Chapter 11
The Infrastructure for Sustainable Mobility

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Abstract The objective of this chapter is to indicate in which direction cities must invest in order to become smart and sustainable in terms of mobility. On the basis of the current trends and considering technological innovation in the mobility sector, the chapter will address those aspects which the planners will have to take into account not only in the design of the new neighbourhoods, but also in the redevelopment of the recovery of the existing ones. The authors discuss both collective mobility and individual mobility, thus ranging from underground railways to electric scooters. In the final part, general criteria for sustainable mobility planning are provided.

11.1 Sustainable Mobility in Smart and Sustainable Cities

Collective mobility will be increasingly integrated and multimodal, whilst individual mobility will become increasingly shared, connected and electric. This is the new urban mobility that is slowly taking hold in all the advanced metropolises of the planet, from Europe to the USA, but also strongly in China, in India and in the most advanced countries of the Far East.

The Paris agreements on climate and the need to define road maps at 2030 and 2050 are contributing to the definition of policies to reduce smog, to face the challenge imposed by climate change and to create and have more sustainable and liveable cities. The new generations are smarter, digital and, not least, cost-conscious (Zawieska and Pieriegud 2018; Ajanovic and Haas 2019).

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All the demographic mark trends describe a strong shift of the population towards the cities. The forecasts indicate that in 2050, there will be as many as seven city dwellers for every 10 inhabitants of the planet.

Growing cities are becoming increasingly critical in terms of harmful emissions, pollution and CO_2, also owing to the growing demand for mobility, which on the other hand is one of the major factors of competitiveness of the cities themselves. For this reason, one refers increasingly to urban plans of sustainable mobility and, in general, to make mobility increasingly green.

So far as individual mobility is concerned, much is driven by the growing availability of electric vehicles, by the growing presence of cycle paths, by the modal share which shows a drop in the rate of motorisation in almost all the advanced metropolises that grow at a steady pace in terms of number of inhabitants but often reduce the number of cars at the same time (Civitas 2015; McKinsey & Company 2018).

A representative case among all is Milan, which over the last twenty years has lost as many as 100 thousand cars and gained as many residents returning to 1.4 million inhabitants, all thanks to ambitious local policies and the tools which follow, amongst all of which the activation of the Area B (low-emission zone) after the success of Area C (congestion).

In this chapter, an attempt is made to indicate in which direction cities must invest in order to become smart and sustainable in terms of mobility. Both collective mobility and individual mobility are discussed, thus ranging from underground railways to electric scooters.

Chapter 12 instead studies the behaviour enabled by the digital revolution, arriving at the concept of Mobility as a Service (MaaS) (Crozet et al. 2019).

Digital platforms, metadata platforms for integrated mobility, sharing in all its forms, from sharing to peer to peer will thus be the topics which will be handled in Chap. 12.

For economy of narration, railway urban mobility has been excluded: this is to be understood as the demand for mobility that originates in extra-urban areas, which is served by the train and which, more and more often, allows urban penetration via city railway stations and underground rail passers. Urban railway transport has the great merit of lightening the load on the other modes of urban transport by taking up a large slice of demand that would otherwise weigh again on the city means. However, it lies typically outside the city administrative competences, being a part of large national railway infrastructure investments. In the context of this book, therefore, which aims to provide a clear indication to local government administrators on how to direct investments, urban railways have been excluded.

A reflection must be made to understand to what extent certain solutions can work regardless of the size of the cities.

Reference is not being made only to large investments, since it is clear that in order to be able to think of an underground railway service, the demand must be that typically generated in middle/large cities, but also, for example, in sharing mobility which will be discussed in Chap. 12. Today, shared mobility is taking off well in large cities, with over half a million inhabitants.

It is probably unnecessary to remind the reader that in order to accelerate this revolution of urban mobility and zero emissions, it is essential that there are concrete policies and actions capable of making cycling, walking, public transport and electric mobility grow. One can rapidly gain the conviction that it is possible to escape from the pollution that characterises urban centres and at the same time reclaim squares and streets, making cities more liveable and safer. To start this revolution, however, courageous and systematic choices are required, national policies that also include unpopular measures such as the carbon tax. Local administrators cannot be left alone in the face of these challenges. The general framework must be defined by national or supranational entities, such as the Conference of the Parties (COP), to which local realities refer.

