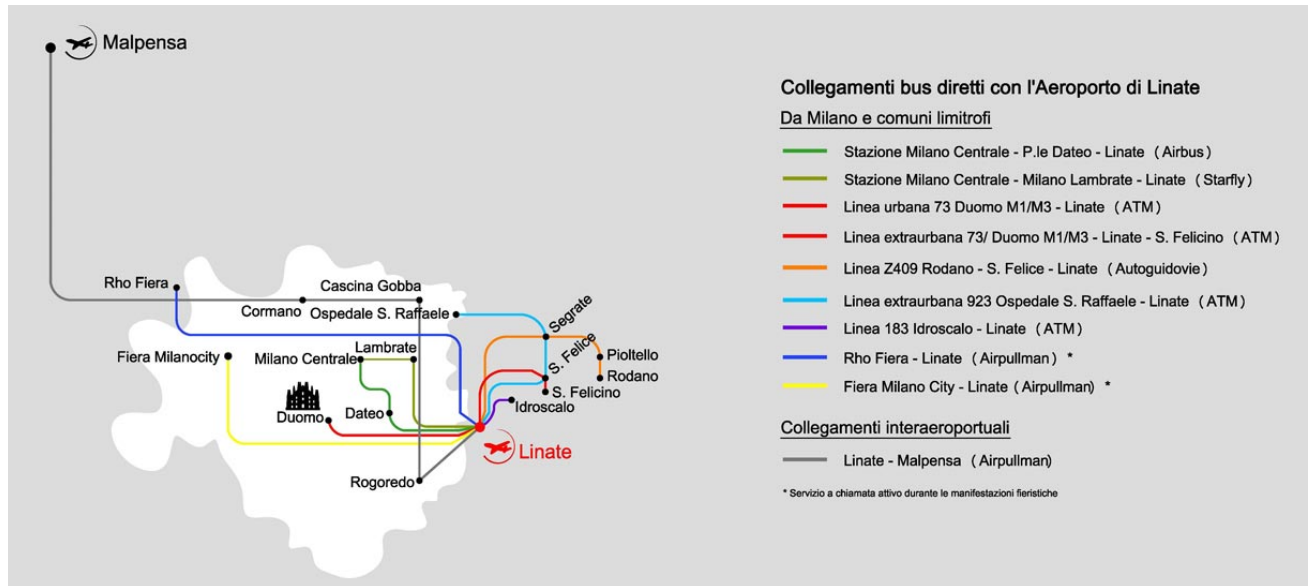
Figure 36: Bus connection at Linate Airport [138]

Table 6: Bus services at Linate Airport

Service	Origin	Travel time	Transport operator	Cost of single ticket
Local public bus line 73 [140]	Duomo M1/M3	60 min	ATM	€2
Linate shuttle [141]	Milano Centrale/ Dateo	25 min	Air Pullman	€7
Airport bus express [142]	Milano Centrale/ Lambrate	25 min	Starfly	€5
Local public bus line 923 [140]	San Raffaele Hospital	100 min	ATM	€2
Linea z409 [143]	Settala	30 min	Autoguidovie	€ 2,80
Malpensa shuttle [144]	Monza	20-30 min	Malpensa shuttle	€8

Malpensa shuttle [144]	Malpensa Terminal 1	70-90 min	Malpensa shuttle	€13
Livigno express [145]	Livigno/ Bormio	4 hours	Livigno express	depends on destination
Flyski shuttle [146]	Trentino/ Dolomiti	depends on destination	Flyski shuttle	depends on destination

5.2.4. New metro line M4

Linate Airport will no longer be connected only by road, but it will also have the new metro line that will connect it with the city center.

The new metro line has zero local emissions, and it could reduce car traffic with considerable benefits both for the environment and for those who live and work in the city. It is estimated that the full implementation of the new M4 and M5 lines could reduce annual car journeys by around 30 million, produce a decrease in emissions of approximately 2% and lead to a reduction in annual oil consumption of about 16.000.000 tons. [147]

In detail, the M4 or "Blue Line" will connect the historic center with the eastern part (Q.re Forlanini and Linate Airport) and with the western part (Q.re Lorenteggio and San Cristoforo Station) as shown the Figure 37.

The new line will have an extension of approximately 15 km, 21 stations, with 6 interchange points: S. Cristoforo FS, Sant'Ambrogio M2, San Babila M1, Dateo FS, Forlanini FS, Sforza Policlinico M3 [147] . The new line opens the first 6 stops from Linate to Dateo on 26 November 2022, while the opening to the San Cristoforo terminus is scheduled for 2024.

