Chapter 12
New Behaviours and Digitalisation for Sustainable Mobility, Mobility as a Service (MaaS)

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Abstract This chapter will deal with changes in the behaviour of city dwellers and digital technologies which can facilitate such behaviour. Mass transportation must certainly remain the backbone of local public transport, both in terms of travel within cities and for that towards cities. However, this chapter will focus on the transformations which are taking place and which will have to be favoured in order to reduce and optimise private transport, a real scourge in large towns and cities. The final part of the chapter covers the concept of *mobility as a service*, being the evolution of the concept of ownership towards that of service.

12.1 Introduction

The current transport landscape is undergoing radical changes: the emergence of a multitude of new applications, business models, and specialisations, in addition to the entry of "new players", bears witness to this change.

Innovation in the transport industry is expected from the integration of new technologies and the development of new concepts of mobility. Smart mobility is the vision of a revolutionised individual and collective mobility, framed as a personalised "service" available "on demand", with individuals having instant access to a seamless system of clean, green, efficient, and flexible transport to meet all of their needs, as a result of emerging technologies such as automated vehicles, sharing mobility, and the Internet of things. Smart mobility is something more than the intelligent transport system (ITS) concept, the latter consisting of the application

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of high technology and computer power to increase the safety and efficiency of the transportation system.

In the previous chapter, the state of the art of technologies which will contribute to the development of sustainable mobility in cities was illustrated. This chapter will deal with changes in the behaviour of city dwellers and digital technologies which can facilitate such behaviour.

Mass transportation must certainly remain the backbone of local public transport, both in terms of travel within cities and for that towards cities. However, this chapter will focus on the transformations which are taking place and which will have to be favoured in order to reduce and optimise private transport, a real scourge in large towns and cities. To do this, a common thread, connecting some obvious macrotrends will be followed.

This chapter will start from the *sharing mobility* that is part of the broader field of the *sharing economy* of which Airbnb[1] is perhaps today the maximum representative. It will pass through the *Internet of Vehicles*, as the technological hardware enabling the whole technological revolution, to arrive at the *autonomous vehicles*, which in the name itself embodies the true revolution: the separation of the vehicle, which becomes autonomous, from its owner/driver. The final part of the chapter covers the concept of *mobility as service* (*MaaS*), being the evolution of the concept of ownership towards that of service.

12.2 From Individual to Shared Mobility

The great availability of cars with ever better performances, of ever-expanding road infrastructures, and of a very widespread supply network as well as the increase in the average revenue—just to mention some of the most important factors—has led, from the 1960s to today, ever more people to own and use individual and personal vehicles, more particularly cars.

The increase in the population which lives and works in cities, combined with the progressive dispersion of activities on the surrounding territories, the so-called *urban sprawl*, has further increased the need for this type of individual mobility. Today, in almost all the developed countries of the world, the social and territorial organisation is based on the widespread availability and regular use of cars (or other personal motor vehicles such as motorcycles and scooters but also trucks for the movement of goods). Today, road transport covers around 90% of land transport (Eurostat 2019).

The main features that have made the use of the private car becoming increasingly widespread are (ONSB 2019):

- **Accessibility**—The road network is by far the most widespread transport infrastructure in the world.

[1] Airbnb is an online portal that connects people looking for accommodation or a room for short periods, with people who have extra space to rent, generally private apartments (https://www.airbnb.com).

- **Continuity**—A private vehicle allows one to reach points that are isolated and even thousands of kilometres away without changing means of transport. It is unbeatable in the so-called door-to-door connections.
- **Availability**—Moving independently, cars allow one to move and stop in total freedom without having to buy tickets or respect timetables and connections.
- **Versatility**—The car is the most versatile means of transport, it can be used for short or long journeys, and it can be used for necessity, work, or leisure, on advanced high-capacity road infrastructures or on simple connecting rural lanes.

On the other hand, in recent years, one has been witnessing a change of trend: in heavily urbanised areas—owning a private car no longer seems strictly necessary, and indeed it is becoming an issue, in favour of collective transport services or sharing mobility, which is increasingly popular (McCarthy and O'Keeffe 2017).

This transformation of habits, which is sweeping the world of mobility, derives both from local authority decisions like congestion charging (Fulton et al. 2017) in Singapore, London, or Stockholm and from the continuous spreading of *sharing economy* models such as co-working, crowdfunding, house sharing, social shopping that are revolutionising some markets which were, historically, based on individual private property. The interest in collaborative consumption is becoming increasingly widespread, especially among the new generations: today's young people are progressively less attracted to possessing a property because they are more interested in being able to use a service.

The shared use of the same mobility service is naturally not a new concept, but it is a common feature of all the forms of transport that do not need the use of a vehicle owned by the company. "Shared mobility services" include both the more traditional collective transport services such as trains, undergrounds, trams, buses, or taxis, and the new services for sharing an "individual" means of transport such as bike sharing, car sharing, carpooling, and other innovative services enabled by the use of digital platforms. In any case, all the shared mobility services require that there be an organisation which provides the mobility service and a plurality of subjects that make use of this service, sharing vehicles and journeys.