The market and the economy once again anticipate legislation, in many cities the number and variety of mobility providers are already capable of winning against the private mobility, both from the point of view of speed and flexibility of travel, and in terms of the travel cost.

Certainly, the clear lack of legislation and the confused regulatory framework has led to the known problems between taxis and Uber, or with free-floating fleets of bikes, or even on the rules of movement of electric scooters. It is one of the main themes to work on.

In this chapter, examining future infrastructures of cities, electric mobility in all its multifaceted meanings will be focused upon. It is now well established in the international scientific community that land transport can be completely decarbonised by passing on a large scale to electric vehicles.

The different forms of mobility can be divided into:

- Collective mobility;
- Individual mobility.

The first goal that the public regulator must set itself is to move as much as possible individual to collective mobility, to increase the overall efficiency of the mobility system, in terms of generalised costs, thus also including the costs related to pollution and road congestion.

11.2 Collective Mobility

Urban public passenger transport plays a particular role in the world of mobility as it is the sector with greater volume of production (in terms of total km covered, number of employees, number of vehicles, etc.).

The complexities of urban public transport are many, including the needs to:

- Carry large masses of people;
- Adapt transport systems to urban topography, normally already strongly configured;
- Ensure intermodality and interchange between different modes of transport.

Table 11.1 Urban transport systems

Rail	Road	Cable/conveyors
Tramway Underground rail Light rail transport Monorail	Trolleybus Electric bus	Cable cars Funiculars Elevators Escalators Travelators

In recent years, in all the most developed countries, urban sustainable mobility plans have been implemented, mainly owing to two different needs: to meet the demand for mobility in urban and metropolitan areas and to make mobility increasingly sustainable and green.

In order to address the development of urban mobility, it is necessary to know the various and different modes of transport available on the market, having clear their respective capacities and potentials, investment costs, infrastructural impact, operation and maintenance costs.

In the following paragraphs, the Key Performance Indicators—KPIs characteristic of urban public transport systems will be *illustrated, together with* the various modes of transport according to the classification normally used in the literature. One feature connoting urban public transport services is the great variety of modes, vehicles, technologies and infrastructures.

This variety is explained by the need to adapt transport services to both the territory and to the demand to be served. Table 11.1 proposes a first classification of electric land-based modes used for local public transport services, while Fig. 11.1 shows the relative weight of road and rail-based public transport modes in the European Union and in some key member states in terms of passenger per km.

Comparing the costs of different transport systems is no easy task (see Fig. 11.2). The main reason is that the cost of a transport system is made up of capital expenditure (CAPEX) and operating expenditure (OPEX). High-capacity modes usually have lower OPEX but higher CAPEX per vehicle * km and it is the contrary, for low-capacity modes.

Furthermore, CAPEX is not constituted only by vehicles, but also by infrastructure that cannot be standardised on the basis of the number of vehicle per km or the number of passengers; i.e. maintaining a metro network roughly depends only upon the number of trains or daily services. Table 11.2 tries to provide just order of magnitude values, since the actual costs depend upon the context.

On the other hand, OPEX per passenger does not change considerably between different transport modes as it does for CAPEX, and it should be noted that, as public transport (PT) is normally a labour-intensive activity, the costs for providing PT services mainly depend upon the cost and productivity of driving personnel and on the commercial speed of services.

In simple terms, the performances of a PT system crucially rely on the mobility flows they should sustain.

These parameters may vary substantially from country to country and even show a great variability within a single region. This is partially due to the specific conditions