The number of users estimated to be served by the new metro is 86 million passengers a year with an operating frequency of 90 seconds during peak hours and 75 seconds as the minimum frequency.
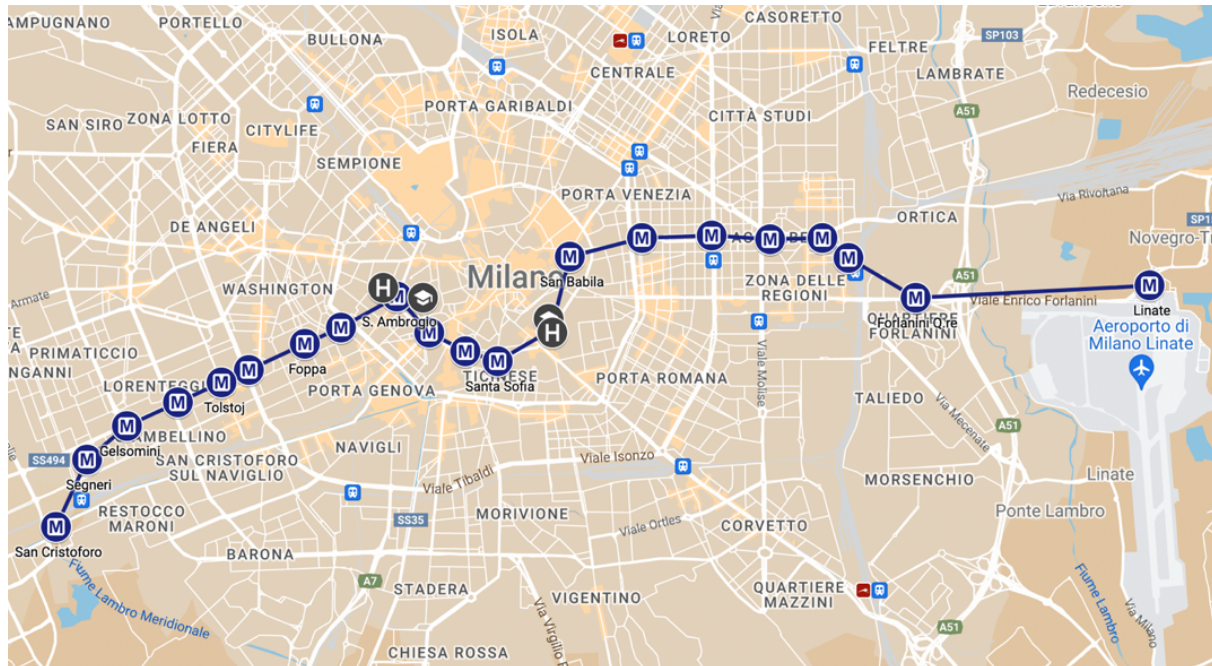
Figure 37: M4 stops [147]

The M4 Line is an integrally automated light rail system, a technological system that maintains the characteristics of the classic rail system, but with higher and less expensive technical performance standards. The innovative driverless automatic guidance system adopts intelligent traffic control technology that guarantees passengers the highest safety standards. The carriage doors only open when the trains stop at the station, eliminating the risk of falls or injuries. The ascent and descent platforms are completely separated from the tracks and moving carriages, ensuring the safety of people.

The station is configured as one of the potentially most important interchange nodes of the future Milan, but also as an hub of the area's social and economic life.
The new underground station makes it possible to collect the user flows coming from the airport, from the numerous car parks in the area, from the provincial road system and from the surface public transport stops.

The airport terminal is connected to the mezzanine of the Linate Airport station and is one of the main accesses to Line M4. The connection is located on the north side of the terminal in the area next to the entrance to the car parks. In this way the user can use the parking, public transport and underground services through a single short, direct and intuitive route.

The second access point to the station is represented by the "Kiss & Ride" building: it is located on the side of the Idroscalo ring road, taking the form of a bridgehead between the Milan-Segrate road network and the underground station and parking area, and constitutes a recognizable and functional point of reference for the exchange

between transport flows. Here, in fact, there is a stop for public transport and a rapid parking area ("Kiss & Ride") for private vehicles. the building welcomes users who, through a system of fixed and escalator stairs and a lift and a subsequent underground connection, can reach the mezzanine area of the M4 station. In the Kiss&Ride building there are some shops and a waiting area.

5.3. Linate smart multimodal hub

In the next future the airport will not only be an access terminal for air services and it will not only be anymore the "first impression of a place and the last memory before leaving". It will be included in the context of the "Linate system", a wider territorial area, characterized by new production facilities, new poles oriented towards leisure, entertainment and shopping.

The airport in this new configuration constitutes the access door for travel with the public transport system and with the new Metro line. [148]

In this new context, clearly the *Linate syste*m becomes a place of the city, where people work, have fun, meet, play sports, do business. And the airport becomes a physical "platform" with a large availability of highly modular spaces, which can offer the city new mobility and logistics services, integrating and amplifying the mobility regulation policies that may be implemented in the near future.

SEA, with the collaboration of NET Engineering, undertook a system study with the aim of defining a strategy to make Linate a *Smart Multimodal Hub* [7] dedicated to intramodality, with a reorganization of spaces and to welcome the new metro station of line 4.

The outcome of this study was to establish guidelines for a reorganization of the spaces, always from an integrated point of view. Starting from the estimation of future demand needs, the project led to the design of a new layout strictly consistent with a wayfinding plan and responsive to the new needs that the technological context and innovative mobility services may determine in future time horizons.

The functional reorganization of the spaces, with a more systemic identification of the functional roles of the individual areas, was assisted by a reconfiguration of the access system and a coherent setting of a vehicle addressing system towards the functional area corresponding to their needs in the most readable, fastest, safest way possible.

In this new environment, the area adjacent to the new future terminus of M4 constitutes the new terminal for innovative mobility services, a smart hub dedicated to intermodality (electric car sharing, bike sharing, e-scooters) equipped with

innovative technologies such as smart lighting, search devices and totems for wayfinding, service areas for the new e-mobility, etc.