Shared mobility services can be classified into two macro-families based on their accessibility and availability:

- Services with fixed itineraries and schedules.
- On-demand services with itinerary to be established each time.

All collective transport systems, whether or not, are part of the first family (trains and subways, trams, buses, etc.). Instead, all the modern sharing mobility services fall within the second family, together with taxis and classic rental services, with or without driver. Among these, the most well known and widespread is undoubtedly car sharing but there are different forms of sharing that can be grouped into three categories (Table 12.1).

- **Vehicle sharing** (car sharing, bike sharing, scooter sharing, and other vehicle sharing) In its most basic form, car sharing is a form of car rental with some key differences: usually, there is no requirement to return a car to a rental station

Table 12.1 Different types of shared mobility

Type	Examples	Descriptions
Commercial car sharing	Car2go	Offers a "floating" fleet that can be located on an app and rented for one-way trips within defined city areas
	Enjoy	Offers a "floating" fleet that can be located on an app and rented for one-way trips within defined city areas
	Sharengo	Offers a "floating" electric fleet that can be located on an app and rented for one-way trips within defined city areas
	DriveNow	Offers a "floating" fleet that can be located on an app and rented for one-way trips within defined city areas
Peer-to-peer car sharing	auting	Matches drivers with passengers for short-time drives, when the vehicle is not in use by the owner
Ride hailing	Uber	Matches private drivers with passengers for intra-city trips on demand
	mytaxi	Matches taxi drivers with passengers for trips on demand
Ride sharing	BlaBlaCar	Matches drivers with passengers for intercity drives
	Jojob	Corporate carpooling

(vehicles that can be rented are spread out over a region), car sharing services are charged by minute of use (vs. days of use in car rental), and all the actions of reservation, pickup, and return are self-service.
Providers include commercial entities as well as private individuals who rent out their own vehicles through peer-to-peer car-sharing programmes. These services make available to consumers all the benefits of car ownership without its attendant costs, including purchase cost, insurance, maintenance, and parking. Nowadays, they are all supported by mobile apps.

- **Ride hailing** (also called ride sourcing or on-demand ride service) These are online platforms (with mobile apps) developed by transportation network companies that allow passengers to "source" or "hail" rides from a pool of drivers that use their personal vehicles.
- **Ride sharing** Classic ride sharing is simply what was previous called carpooling: two or more travellers sharing common, pre-planned trips made by private automobile. In recent years, thanks to GPS and mobile technologies, ride sharing has evolved into a real-time or dynamic ride sharing that can match drivers with riders in real time without advanced planning. This ride-matching process is conducted through mobile apps that connect drivers with passengers travelling along similar routes, in real time, at predesignated pickup locations (commonly called casual carpooling or "slugging").

In recent years, in response to this change, an increasing number of car manufacturers, in addition to leasing and rental companies, are investing in car-sharing services. The internal reorganisation is transforming the whole automotive sector.

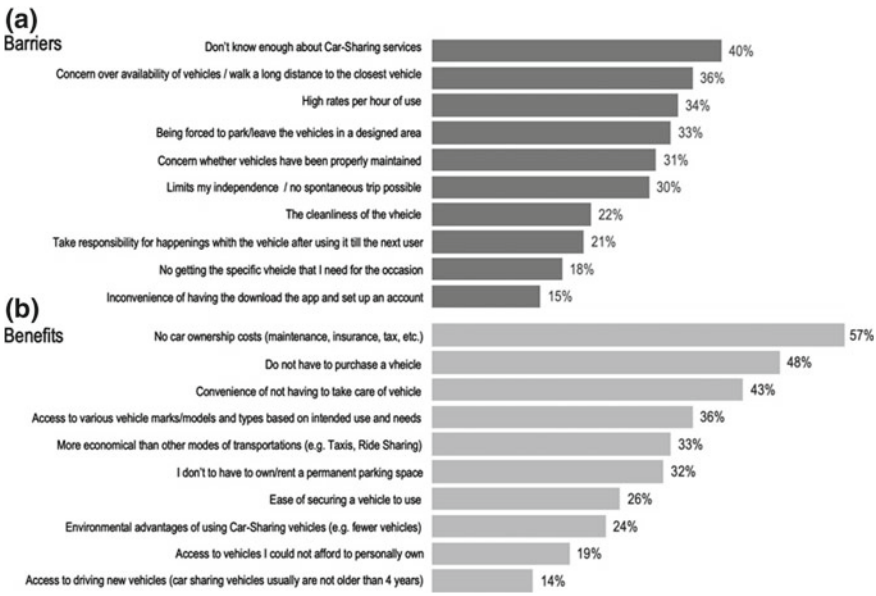

Fig. 12.1 Barriers (**a**) and benefits (**b**) of using car sharing (Yakovlev and Otto 2018)

Leading car-sharing companies such as car2go or DriveNow (recently merged into ShareNow[2]), Maven, are fully owned by car manufacturers which are changing their traditional business models where they earned money from only selling and maintaining cars: by providing car-sharing services, they also earn from operating the car itself.