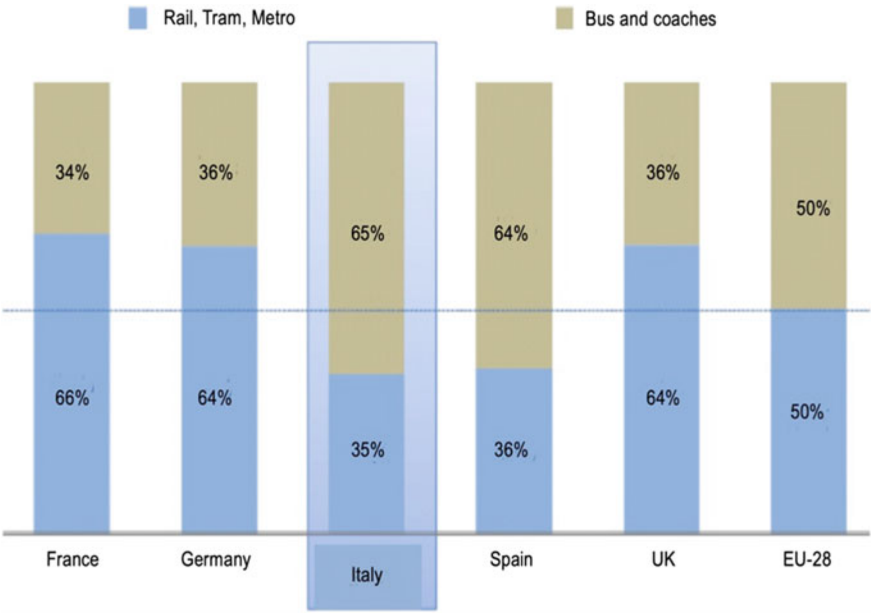

Fig. 11.1 Weight of road and rail-based public transport modes in the EU (EC 2015)

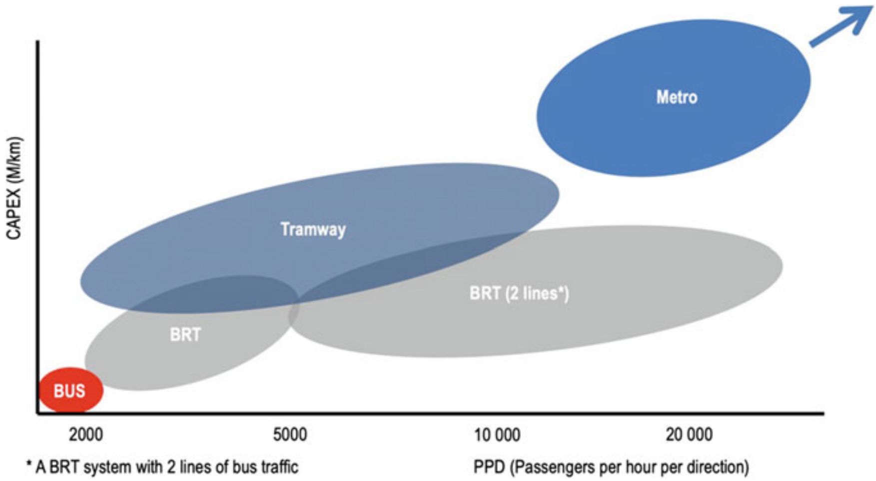

Fig. 11.2 Comparing the costs of different transport systems

Table 11.2 Average comparison between the costs of different modes of transport

Mode	Millions €/km of network
BRT[a]	5–15
Tram	15–40
Metro	80–200

[a] A Bus Rapid Transit (BRT) is a transport system based on high-frequency bus routes, segregated lanes and other forms of prioritisation over private traffic (i.e. at junctions)

in which services are operated but also reflects different efficiency levels. This is the reason for which, particularly in markets, where competition is not so extensive, universities, consultancies and public sector bodies have been struggling to calculate, through statistical, econometric, empirical models, the so-called standardised cost, that is the cost for providing a non-specified PT service with a given productivity level.

However, it should be noted that these models must be handled carefully, as their results strictly depend on the input parameters in the model itself. Table 11.3 shows the main urban local public transport vehicles classified according to their performance, first of all, the capacity in terms of passengers per hour per direction.

As described above, the main challenge for the regulators is to increase the share of collective mobility. To do this, it is necessary to bear in mind that mobility is, by nature, intermodal, since the door-to-door connection can hardly be done with a single collective means. By intermodality it is also meant: on foot + collective means, bike + collective vehicle, car or scooter + collective vehicle.

The main reason why in most cities today the individual transport largely exceeds the collective transport is precisely because individual transport is congenital door to door. To compete, the collective transport must be widespread and extensive, frequent and continuous over time so that the main differences will be only costs and speed, on which a good public transport system is normally competitive.