In 2020 a project was implemented for the new passenger wayfinding of the Milan Linate passenger terminal [149] The importance of wayfinding has been reaffirmed within the LAirA studies in the dedicated chapter. The passenger who enters these large spaces feels the need to quickly resolve the pre-flight operational phases to enjoy a relaxing phase, perhaps strolling through the shops or just resting on a chaise-lounge. [150].

Signage becomes even more important from a MaaS perspective: people need clear directions to have a relaxed and efficient intermodal travel. It is essential that the passenger is given clear and immediate information on where to go and what to do. Directional signage therefore plays a key role within the Terminal. It not only fulfills the functional task of indicating a direction but is also a design object that contributes to making the spaces on which it stands welcoming. Among the key characteristics of good signage is the ability to give identity to the signage system with a simple but recognizable sign and flexibility over time.

6 Conclusion and future developments

The objective of the thesis, to explore the new mobility phenomenon with reference to the Milan metropolitan city, has started with a literature review.

Analyzing case studies and existing projects, the key features that distinguish the paradigm are identified: the demand-driven approach, the interest in sustainability, the centrality of public transport and sharing mobility.

All these elements are the basis of the attempt to develop the MaaS model in Milan, that will revolutionize the way people experience mobility. With the entry into the project of other cities Rome, Naples, and Florence Bari and Turin later, the project will become increasingly present in Italy.

After the closure on 9 September 2022 of the public notice to collect expressions of interest, the next steps in the development of MaaS in Milan will be those of the choice of digital platform of MaaS operators and the start of the experimentation scheduled for summer 2023.

The MaaS operators' proposals received by the municipality of Milan are about a dozen and demonstrate the interest of the sector in this business model.

Among the major difficulties that will be encountered there is the technological one. The MaaS4Italy tender requires the creation of a national repository "Data Sharing and Repository Facilities" (DS&SRF), an infrastructure for data sharing and the collection and display of services. The main problem is that this depository at the moment does not exist and there are no precise indications on its creation.

There are also uncertainties about the methods of experimentation. The territorial extent of the experimentation depends on the territorial coverage of the participating transport operators. The joining to the experimentation of Transport Operators with a wider radius allows a significant expansion of the covered area, foreseeing the collaboration with subjects having a supra-provincial territorial amplitude (Trenord, Agency for Local Public Transport of the area of the Metropolitan City of Milan, Monza and Brianza, Lodi and Pavia).

For the promotion of the new model, the provision of vouchers and discounts to specific target of users will be provided, in order to guide and understand the dynamics of adopting MaaS.

Regarding the number of platforms that will be involved in the trial, no limit has been set. Presumably in the experimental phase more than one platform will be used and coexist, but only some will create interest for users and will survive.

It must be considered that a high number of platforms can make the MaaS ineffective because it could be counterproductive, create disaggregation and go against the principles on which it is based. On the other hand, one platform may not be enough. In fact, with more than one platform available, there is the possibility of having platforms for different segments of demand. For example, an application can be dedicated to tourists and contain not only the transport system, but also access and info on hotels or museums. Another target is that of commuters or students who have different needs.

Another useful service would be to have a dedicated page in each platform for specific events involving the city. For example, during the period of *Salone del Mobile* in 2022, over 400.000 people arrived in the city [25], and a MaaS platform could offer to users, in addition to transport info, also information on the Rho exhibition and the dedicated week's events.

Therefore, the emerging phenomenon of MaaS, which is gaining popularity in all Europe, is not just about mobility in urban environments. The fields of application of the model also apply to the accessibility and travel experience of airport users, as we have seen in the case of Linate and for the integration of useful services for citizens, not closely related to transport sector.

The importance of good signage is essential in an intermodal perspective in which people change means of transport and must be directed.

After a trial period which will involve Linate airport, when MaaS will be much more present in Lombardy it is likely that the same model will also be applied to other airports such as Malpensa and Orio al Serio Airport.

Malpensa is currently a living lab of the *Orchestra* project [151], funded by the EU in the Horizon 2020 programme, which experiments with solutions for multimodal traffic management by connecting road, railway, air and naval networks and infrastructures within the concept of MaaS. The project will end in 2024 and will make it possible to validate the guidelines and solutions identified for interconnecting different transport systems for people and goods, through systems capable of monitoring and sharing traffic data in real time, in order to avoid any type of of interruption or delay in transport flows, even in the event of obstacles.

Orio al Serio airport is also moving in this direction. In the 2019 PUMS of the municipality of Bergamo [152], the municipality supports the use of technologies applied to the passenger mobility system from a MaaS perspective. In particular, a railway connection is planned between the Bergamo Airport and the central station of Bergamo. This new infrastructure could promote intermodal mobility in accordance with MaaS principles. [153]

Bibliography

[1]   whim, «whim,» [Online]. Available: https://whimapp.com/helsinki/en/history-of-maas-global/.

[2]   «cop27,» 2022. [Online]. Available: https://cop27.eg/#/vision#goals.

[3]   European Commission, «Eu climate action,» [Online]. Available: https://climate.ec.europa.eu/eu-action_en.

[4]   «sea miano,» 2022. [Online]. Available: https://seamilano.eu/it.

[5]   Sea, «Annual report 2021,» 2021.

[6]   «milano smart city alliance,» 2022. [Online]. Available: https://milanosmartcity.it.