Thanks also to these investments, vehicle-sharing services are increasingly diffuse despite some initial difficulties (Yakovlev and Otto 2018) owing, above all, to scepticism towards the new form of mobility (a). With the further development and spread of vehicle sharing, these obstacles will soon be overcome and progressively more people will use these services, also because the convenience of vehicle sharing in large cities is widely recognised by consumers (b). No car ownership costs (57%), no car purchase costs (48%), and the convenience of not having to take care of the vehicle (43%) are considered (by the percentages of people asked, shown in brackets) to be the three major benefits of car sharing (Fig. 12.1).

Undoubtedly, all forms of vehicle sharing are developing only in large metropolitan areas. In fact, the success of this mode of transport is achieved exclusively by making large fleets available in order to provide a truly capillary service which is competitive with the private car. However, large fleets require many customers and those numerous customers are more easily found in large urban areas. Nevertheless when examining situations such as that of Europe, where there are also many small- or

[2]Share Now is a car-sharing provider of the automobile companies BMW and Daimler. Emerged from the joint venture between the two companies, car2go and DriveNow were founded in 2019 (https://www.share-now.com).

medium-sized urban centres, it is necessary to understand how to accompany shared mobility services. A possible solution is that the sharing company which starts a service in a medium–small city immediately declares its customer break-even and that, in the growth phase towards break-even, there are public contributions to the deficit of the sharing companies, in a similar manner to what happens with local public transport.

12.3 Internet of Vehicles and Autonomous Vehicles

All the solutions that can be offered by shared mobility are and will be made possible thanks to the latest technological innovations which are rapidly and drastically changing the transport sector (Fig. 12.2). To ensure a widespread and effective service, all fleets of different vehicles (machines, scooters, bicycles, scooters, etc.) must be connected to the Internet of things to ensure both optimal management of the fleet by the service provider and access by users. The shared mobility services are in fact possible thanks to the support of mobile applications that allow access to the service, use the service, and pay for the service without any intervention by the staff of the company that manages the service.

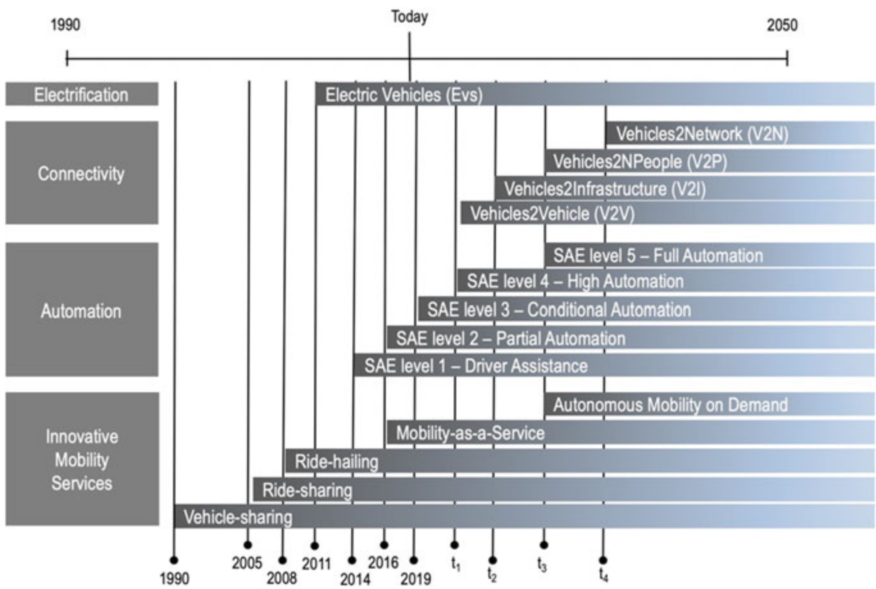

Fig. 12.2 Timeline of the maturity of vehicle technologies and mobility services (Coppola and Esztergàr-Kiss 2019)

The digitalisation of all these activities was possible thanks to the development of information and communication technologies (ICTs) which are continuously applications for better and more targeted use of vehicles and infrastructures in order to optimise the performance of the entire mobility network.

The continuous connection of the vehicles to the service management network is the first step in what is called the *Internet of Vehicles*, a subgroup of the much more famous *Internet of things*. *IoT* is a concept that represents one of the possible evolutions of the use of the Internet that is taking hold in these years: objects can communicate data about themselves and access information shared by others.

If we apply this concept to vehicles, connected vehicles will have to be not only able to exchange an increasing amount of information with a central server but also capable of communicating with all the different elements of the mobility system so as to create a much more complete connection system, usually designated *vehicle-to-everything* (V2X).