The backbone of any collective transport system in metropolitan cities is rail, underground and tram transport. The poor development of these networks depends also upon the lack of non-repayable public funding.

In almost all EU countries, there is a notable asymmetry between railway infrastructures, normally 100% funded by the widespread state taxation, and metropolitan infrastructures that normally receive only partial funding from the state and whose costs therefore remain a charge on the local authorities.

However, since local authorities rarely have sufficient tax revenues, the result is a significant slowdown in the construction of networks compared to the need for mobility. In essence, it would be necessary that at the level of the EU and of individual states, the extra-urban railway and the urban railway should be considered in the same way to avoid the paradox of underfunding precisely the networks with the highest utilisation rate.

Table 11.3 Collective transport—features and performances

	Unconstrained 12 m Promiscuous	Unconstrained 18 m Protected	Constrained Tramways Promiscuous	Constrained Tramways Protected	Constrained Classic Underground	Constrained Automatic Underground	Services Not programmed
Potentiality	<2500 p/h/d	2000–4000 p/h/d	2000–6000 p/h/d	3000–15,000 p/h/d	8000–45,000 p/h/d	6000–25,000 p/h/d	– p/h/d
Capillarity accessibility (m)	200	200	200	200–300	500–800	500–800	High
Regularity	Very low	Good	Very low	Good	Great	Great	Low
Frequency	Average low	High low	Average low	High low	High low	Medium high	Good
Speed (max.) (km/h)	50	50	50–80	80	50–80	80	50
Commercial speed (km/h)	10–15	15–25	20–30	30–40	20–30	30–40	10–20
Travel speed							
Short dist.	Low	Average	Low	Medium high	Medium-high	Medium-low	–
Long dist.	Very low	Medium-low	Very low	Low	Low	Very high	–

It should be noted that in the last few decades, the non-repayable public funding failure has been replaced by private investments in project finance, often financed by the construction companies themselves which have taken over the financing in order to build.

The result for the balance sheet of the local authorities is however often disastrous since the interest rates that the builders obtain from the banking system are very high, often having such companies a low credit rating, and these interests enter the overall debt that must be repaid by the local authority transport companies. Local authorities almost always pay remuneration to project finance with a fixed fee, completely absorbing the traffic risk. The overall result is an infrastructure cost that grows considerably owing to interest on the debt and makes it even more untenable for the local authority to start new investments.

11.2.1 Trams

It is considered worthwhile to spend few words on the tram, probably the oldest means of collective urban transport, but which is experiencing a new rejuvenation throughout the world.

There are several innovative technologies with which it is possible to create new-generation tram lines that are, unlike traditional ones, without an overhead contact line. These technologies are well suited to overcome some constraints typical of the historic centres of large cities, contributing to the development of eco-sustainable mobility. The innovative "catenary free" systems, which saw the first important applications in Europe especially in Spain and France, have the following strong points:

- reduction of aesthetic, environmental and urban impact;
- reduction of the zone of respect with greater possibility of overcoming obstacles (e.g. bridges);
- reduction of impact on traffic in case of adverse weather conditions (snow, ice).

A classification can be made based on the methods of energy withdrawal and transfer:

1. Pick up from the traditional contact line (existing only on part of the track) through a traditional pantograph, placed on the roof of the tram;
2. Withdrawal from a third track (third rail); in this case, the pantograph becomes a skate placed on the bottom of the tram and applied to its bogies, so-called conduction system;
3. Withdrawal by electromagnetic induction between metal loops, sunk into prefabricated panels placed on the ground, with a skate present on the vehicle, so-called induction system.

The vehicle can be equipped with on-board supercapacitors and batteries.

11.2.2 Electric Buses

For public transport even on the street, electrification seems the obvious alternative to keep pace with urban growth and to care for the city environment at the same time, using full electric or electric hybrid buses (Lin et al. 2019). With the right charging technology, the advantages of electrified buses can be utilised: less energy consumption in comparison with buses with internal combustion engines, use of renewable energy, less noise, lower particle emissions, less CO_2, lower life cycle costs and reliable service.