[7]   «Net engineering,» 2021. [Online]. Available: https://www.net-italia.com/selezione-progetti/nuovo-hub-intermodale-di-milano-linate/.

[8]   hub, EU science, «European Commission,» [Online]. Available: https://joint-research-centre.ec.europa.eu/scientific-activities-z/transport-sector-economic-analysis_en.

[9]   United Nations, «Department of economic and social affairs,» 2017. [Online]. Available: https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100.

[10]   United Nations, «United Nations,» [Online]. Available: https://www.un.org/en/our-work/support-sustainable-development-and-climate-action.

[11]   Mims, «Osservatorio Nazionale sharing mobility,» 2021. [Online]. Available: https://osservatoriosharingmobility.it.

[12]   MaaS Alliance, «White Paper "Guidelines & Recommendations to create the foundations for a thriving MaaS Ecosystem",» 2017. [Online]. Available: https://maas-alliance.eu.

[13]   M. Kamargianni e M. Matyas, «The Business Ecosystem of Mobility-as-a-Service,» 2017.

[14]   R. Riccio, «cybersecurity360,» 2019. [Online]. Available: https://www.cybersecurity360.it/legal/privacy-dati-personali/unapp-per-ogni-necessita-tutti-i-vantaggi-e-i-rischi-in-materia-di-sicurezza-e-protezione-dati/.

[15]   ERTICO – ITS Europe, «Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning,» 2019.

[16]   Durand & Harms, «Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review),» 2018.

[17]   I.C.Marianne Karlsson et al, «Public-private_innovation_barriers_in_the_case_of_mobility_as_a_service_in_West_Sweden).,» 2016.

[18]   A. M. F. e. al., «Mobility as a Service: A Critical Review of Definitions, Assessments of Schemes, and Key Challenges,» 2017.

[19]   «MaaS4EU,» [Online]. Available: https://www.maas4eu.eu.

[20]   McKinsey&Company, 2020. [Online]. Available: https://www.mckinsey.com/featured-insights/the-next-normal.

[21] Deloitte, «Understading the sector impact of Covid-19,» 2020.

[22] M. I. C. Karlsson & Sochor, «Creation of mobility packages based on the MaaS concept,» 2017.

[23] D. Hörcherab e D. J.Grahama, «MaaS economics: Should we fight car ownership with subscriptions to alternative modes?,» 2020.

[24] J. S. e. al, «A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals,» 2018.

[25] TTS Italia, «Linee Guida per lo sviluppo dei servizi MaaS in Italia,» 2021.

[26] «Google Maps,» 2022. [Online]. Available: https://www.google.it/maps/preview.

[27] X. Z. e. al, «Potential values of maas impacts in future scenarios,» 2021.

[28] M. K. &. Matyas, « The Business Ecosystem of Mobility-as-a-Service,» 2017.

[29] P. e. al, «Future implementation of mobility as a service (MaaS): Results of an international Delphi study,» 2020.

[30] M. e. al., «integrating personalied and assible itinerarie in maas ecosystem throsu microservices,» 2016.

[31] United Nations Workshop Transport Research and Innovations, « ACCELERATING THE IMPACT OF TRANSPORT RESEARCH AND INNOVATION INITIATIVES,» 2016.

[32] Finger e Audouin, The Governance of Smart Transportation Systems, 2019.

[33] G. Smith e e. al, «Mobility as a Service: Development scenarios and implications for public transport,» 2018.

[34] F. e. al., «On the likelihood of using Mobility-as-a-Service: A case study on innovative mobility services among residents in the Netherlands Author links open overlay panel,» 2019.

[35] G. Smith e e. al., «Adopting Mobility-as-a-Service: An empirical analysis of end-users' experiences,» 2022.

[36] «Garante per la protezione dei dati personali,» 2016. [Online]. Available: https://www.garanteprivacy.it/regolamentoue.

[37] Skedgo, «Why MaaS is the future of transport,» 2022.

[38] Jupiter research, «MOBILITY-AS-A-SERVICE REVENUE TO EXCEED $52 BILLION BY 2027, AS CORONAVIRUS STUNTS GROWTH IN 2020,» 2020. [Online]. Available: https://www.juniperresearch.com/press/mobility-as-a-service-revenue-to-exceed-$52.

[39] «interreg-central europe,» 2019. [Online]. Available: https://www.interreg-central.eu/Content.Node/LAirA.html.

[40] D. Bao, «Relevance of airport accessibility and airport competition,» 2016.

[41] Interreg central Europe , «Educational model on understanding FUA – airports landside mobility integration,» 2019.

[42] «HQ Engineering,» 2022. [Online]. Available: https://www.hqe.it/2022/08/11/rete-infrastrutturale-pubblica-ricarica-elettrica-italia-avanzamento/.

[43] «Milano Malpensa,» 2022. [Online]. Available: https://www.milanomalpensa-airport.com/it/guida-per-il-passeggero/news/superfast-charging-station-linate.

[44]   «Budapest Airport,» 2022. [Online]. Available:
         https://www.bud.hu/en/passengers/transport/public_transportation/trains.

[45]   «Trenord,» [Online]. Available: https://www.trenord.it/en/routes-and-
         timetables/services/airport-routes-mxp/.