An important goal of the V2X is to allow real-time communication between a vehicle and all the entities that may affect the vehicle or vice versa. There are many levels of communication which can be grouped into:

- **Vehicle-to-driver** (V2D) systems for exchanging data between a vehicle and the driver.
- **Vehicle-to-network** (V2N) systems for exchanging data between a vehicle and a control centre.
- **Vehicle-to-infrastructure** (V2I) systems for exchanging data between a vehicle and infrastructures and supporting roadside units.
- **Vehicle-to-vehicle** (V2V) systems for exchanging data between a vehicle and surrounding vehicles. This can be done by creating the so-called vehicular ad hoc networks (VANETs) that is the spontaneous creation of a wireless network between nearby vehicles.
- **Vehicle-to-people** (V2P) systems for exchanging data between vehicle, smartphones, or other dedicated devices that support awareness for vulnerable road users such as pedestrians and cyclists.

If large cities are being considered, V2X is only possible thanks to advanced communication technologies and data management logics.

So far as communication is concerned, the speed required for V2X can only be achieved by exploiting the potential of 5G technology. The spread of this technology will introduce a new generation of high-speed, low-latency communications which will enable the implementation of V2X (Chen et al. 2017).

The management of the enormous volumes of data that will be quickly generated by these systems requires the technologies and analysis algorithms of the *big data* field. For example, traffic data from individual vehicles must be analysed in real time in order to be able to check the infrastructure for better management of the mobility network (Talebpour and Mahmassani 2016).

For example, a control room can monitor traffic lights or impose dynamic limits of optimal speeds to facilitate the flow of vehicles within the city: it can even monitor

Fig. 12.3 Levels of driving automation by SAE international's J3016 standard. (https://www.sae.org/)

all the parking areas in real time and control the situation by directing the vehicles into assured parking lots.

Finally, all will have to fulfil the highest levels of computer security. *Cyber-security* is a key aspect in the development and effectiveness of all the different V2X communications which must be protected from any kind of intrusion by outsiders.

Thanks to the implementation of all these technologies, vehicles connected with V2X systems will thereby be permitted to interface with the surrounding environment, not only facilitating a better management of the mobility network but also allowing the vehicles themselves to have access to useful information in order to foresee many dangerous situations that often lead to road accidents (Talebpour and Mahmassani 2016).

The amount and speed of information that a single vehicle could receive are such that it cannot be managed by a human driver and it is naturally necessary to have *artificial intelligence* (AI) which can exploit the information received and, based thereon, condition the driving of the vehicle itself.

The interventions to which AI has access can be very different, from the simple creation of warnings for the driver to complete control of the vehicle. The classification most commonly used to define the level of vehicle automation is that proposed by the International Society of Automotive Engineers (SAE).

SAE defines a taxonomy and definitions for on-the-road motor vehicle automated driving systems, distinguishing between six levels of automation.[3]

[3]https://www.sae.org/.

In the first three levels (see Fig. 12.3), the degree of automation is low, and one refers to assisted driving, while, starting from level 3, the characteristics of an autonomous vehicle are defined. In simple terms, “an *autonomous vehicle* is one that can drive itself using various in-vehicle technologies and sensors, including adaptive cruise control, active steering (steer by wire), anti-lock braking systems (brake by wire), GPS navigation technology, lasers, and radar”.[4]

The high level of automation and communication present in the AV will surely bring advantages both for those who manage the mobility systems and for users, but there is still great uncertainty about the benefits, costs, impact on travel, and the growth of demand (Litman 2019).

For example, in an autonomous vehicle the driver is not expected to monitor constantly the roadway, allowing passengers to rest or work during the trip, reducing stress, and improving productivity.

As already indicated in the previous chapter, several studies are simulating the impact of autonomous driving in city traffic and in particular on the estimate of the minimum car fleet necessary to meet the current transport demand. For example, the result of a study by MIT is an estimate, rather surprisingly, of a possible fleet reduction from 30%, using a real-time optimisation logic, up to 40%, having the full knowledge of daily trip demand (Vazifeh et al. 2018).

Regarding safety, since human error contributes to 90% of crashes (Road Safety Authority 2013), it could be argued that autonomous vehicles will reduce crash rates and insurance costs by 90% (McKinsey 2016).

This overlooks additional risks that these technologies can introduce (Koopman and Wagner 2017), such as hardware and software failures, malicious hacking, increased risk-taking due to “over-trusting” technology (Millard-Ball 2016), additional risks to non-auto travellers, PBIC (2017), and reduced investment in conventional safety strategies (Lawson 2018).

At present, there is much interest in and curiosity about AVs since one is in a phase in which some car manufacturers are offering the first models with SAE Level 3 systems (e.g. Tesla Autopilot, Volvo Drive Me). On the other hand, much still needs to be done from the point of view of the technologies, from that of the infrastructure, and moreover from that of the legislation.

Finally, if the costs are considered, owing to the technological hardware necessary for the AV, the cost of maintenance and of necessary mappings, the prices of the AV will be on average higher than the human-driven vehicles (Litman 2019).

The AV can be competitive on a large scale only if widely implemented in sharing services thanks to which the AVs can guarantee a door-to-door service.