In recent years, all the major bus manufacturers, in addition to some newcomers, have developed and tested full electric buses, with some interesting innovations such as the Alstom Aptis, in some respects a cross between a bus and a tram.

Despite the increasing supply and capacity of batteries, up to 350 kWh, the autonomy in operation barely reaches that average of 250 km necessary to guarantee the entire daily shift of the single bus. Thus, the need has arisen to integrate the network with recharging infrastructures along the route (see Fig. 11.3). The two main solutions currently used are:

- *Opportunity charge*: high-power charging systems at the terminus with a pantograph system.
- *Electric roads*: moving charging systems inserted in the road infrastructure with catenary, conduction or induction technologies.

Both of these solutions significantly reduce the use of on-board batteries and are therefore convenient where one must manage large fleets of several hundred or thousands of vehicles.

Different companies are at the forefront of this technology to help operators to find a solution tailored to their individual challenges. Table 11.4 reports different possible solutions applied to electric buses.

Fig. 11.3 Different modeS to recharge the electric buses. **a** Plug-in charging and **b** pantograph charging (ABB 2019)

Table 11.4 Different solutions applied to E-buses

Off-board top-down pantograph	On-board bottom-up pantograph	Charging via connector
The buses need to be equipped with contact rails, a WiFi antenna and the necessary control and switchgear units	This solution is a fast-charging system mainly used in cities with the existing DC networks, such as for tramways. The most apparent feature of this charging solution is the bottom-up pantograph mounted on the bus roof	This solution is designed for fast charging of electric vehicles (EV). Plug-in DC chargers are available as single or twin chargers the last-mentioned with the advantage of reduced infrastructure expenditure. Based on proven technology, DC chargers are highly reliable and user-friendly
Opportunity charging at terminal station via 4-pole off-board pantograph	Opportunity charging at terminal station through 2-pole catenary	Fast and efficient charging solution from 30 to 150 kW
Fully automated charging process with charging power levels of 150/300/450 kW/600 kW	750 DC power input	Safe, robust, durable, stable and user-friendly
Charging power: 110/300/450 kW/600 kW	60 kW or 120 kW of charging power for minimising the required charging time	Charge any CCS or GB/T-compatible vehicle
Grid connection: 400 V to 20 kV AC, 50/60 Hz	Roof-mounted pantograph and DC/DC inverter	Battery charging status, power consumption and autonomy are displayed
Wireless communication via Wi-Fi IEEE 802.11a based on ISO 11118		Charging cycle finishes automatically or can be interrupted by user command
Remote access, service and control		Remote access, service and control

11.3 Individual Mobility

Until a few years ago, individual mobility coincided with private transport, bicycles, scooters and cars, with the only exception being the public service provided by taxis.

The digital revolution and sharing are changing habits. Certainly, the main individual means remain the private one, but one is witnessing dynamics of growing supply and demand in the various sharing sectors, with giants such as UBER and BlaBlaCar[1] or Share Now[2] driving the sector now populated by many providers.

[1]BlaBlaCar is a Web car-pooling platform that operates in 22 countries. With 80 million users, it is the most used in the world (https://www.blablacar.com).

[2]Share Now is a car-sharing provider of the automobile companies BMW and Daimler and thus one of five mobility service providers that emerged from the joint venture between the two companies

Since these are individual 2- or 4-wheel vehicles, the various electrical technologies available and the consequent necessary infrastructural developments will be analysed in the following paragraphs.

11.3.1 Cars

All the large car manufacturers have gone so far as to create electric models, at the moment giving the impression more of the following regulatory obligations than the real will to turn towards green mobility. Figure 11.4 shows some models of electric cars currently on the market.

The EU, Japan, several US states and several regions of China are forcing manufacturers, via legislation, to rapidly bring emissions below 100 g/km of CO_2. To avoid heavy penalties, all manufacturers now have several EV models in their catalogue. However, the marketing and price strategy still rewards those cars with internal combustion or hybrid engines. According to the writers, this depends on the absolute lack of batteries, but there is also the difficulty of battery capacity. At the global level, battery production can currently cope with the maximum of 3–4% of electric vehicle production, equivalent to 2–3 million vehicles per year.