[46]   Interreg central Europe, «LOCAL STRATEGY – GUIDELINES FOR POZNAŃ
         ŁAWICA AIRPORT LOW CARBON EMISSION LANDSIDE ACCESSIBILITY».

[47]   «Vienna International Airport,» [Online]. Available:
         https://www.viennaairport.com/en/passengers/arrival__parking/airport_cycle_route.

[48]   «Milano Linate,» 2022. [Online]. Available: https://www.milanolinate-
         airport.com/en/from-to/car-sharing.

[49]   LAirA Project, « WAYFINDING AT AIRPORTS – a LAirA Project Report,» 2019.

[50]   Flows modelling mobiltiy, «wayfinding,» 2018. [Online]. Available:
         https://www.flowsmag.com/it/2018/06/14/wayfinding-design-contesto-urbano/.

[51]   «Bolt at Budapest Airport,» 2022. [Online]. Available:
         https://bolt.eu/en/airports/bud/.

[52]   «Warsaw Chopin Airport,» [Online]. Available: https://www.lotnisko-
         chopina.pl/en/index.html.

[53]   «Yuor London Airport Gatwick,» 2022. [Online]. Available:
         https://www.gatwickairport.com.

[54]   «Milan airports,» [Online]. Available: https://www.milanolinate-
         airport.com/it/aeroporto-servizi/app.

[55]   «Google Play,» 2022. [Online]. Available:
         https://play.google.com/store/apps/details?id=com.ideolo.malpensa&gl=IT.

[56]   «Munich Airport,» 2022. [Online]. Available: https://www.munich-
         airport.com/transport-directions-260334.

[57]   «passngr,» [Online]. Available: https://www.passngr.de/de/.

[58]   «MVG,» 2021. [Online]. Available: https://www.mvg.de/services/mobile-
         services/mvgo.html.

[59]   «trafi,» 2022. [Online]. Available: https://www.trafi.com/solent/.

[60]   «MVG. M-login,» [Online]. Available: https://login.muenchen.de/mvgo.html.

[61]   «Whim,» 2022. [Online]. Available: https://whimapp.com.

[62]   «Upstream - WienMobil,» 2022. [Online]. Available: https://www.upstream-
         mobility.at.

[63]   «moovit,» 2022. [Online]. Available: https://moovit.com/it/ .

[64]   «FREE NOW,» 2022. [Online]. Available: https://www.free-now.com/it/ .

[65]   «google play,» 2022. [Online]. Available:
         https://play.google.com/store/games?gl=IT&utm_source=emea_Med&utm_medium=
         hasem&utm_content=Dec2020&utm_campaign=Evergreen&pcampaignid=MKT-
         EDR-emea-it-1001280-Med-hasem-py-Evergreen-Dec2020-Text_Search_BKWS-
         test_ctrl_ca%7CONSEM_kwid_43700008794309718&gclid.

[66]   Regione Lombardia, «4motors.eu,» 2022. [Online]. Available:
         https://www.4motors.eu/it/regioni/lombardia.

[67]   «istat,» 2021. [Online]. Available: https://www.istat.it.

[68] «tuttitalia.it,» 2021. [Online]. Available: https://www.tuttitalia.it/lombardia/18-milano/statistiche/popolazione-andamento-demografico/.

[69] «tuttitalia.it,» 2021. [Online]. Available: https://www.tuttitalia.it/lombardia/provincia-di-milano/34-comuni/popolazione/.

[70] Comune di Milano, «Documento di scoping. AGGIORNAMENTO PGTU E PUP 2022,» 2022. [Online]. Available: https://www.comune.milano.it/documents/20126/446894146/Allegato+2_Documento+di+Scoping.pdf/0b9f69c5-cbb7-0a02-9664-67d18a22b149?t=1656603136887.

[71] «Comune di Milano,» [Online]. Available: https://www.pgt.comune.milano.it/vasraall2-quadro-di-riferimento-territoriale-e-ambientale/3-analisi-del-sistema-paesistico-ambientale/32-contesto-geologico-e-idrogeologico/33-qualita-dellaria/333-esposizione-della-popolazione-allinquinamento-atmosferico.

[72] «Italia in dati,» 2021. [Online]. Available: https://italiaindati.com/inquinamento-in-litalia/.

[73] INEMAR -ARPA Lombardia , «Inventario Emissioni in Atmosfera: emissioni in Regione Lombardia nell'anno 2017,» 2020.

[74] «ARPA,» 2022. [Online]. Available: https://www.arpalombardia.it/Pages/Aria/Modellistica/Indice-qualità-aria.aspx.

[75] «Regione Lombardia,» 2022. [Online]. Available: https://www.regione.lombardia.it/wps/portal/istituzionale/HP/DettaglioRedazionale/servizi-e-informazioni/cittadini/Tutela-ambientale/Qualita-dell-aria/misure-di-limitazione-per-qualita-aria/misure-di-limitazione-per-qualita-aria.

[76] «Comune di Milano,» [Online]. Available: https://www.comune.milano.it/documents/20126/12289339/90X140_progetto_ViaBrivio.pdf/b2f08963-c3ea-0995-b5ff-6e3e6a6b2fcb?t=1591363785604.