The autonomous driving technology will therefore have an important effect on the urban planning of cities, which has always been strongly influenced by the presence of cars, both when moving and when parked. In fact, it will allow a more rapid

[4] https://www.gartner.com/it-glossary.

development of the *sharing mobility* which, as already mentioned, will lead to a great reduction in the number of vehicles with consequent recovery of city spaces for new or different activities.

12.4 Mobility as a Service—MaaS

MaaS is a relatively new concept, presented at the European ITS Congress in Helsinki in 2014, which is mainly based on the integration, in a single application, of services generally offered by different mobility providers. Already today, technological advances have made available a wide range of digital tools related to transport and mobility, permitting the appearance of different categories in the field of intelligent mobility (El Kaim 2016). Trying to tidy up the tangle of apps related to mobility now currently available, it is useful to divide them into four broad categories, delineated by the apps' primary function (Shaheen et al. 2016):

- **Mobility apps** are apps with a primary function to assist users in planning or understanding their transportation choices and may enhance access to alternative modes.
- **Smart parking apps** provide information on parking cost, availability, and payment channels. These apps are often paired with smart parking systems.
- **Vehicle connectivity apps** are apps that allow remote access to a vehicle through an integrated electronic system that can be used in cases of emergency (e.g. locked out of a car, requesting assistance after an accident, etc.); they are generally developed by automobile manufacturers.
- **Courier network services** (also referred to as flexible goods delivery) are apps that provide for-hire delivery services for monetary compensation using an online application or platform to connect couriers using their personal vehicles, bicycles, or scooters with transport demand for light freight (e.g. packages, food).
- **Complementary apps** can be interesting for mobility, such as health apps, environment and energy consumption apps, and insurance apps.

All these apps, with basic functions, can then be incorporated and managed by applications of a higher level which can access them. These applications, which can be managed by third parties, are therefore "smarter" since they can integrate more than one service. These smart digital mobility entities can be in turn grouped in three main families:

- **Smart Mobility Providers**: Entities which enable or own a mode of transport and offer an access to its services by means of computer applications, mobile apps, API, etc. Examples: shared mobility providers, public transport companies, private bus companies, car manufacturers (Table 12.2).
- **Smart Mobility Integrators**: These provide digital platforms which link to the right combination of various modes of transportation in order to offer an integrated, multimodal door-to-door mobility solution using a mobility platform by leveraging

Table 12.2 Smart mobility provider's mobility apps

Type	Examples	Descriptions
Business-to-consumer (B2C) sharing apps	CAR2GO enjoy	Apps that sell the use of shared transportation vehicles from a business to an individual consumer, including one-way and round-trip car sharing
Peer-to-peer (P2P) sharing apps	auting share your car	Apps that enable private owners of transportation vehicles to share them peer to peer with others, generally for a fee
Taxi apps	mytaxi itTaxi	Apps that supplement regulated city taxicabs
E-hail apps	lyft	Apps that supplement street hails by allowing location-aware, on-demand hailing
Ride sharing	Bla Bla	Apps that provide a platform for sourcing rides. This category is expansive in its definition so as to include "ride-splitting" services in which fares and rides are split among multiple strangers who are travelling in the same direction
Public transit apps		Apps that enable the user to search public transit routes, schedules, near-term arrival predictions, and connections. These apps may also include a ticketing feature, thereby providing the traveller with easier booking and payment for public transit services

technological expertise, operational excellence, infrastructural advancements and innovative business propositions. Examples: platform providers, B2C providers, API providers (Table 12.3).

- **Smart Mobility Aggregators**: These propose a selection of mobility services as their core business, either as stand-alone providers or through partnerships. They provide both digital platforms (including on-the-go payment and ticketing systems) and physical mobility facilities (e.g. parking zone for bike or car sharing), with the aim of becoming the mobility hub for any transportation need and of offering single payment solutions for multi-mode transportation.

Table 12.3 Smart mobility integrator's mobility apps

Type	Examples	Descriptions
B2C apps/journey planners	Citymapper, ubi, FREE2MOVE, here, moovit	Apps that route users by considering multiple modes of transport and providing the user with travel times, connection information, and distance and trip cost
Travel planners (visitors)	Google Trips	Apps that support the organisation of a travel, including transport, hotels, and so on
Complete platforms	OpenTripPlanner, Rome2Rio	Complete platforms consisting in mobile apps, website, routing algorithm, API
API	*Navitia.io (Keolis, FR), OpenTransportNet (EU project), Transitland (from Mapzen), TransitFeeds (open source, USA), Transitlime (open source, USA), TransportAPI*	Components for apps building

The MaaS concept refers to the last category and is the newly emerging concept involved with mobility integration, providing a new way of thinking in terms of how the delivery and consumption of transport (or mobility) are managed (Fig. 12.4). It uses ICT integration, ticket integration, and payment integration in order to offer to users a tailor-made multimodal seamless mobility service, by means of a public or private mobility aggregator (MaaS Alliance 2017).