Certainly, cities are the main beneficiaries of the transition to electric cars, both in terms of CO_2 and local pollution. To stimulate demand and supply, cities can introduce congestion charges based on the level of vehicle emissions, but at the

Fig. 11.4 Radar for the development of the electric vehicle (Ancitel Energia e Ambiente 2016)

founded in 2019. With Share Now, the previously competing providers car2go and DriveNow form a joint car-sharing service.

same time, they must invest in public and private charging infrastructure. A more systematic and broader use of fair and efficient tolls based on the "user/polluter pays" principle will direct users towards more sustainable transport choices.

Battery

The coming of electric mobility today is intimately linked to two strategic factors.

The first is that of the infrastructure of the territory through sufficiently widespread recharging points. The second is that of the charge capacity of the batteries and the rapidity of charging, to which an ever-increasing autonomy is required to allow the electric vehicle to equate, in a not too far distant future, to the conditions of use of a traditional endothermic engine vehicle also on long-distance routes. The batteries that today offer the greatest prospects in this regard are those operating on the basis of lithium chemistry, which have been used for many years in the power supply of consumer electronics (PCs, smartphones, small appliances) (Report Linker 2019).

The very strong diffusion that this technology has encountered in energy storage, replacing the previous chemical types, is essentially due to two fundamental characteristics. The first is the charge density, that is, the amount of electric charge which, for the same useful surface area for the accumulation, is able to absorb, which, in lithium accumulators, is significantly higher than that of all other types of batteries. The second, instead, is represented by the significantly lower weight per unit volume of these batteries, when compared to the other types existing on the market.

These two features make lithium accumulators particularly suitable for the consumer electronics sector, where many devices (in particular PCs, tablets and smartphones) require ever more energy (due to the many functions they perform) in less space, in the need for the use of batteries that do not make the equipment too heavy. For similar reasons, lithium batteries are now the only chemical type used in pure electric vehicles, since the energy storage capacity and lightweight are the two essential elements to make this form of sustainable mobility feasible.

When an electric vehicle battery has exhausted its life cycle and no longer guarantees the same original performance, it must be replaced. These batteries, however, when disposed of from electric vehicles, may still have a second useful life in their reuse as energy storage batteries for the most diverse uses, as they still retain a charge capacity equal to 70% of the original one. The theme is currently very much in the limelight. The interest, and new business activity in the reuse of these batteries for energy storage are growing. Additionally, car manufacturers are also strongly interested in the "second life" of the batteries used in their cars, since the lengthening of their useful life and the creation of a secondary business can have a positive impact on battery management costs, thereby facilitating the success of the electric market. The issue of recycling lithium batteries is thus "a current event", as is the large spread of this type of batteries on the market. For example, there is a British start-up company, operative since 2015, which gathers in these used lithium-ion batteries to create battery packs as backup power for off-grid lighting in fragile economic areas.

The *handling as waste* of these batteries does not present, in principle, particular critical aspects, although their entry on a relatively recent market, that has not yet generated large waste streams until a few years ago, has not even justified the study and consolidation of technologies. For this reason, research on the best treatment and recycling processes is still open, presenting hypotheses and sometimes very different approaches.

One of the most important aspects to be faced is represented by the first phase of grinding up these accumulators and the need to guarantee this activity in absolute safety, to avoid explosions or fires. The subsequent phases must then address the issue of recovering materials and metals, from the simplest, i.e. casings and electrical circuits, to those that are less simple such as the chemically active part of the accumulator, also called "black mass". The real challenge is to be able to define a treatment and recycling process whose costs can be sustained by the sale of secondary raw materials recoverable from the process itself.

Returning to cars, even in the case of city cars, manufacturers are focusing on medium/large batteries, currently 40/50 kWh. These capacities allow a city car with the average typical daily journey of 30 km, a need for weekly, and not daily, charging. This therefore positively impacts the city's charging columns, the use of which is subsequently optimised.

From the point of view of parking infrastructure there are no restrictions, such as those already in force for gas-driven vehicles, for the use of electric vehicles even if the extinguishing of a fire of a battery requires specific technical knowledge on the part of the fire brigade.