[77] Regione Lombardia, «Matrice O/D Lombardia,» 2014. [Online]. Available: https://www.regione.lombardia.it/wps/wcm/connect/d93b792f-0f1a-49ac-b9e1-d3bfd7511524/Presentazione+Matrice+OD.pdf?MOD=AJPERES&CACHEID=ROOTWORKSPACE-d93b792f-0f1a-49ac-b9e1-d3bfd7511524-lCXZLey.

[78] «aci,» 2021. [Online]. Available: https://www.aci.it .

[79] «atm,» [Online]. Available: https://www.atm.it.

[80] atm, «Carta della mobilità 2022,» 2021. [Online]. Available: https://www.atm.it/it/IlGruppo/ChiSiamo/Documents/Carta%20della%20Mobilità%202022.pdf.

[81] Trenord, «Trenord,» 2022. [Online]. Available: https://trenord-europe-trenord-endpoint-prd.azureedge.net/fileadmin/contenuti/TRENORD/2-Linee_e_orari/Linee_regionali/Regionale_2021_A4_rev01w.pdf.

[82] «atm,» 2022. [Online]. Available: https://www.atm.it/it/AltriServizi/Trasporto/Pagine/Mappe.aspx.

[83] «agenzia TPL - programma di bacino,» [Online]. Available: https://www.agenziatpl.it/servizi-tpl/programma-dei-servizi-di-bacino.

[84] «autoguidovie,» 2022. [Online]. Available: https://autoguidovie.it .

[85] «nord est trasporti NET,» 2022. [Online]. Available: https://www.nordesttrasporti.it .

[86] «Air Pullman,» 2022. [Online]. Available: https://www.airpullmanspa.com .

[87]   «pmt,» 2022. [Online]. Available: https://www.pmtsrl.it/en/ .

[88]   «stavautolinee,» 2022. [Online]. Available: https://stavautolinee.it/azienda/ .

[89]   «movibus,» 2022. [Online]. Available: http://www.movibus.it/lazienda/ .

[90]   «Agenzia TPL,» 2019. [Online]. Available: https://www.agenziatpl.it/servizi-tpl/sistema-tariffario-integrato.

[91]   «agenzia TPL,» 2019. [Online]. Available: https://www.agenziatpl.it/servizi-tpl/sistema-tariffario-integrato .

[92]   J. Eckhardt e e. al., «Mobility As A Service For Linking Europe (MAASiFiE),» 2017.

[93]   Polydoropoulou e e. al., «Ready for Mobility as a Service? Insights from stakeholders and end-users,» 2018.

[94]   «Comune di Milano,» 2022. [Online]. Available: https://www.comune.milano.it/servizi/car-sharing.

[95]   «google play,» 2022. [Online]. Available: https://play.google.com/store/games?hl=it&gl=US.

[96]   «enjoy,» 2022. [Online]. Available: https://enjoy.eni.com/it/milano/home.

[97]   «sharenow,» 2022. [Online]. Available: https://www.sharenow.it.

[98]   «e-Vai,» 2022. [Online]. Available: https://www.e-vai.com.

[99]   «ubeeqo,» 2022. [Online]. Available: https://www.ubeeqo.com/it-it.

[100] «leasys,» 2022. [Online]. Available: https://www.leasys.com/it-it.

[101] «comune di milano,» 2022. [Online]. Available: https://www.comune.milano.it/servizi/bike-sharing.

[102] «milano repubblica,» 2022. [Online]. Available: https://milano.repubblica.it/cronaca/2022/09/22/news/nuove_piste_ciclabili_milano-366682223/.

[103] «ridemovi,» 2022. [Online]. Available: https://www.ridemovi.com/it/.

[104] «lime,» 2022. [Online]. Available: https://www.li.me/it-it.

[105] «bikemi,» 2022. [Online]. Available: https://bikemi.com.

[106] «comune di milano,» 2022. [Online]. Available: https://dati.comune.milano.it/dataset/ds60_infogeo_piste_ciclabili_localizzazione_/resource/3efb82fe-7ef8-4774-afda-4de869956fa0?inner_span=True .

[107] «comune di milano,» 2022. [Online]. Available: https://www.comune.milano.it/servizi/scooter-sharing.

[108] «comune di milano,» 2022. [Online]. Available: https://www.comune.milano.it/servizi/monopattini-in-sharing.

[109] osservatorio nazionale sharing mobility, «6° rapporto nazionale sharing mobility,» 2022.

[110] Università Bocconi,Milano, «Mobilità urbana e tecnologia: l'impatto dell'e-hailing,» 2018.

[111] Governo italiano, «italia digitale 206,» [Online]. Available: https://innovazione.gov.it/italia-digitale-2026/.

[112] «Dipartimento per la trasformazione digitale,» 2022. [Online]. Available: https://innovazione.gov.it/notizie/articoli/mobility-as-a-service-for-italy-la-mobilita-urbana-va-in-digitale/.

[113] MITD, MIMS, «Manifestazione di interesse "MAAS4ITALY",» 2022.

[114] tts italia, 2022. [Online]. Available: https://www.ttsitalia.it/wp-content/uploads/2022/07/Giorgio-Pizzi.pdf.

[115] «osservatorio sharing mobility,» 2022. [Online]. Available: https://osservatoriosharingmobility.it/maas4italy-il-futuro-in-italia-e-mobility-as-a-service/.

[116] Presidenza del Consiglio dei Ministri, «decreto di approvazione graduatoria definitiva,» 2022.