MaaS is based on a disruptive digital business model, offering services on subscription in the form of mobility packages, similar to a monthly telephone contract, although it could accept pay-per-ride micro-transactions. This bundling of mobility modes presents a shift away from the historic ownership-based transport system towards an access-based system. The contract could also include other complementary services, such as trip planning and reservation, hotel, events, and payments, through a single interface (Kamargianni and Matyas 2017).

The first to experiment with this type of service were the Finns and, specifically, the inhabitants of Helsinki who, since 13 June 2016 ("a groundbreaking day for urban travel"),[5] have the opportunity to use the Whim app. Thanks to this app, it is possible to search for the best route, consult timetables, choose travel options,

[5] https://whimapp.com/.

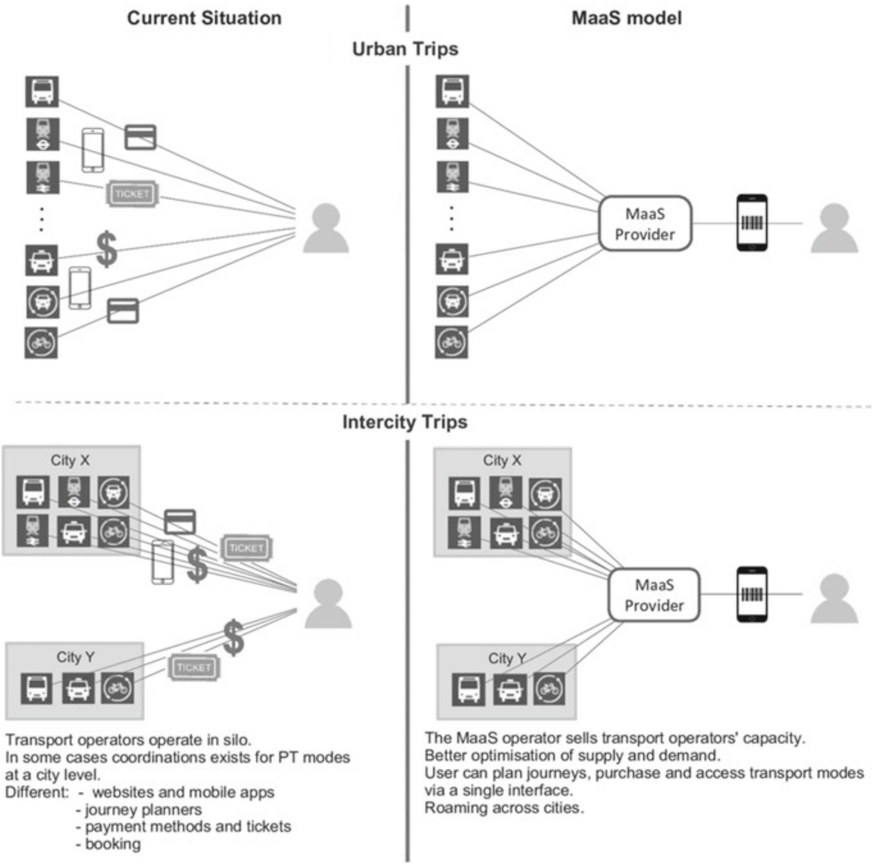

Fig. 12.4 With and without MaaS from user's perspective (Kamargianni and Matyas 2017)

and book and use the various services by purchasing a single ticket (single-ticket principle), choosing between local public transport, taxis, sharing mobility services, and rental cars (see Fig. 12.5). After the launch of Whim, it was found that among the MaaS users the modal share of public transport was increased from 48 to 74%.[6]

Following the success of Whim today, there are many examples of MaaS applications and pilot projects[7] that have shown that MaaS can be a valid tool for promoting shared modes (Matyas and Kamargianni 2018).

Among these, we mention the Communauto/Bixi project started in Quebec, Canada, where some municipal transport companies have decided to offer packages that include in their offer of public transport the possibility of using bike-sharing and car-sharing services. In Gothenburg, Sweden, UbiGo ("We want to simplify your

[6]https://whimapp.com/.

[7]https://maas-alliance.eu.

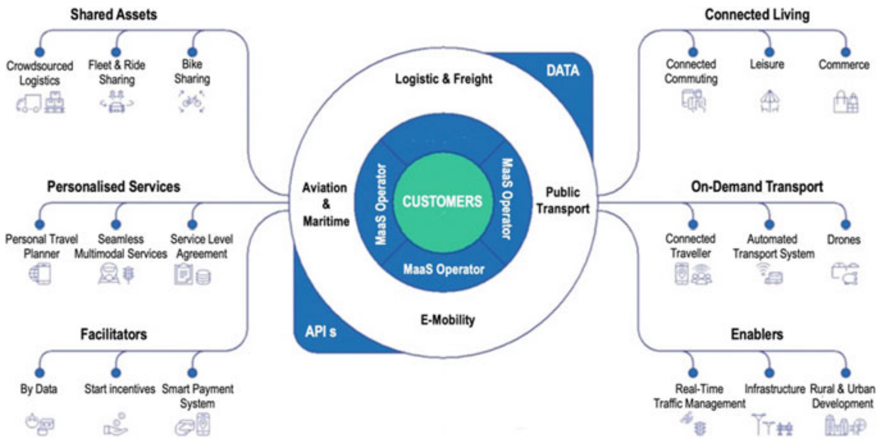

Fig. 12.5 Mobility as a service framework (Huhtala-Jenks 2016)