[117] «innovazione.gov,» 2022. [Online]. Available: https://innovazione.gov.it/notizie/avvisi-pubblici/mobility-as-a-service-for-italy-fondo-complementare/ .

[118] Dipartimento per la trasformazione digitale, «innovazione.gov,» 2022. [Online]. Available: https://innovazione.gov.it/notizie/articoli/bari-firenze-e-torino-nuove-citta-capofila-per-il-progetto-mobility-as-a-service/.

[119] «innovazione.gov,» 2022. [Online]. Available: https://innovazione.gov.it/argomenti/maas/.

[120] «AMAT,» 2022. [Online]. Available: https://www.amat-mi.it/it/progetti/mobility4mi/ .

[121] United Nations, «United Nations,» [Online]. Available: https://sdgs.un.org/goals/goal11.

[122] Regione Lombardia, «e015,» [Online]. Available: https://www.e015.regione.lombardia.it.

[123] C. A. Carnevale, «E015 e la rivoluzione degli ecosistemi digitali,» 2017.

[124] Regione Lombardia, «E015 digital ecosystem,» 2017.

[125] AMAT, «Documento di Piano urbano della mobilità,» 2018.

[126] Comune di Milano, «AVVISO PUBBLICO PER MANIFESTAZIONE DI INTERESSE FINALIZZATO ALL'INDIVIDUAZIONE DI MAAS OPERATORS NELL'AMBITO DEL PROGETTO "MOBILITY AS A SERVICE FOR ITALY – MILANO",» 2022. [Online]. Available: https://servizi.comune.milano.it/documents/20121/41781463/Avviso+MaaS+Operator.pdf/a7a034b1-75f5-a37f-c05a-e4de257b8e4c?t=1658163820172.

[127] Comune di Milano, «Servizi Comune di Milano,» 2022. [Online]. Available: https://servizi.comune.milano.it/dettaglio-contenuto/-/asset_publisher/pqxq/content/avviso-pubblico-per-manifestazione-di-interesse-finalizzato-all-individuazione-di-maas-operators-nell-ambito-del-progetto-mobility-as-a-service-for-italy-milano-cup-b49g22.

[128] AMAT, «Convegno_MaaS4Italy_DM,» in *MaaS4Italy: il futuro in Italia è Mobility as a Service*, Roma, 2022.

[129] «sea milano airports,» 2022. [Online]. Available: http://dnf2018.seamilano.eu/it/gli-aeroporti-di-linate-e-malpensa.

[130] «Google Heart,» 2020. [Online]. Available: https://www.google.it/intl/it/earth/.

[131] SEA, «Milan airports low-carbon landside accessibility strategy,» 2018.

[132] Sea, «milano linate,» 2022. [Online]. Available: https://www.milanolinate-airport.com/it/voli/compagnie-aeree.

[133] SEA - Interrreg central europe project, «Milan airport accessibility,» 2018.

[134] Sea, «Milano Linate,» [Online]. Available: https://www.milanolinate-airport.com/it/da-per/in-auto.

[135] KPMG, «Business Model mobilità elettrica per gruppo SEA,» 2018.

[136] SEA - Interreg Central Europe, «Milan airports accessibility,» 2018.

[137] SEA, 2022. [Online]. Available: https://www.milanolinate-airport.com/it/da-per/in-taxi.

[138] SEA, «Milano Linate,» 2022. [Online]. Available: https://www.milanolinate-airport.com/it/da-per/in-bus.

[139] flixbus, «flixbus,» 2022. [Online]. Available: https://www.flixbus.it/autobus/milano-linate-aeroporto.

[140] atm, «atm,» 2022. [Online]. Available: https://www.atm.it/it/Pagine/default.aspx.

[141] linate shuttle, «linate shuttle,» 2022. [Online]. Available: https://www.milano-aeroporti.it/linate-shuttle/index.html .

[142] «Air bus express,» 2022. [Online]. Available: https://www.airportbusexpress.it/it-IT/orari-aeroportuali.

[143] autoguidovie, 2022. [Online]. Available: https://milanosudest.autoguidovie.it/files/Milano%20Sud-Est/Linee/Orari/Invernale_scolastico_21-22/Linea%20z409_FER%20INV.pdf.

[144] malpensa shuttle, 2022. [Online]. Available: https://www.malpensashuttle.it.

[145] «livigno express,» 2022. [Online]. Available: www.livignoexpress.com..

[146] «flisky shuttle,» 2022. [Online]. Available: https://www.flyskishuttle.com/it/Step2.aspx?aerA=9&gioA=23/11/2022&tipo=AR&aerR=9&gioR=25/11/2022&locA=17&locR=17&adu=2&bam=0&b_812=0&orarioVoloA=12:00&orarioVoloR=18:00.

[147] M4 S.p.A, «M4,» 2022. [Online]. Available: https://www.metro4milano.it/cantieri/linate-aeroporto/#.

[148] [Online]. Available: https://www.net-italia.com/selezione-progetti/nuovo-hub-intermodale-di-milano-linate/.

[149] gnosis, «gnosis progetti,» 2020. [Online]. Available: https://www.gnosisarchitettura.it/it/progetto/1133/wayfinding-linate.

[150] SEA- Interreg Central Europe, «milan airports low-carbon landside accessibility strategy,» 2018.