journey from A to B")[8] adds, to the previous types of transport, the possibility of renting a car and using taxis through a single application which, among other features, has the interesting possibility of assigning bonuses to users if they make choices of sustainable movement by exploiting shared transport services with low environmental impact. In Italy, the NUGO application, developed by the Ferrovie dello Stato group, today already integrates more than 200 mobility providers, including intercity and regional rail transport, urban transport in many Italian cities, various car-sharing and bike-sharing providers, parking lots, car rentals, and more.

In general, the business model of MaaS apps allows to access different transportation options with just one account: within the application, one can plan, book, and pay trips using the services of the partners (Table 12.4).

Typically, a digital mobility solution makes use of a *Journey Planner*, i.e. a search engine aimed to find optimal routes and ways of moving between a set of locations (Shaheen et al. 2016).

Trip Planner, Travel Planner, and Route Planner are often used as synonyms of Journey Planner:

- *Route Planners* are typically thought of as using only one mode of private transportation (such as driving a vehicle, walking, or cycling).
- *Journey Planners* usually make use of at least one public transport mode which operates according to published schedules.
- *Trip Planner and Travel Planner* are often used as a trip organiser, i.e. for tourist or visitor travel.

The process of planning a journey from one location to another mainly involves decisions on the mode of transport (e.g. car, bicycle, public transport, on foot) and potential routes to reach the destination. The choice of mode of transport and of routes

[8] https://www.ubigo.me/.

Table 12.4 MaaS core characteristics (Jittrapirom et al. 2017)

Journey planning and integration of transport modes	A goal of MaaS schemes is to encourage the use of collective transport services, by bringing together multimodal transportation, allowing the users to choose, and facilitating them in their intermodal trips. Urban modes may be included: public transport, taxi, car sharing, ride sharing, bike sharing, car rental, on-demand bus services; but also long-distance buses and trains, flights, and ferries
Tariff option	MaaS platform offers users two types of tariffs in accessing its mobility services: "mobility package" and "pay-as-you-go". The package offers bundles of various transport modes and includes a certain amount of km/minutes/points that can be utilised in exchange for a monthly payment. The pay-as-you-go charges users according to the effective use of the service
One platform	MaaS relies on a digital platform (mobile app or web page) through which the end-users can access to all the necessary services for their trips: trip planning, booking, ticketing, payment, and real-time information. Users might also access to other useful services, such as weather forecasting, synchronisation with personal activity calendar, travel history report, invoicing, and feedback
Multiple actors	MaaS ecosystem is built on interactions between different groups of actors through a digital platform: demanders of mobility (private customer or business customer), a supplier of transport services (public or private), and platform owners (third party, PT provider, authority). Other actors can also cooperate local authorities, payment clearing, telecommunication, and data management companies
Use of technologies	Different technologies are combined to enable MaaS: devices, such as mobile computers and smartphones; a reliable mobile Internet network (Wi-Fi, 3G, 4G, LTE); GPS; e-ticketing and e-payment system; DBMS and integrated infrastructure of technologies (i.e. IoT)

(continued)

Table 12.4 (continued)

Demand orientation	MaaS is a user-centric paradigm. It seeks to offer a transport solution that is best from customer's perspective to be made via multimodal trip planning feature and inclusion of demand-responsive services, such as taxi
Registration requirement	The end-user is required to join the platform to access available services. An account can be valid for a single individual or, in certain cases, an entire household. The subscription not only facilitates the use of the services but also enables the service personalisation
Personalisation	Personalisation ensures end-users' requirements, and expectations are met more effectively and efficiently by considering the uniqueness of each customer. The system provides the end-user with specific recommendations and tailor-made solutions on the basis of his/her profile, expressed preferences, and past behaviours. Additionally, they may connect their social network profiles with their MaaS account
Customisation	Customisation enables end-users to modify the offered service option according to their preferences. This can increase MaaS' attractiveness among travellers and its customers' satisfaction and loyalty. They may freely compose a specified chained trip or build their mobility package with a different volume of usage of certain transport modes to better achieve their preferred travel experiences

could take into account several factors. The most important factors are journey time, journey cost, number of interchanges, type of transport means; but other factors can be taken into account such as sustainability issues (Fig. 12.6).

The core component of a journey planner is the (shortest) path search algorithm. For road route planning, one can compute driving directions in milliseconds or less, even at continental scale. The techniques for solving the vehicle routing problem include basic approaches, but also heuristic search algorithms aimed at solving classic

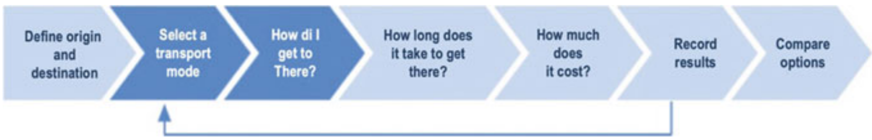

Fig. 12.6 Mobility as a service, conceptual scheme

operational research problems such as the travelling salesman problem (TSP), its generalisation given by the dial-a-ride problem (Cordeau and Laporte 2007), and the integrated dial-a-ride problem that includes the integration of demand-responsive services with fixed route services.

Journey planning on public transport systems, although conceptually similar, is a significantly harder problem owing to its inherent time-dependent and multicriteria nature. The multimodal route planning problem, which seeks journeys combining schedule-based transportation (buses and trains) with unrestricted modes (walking and driving), is even more difficult, relying on approximate solutions even for metropolitan inputs (Bast et al. 2015). The ultimate goal, a worldwide multimodal journey planner, must take into account real-time traffic and transit information, historic patterns, schedule constraints, and monetary costs. Moreover, all these elements should be combined in a personalised manner (World Economic Forum 2014).

MaaS will certainly become the most widespread way to move, in the same way that Apple Music and Spotify revolutionised the world of music or Netflix revolutionised the world of films. Cities and local government regulators have an important task: to prevent mobility providers from slowing down this unstoppable process by refusing commercial agreements for the development of a single mobility supplier.

Over the interests of individual companies, the general interest of the citizen/customer must prevail. Indeed, the public service regulators could impose on both historic and new suppliers the integration into a public platform which, in order to keep the fees low, must be regulated at national, European, or international level.

12.5 Conclusions

Given that the goal of the public administration bodies (local and regional councils) which promote mobility solutions is to ensure that the use of private cars must be gradually abandoned, there are many advantages provided by MaaS for private individuals, for companies that offer transport services and for the community as a whole.

First of all, there is a reduction in traffic and pollution (both atmospheric and acoustic). Operators in the transport world, having a vast amount of data on which to build their strategies, will be able to optimise their services by responding in a timely manner to the needs of their interlocutors. In this regard, even traffic managers will be able to opt for solutions and modular prices based on usage, timetables, and the current traffic situation.

Moreover, thanks to the offer of much more efficient planned travel solutions, service users will be able to have cheaper, faster, and safer journeys thanks to always having access to information updated in real time on the situation of the route they are taking.

Figure 12.7 shows the concepts expressed in this chapter concerning the mobility as a service and the new paradigms of sustainable mobility:

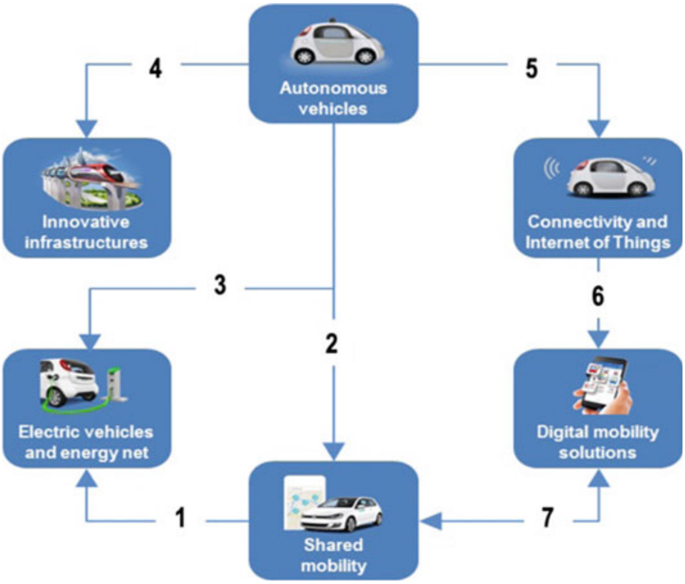

Fig. 12.7 Mobility as a service, new paradigms of sustainable mobility

- An uptake in shared mobility will accelerate electrification, since greater utilisation is favourable for the economics of electric vehicles.
- Self-driving could cause the merger of shared mobility business models into a single proposition, competitive with private car ownership and public transport.
- Self-driving vehicles, both private and shared, will probably increase demand for, and consumption of mobility, in which case electric vehicles offer lower total cost of ownership.
- Self-driving electric vehicles will have a different usage and hence have different requirements for charging infrastructure.
- Self-driving vehicles might accelerate the uptake of IoT applications.
- Connectivity and Internet of things (IoT) will enable progressively more digital mobility applications.
- The availability of digital mobility solution can support shared mobility and vice versa.

Finally, if one considers the possibility of having electric, autonomous, and shared vehicles then it is possible to outline a scheme in which all the major mobility trends have an effect of mutual reinforcement in favour of a more integrated, multimodal, and thereby more efficient and effective mobility.

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