[151] «Alternativa sostenibile,» 2022. [Online]. Available: https://www.alternativasostenibile.it/articolo/progetto-orchestra-malpensa-si-progetta-la-mobilità-del-futuro.

[152] Comune di Bergamo, «Comune di Bergamo,» 2019. [Online]. Available: https://www.comune.bergamo.it/sites/default/files/2019-03/PUMS-Bergamo_Proposta-di-Piano_v4.pdf.

[153] sole 24ore, «A Orio al Serio arriverà il treno, l'aeroporto apre la nuova ala ovest,» *sole24ore,* 2022.

[154] [Online]. Available: https://www.istat.it .

[155] [Online]. Available: https://www.4motors.eu/it/regioni/lombardia .

[156] [Online]. Available: https://www.tuttitalia.it/lombardia/18-milano/statistiche/popolazione-andamento-demografico/ .

[157] [Online]. Available: https://www.tuttitalia.it/lombardia/provincia-di-milano/34-comuni/popolazione/ .

[158] [Online]. Available: https://www.comune.milano.it/documents/20126/446894146/Allegato+2_Documento+di+Scoping.pdf/0b9f69c5-cbb7-0a02-9664-67d18a22b149?t=1656603136887 .

[159] «MyCorridor,» 2019. [Online]. Available: http://www.mycorridor.eu .

[160] «sea milano,» 2022. [Online]. Available: https://seamilano.eu/it.

[161] S. airport, «Annual report 2021,» 2021.

[162] «milano smart city alliance,» 2022. [Online]. Available: https://milanosmartcity.it/project/3244/maas-sea/.

[163] «assaeroporti,» 2022. [Online]. Available: https://assaeroporti.com/statistiche/.

[164] «flows modelling mobility,» 2022. [Online]. Available: https://www.flowsmag.com/it/2019/12/19/il-nuovo-smart-hub-di-milano-linate/.

[165] Interreg Central Europe, «TRANSFERABILITY REPORT PASSENGER PILOT PROJECT,» 2019.

[166] SEA, LAIrA project, «Milan Airport Accessibility,» 2018.

[167] «milano linate,» 2022. [Online]. Available: https://www.milanolinate-airport.com/it/da-per/in-metro.

[168] «istat,» 2021. [Online]. Available: https://www.tuttitalia.it/lombardia/18-milano/statistiche/indici-demografici-struttura-popolazione/.

[169] SEA, «Masterplan aeroportuale. aeroporto di Milano Linate,» 2016.

Glossary

API - Application Programming Interface. it is a software intermediary that allows two applications to communicate and the data transmission between each other.

DS&SRF - Data Sharing and Repository Facilities. It is the national enabling platform used for the Maas4Italy project. It is an infrastructure for sharing data and collecting/displaying services.

ENAC- Ente Nazionale per l'Aviazione Civile, it acts as the sole authority for technical regulation, certification, supervision and control in the civil aviation sector in Italy in compliance with the powers deriving from the Navigation Code.

FUA – Functional urban area aggregate contiguous municipalities, composed by a City and its commuting zone. The commuting zone is defined by the commuting flows for work reasons recorded in the 2011 general population census.

IQA - The air quality index is an indicator that allows to provide an immediate and synthetic estimate of the state of the air. There is no single way to define such an index and various formulations are currently used in Italy and in Europe which consider the measured, estimated or predicted concentrations of a variable number of pollutants which have effects on health, especially of the respiratory, cardiac and cardiovascular.

ITS – Information technology system is the use of any computers, storage, networking and other physical devices, infrastructure and processes to create, process, store, secure and exchange all forms of electronic data.

LAirA – Landside Airport Accessibility is a project financed by EU, lasted between 2017 and 2019, which addressed the multimodal, smart and low carbon mobility integration of airports in the mobility systems of functional urban areas.

LIVING LAB - A Living Lab is an infrastructure for testing new technologies in real conditions in a limited geographical context and in a limited period of time, with the aim of testing their feasibility and degree of utility for end users (citizens, businesses , beneficiaries, etc.). Interaction with users allows continuous improvement of the technology characteristics in view of its application on a larger scale.

MaaS – Mobility-as-a-Service integrates various forms of transport and transport-related services into a single, comprehensive, and on-demand mobility service. MaaS offers end-users the added value of accessing mobility through a single application and a single payment channel

MICROMOBILITY – It refers to a range of small and light vehicles, such as bicycles or scooters, for transportation over short distances provided by lightweight, usually single-person vehicles

MULTIMODAL HUB – The multimodal hub is a mobility service infrastructure to switch seamlessly between the car and different modes of transport, allowing to make city centers car-free.

OD MATRIX - Table having as many rows and as many columns as the zones of origin and destination of the area considered. Each cell of the table contains the number of movements that occur between the various areas of the territory and represent the demand flows.

SDG - Sustainable Development Goals are a collection of 17 interlinked global goals designed to be a "shared blueprint for peace and prosperity for people and the planet, now and into the future", set up in 2015 by the United Nations General Assembly and are intended to be achieved by 2030.

WAYFINDING - it does not only refer to communicative artefacts, such as signs and information boards, but we refer to all those instrumental artefacts designed and conceived for spaces in which we need to orient ourselves, move and live. To facilitate orientation and usability, spaces must be easily legible, the role of wayfinding is to make possible and easy to understand how they are organized.

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