Hydrogen

With a hydrogen car, one means a vehicle that converts the chemical energy of this element into mechanical energy. Hydrogen can burn in an internal combustion engine, and in this case, one refers to a hydrogen internal combustion engine vehicle (HICEV), or alternatively a reaction can be caused with oxygen in a fuel cell, thus producing electricity. In this case, fuel cell electric vehicle (FCEV) is the term employed.

The main advantage of the hydrogen car is precisely that of not producing any greenhouse gases since only absolutely non-polluting water vapour is emitted from the car's exhaust pipe. Analysing the peculiarities of hydrogen cars, both the advantages and, inevitably, the disadvantages associated with this type of car must be evaluated.

The first advantage is that these cars allow harmful emissions to be reduced by 100%, since only water vapour is released from the exhaust pipe. Moreover, thanks to the electric energy coming from the fuel cells, the batteries of the electric motor can be recharged more quickly than a totally electric car. Lastly, the time needed to refuel is much lower, from 3 to 5 min.

The negative aspects of hydrogen cars include, first of all, the purchase price, currently not exactly in the popular car bracket, secondly, the almost total absence worldwide of dedicated filling stations and, last but not least, the considerable weight of these cars due to the cylinders in which the hydrogen is stored. Once again, the question is strategic. If battery solutions are chosen, a network of charging stations has to be developed, whereas if hydrogen is favoured, it is a network of hydrogen distributors which must be implemented.

At the moment, only a few countries, amongst which the most important is Japan, are investing in production and distribution of hydrogen.

Autonomous Drive

The development of autonomous driving mainly for cars and light commercial vehicles should be considered in urban planning. Investments in this technology are truly enormous, both on the part of traditional manufacturers and on the part of the digital giants and the new economy, such as Google, Apple or Amazon. All the most recent estimates predict that as early as 2040, autonomous vehicles will be between 40 and 70% of the total (Daviex 2018; Union of Concerned Scientists 2018).

From the infrastructural point of view, there are no specific requirements, except that the cities must be dotted with well-maintained *signposts and markers*.

From the point of view of traffic flows, several studies show that autonomous driving will lead to a significant reduction in the number of cars in movement on the roads.

A recent MIT study in the Manhattan area shows that once all vehicles have passed over to autonomous driving, the number of cars on the road can be reduced by 50% (AGELAB–MIT 2019). Obviously, this data must be considered in long-term urban planning.

11.3.2 Micro-mobility

Micro-mobility refers to the set of vehicles and modes used for short journeys and for the transport of a maximum of one or two people (Heineke et al. 2019; Zarif et al. 2019). City planners know that they cannot always simply add more routes and stops into the conventional public transport system, because that would cost too much or result in other undesirable outcomes. At the same time, the first/last mile problem discourages many commuters from using mass transit at all. An integrated transportation system which includes public transportation and such flexible alternatives as micro-mobility vehicles can help to fill the gap (Dutta and Sutarwala 2019; Chang et al. 2019).

This type of mobility includes all those vehicles such as electric scooters, segways, monowheels and electric bikes (see Fig. 11.5). Additionally, this also means all those services of rental of electric bikes or scooters which are becoming more widespread in the major cities.

These services offer people the possibility of renting a vehicle to move around, reserving and paying for it via a related mobile app. The *typical provisional municipal regulations* foresee an “experimental operation” in the cities of this kind of means of transport. It clearly refers to a type of intermodal mobility and therefore is intended to interface with public transport but also requires of mayors to create all the opportunities to implement in their cities those infrastructures which are necessary, being first and foremost, dedicated lanes. In fact, electric scooters, segways, monowheels

Fig. 11.5 Different symbols of micro-mobility

and hoverboards will require new updates of the Highway Code: here, one is talking about the introduction of a new category dedicated to "eco-sustainable vehicles".

Although it is true that these vehicles can be driven without a driving licence, nonetheless, they will certainly have to abide by the rules. Undoubtedly, the compulsory use of the helmet will be introduced, and a specific insurance will probably also need to be provided. A whole series of very specific limits will arise: new-generation electric vehicles, even the smallest ones, must have reflectors and position lights and cannot in any way exceed 30 km/h.

These small and practical battery-powered vehicles experienced a real boom between 2018 and 2019, and mostly, the youngest sections of the population have contributed to the spread of this phenomenon. The main reasons that led to the success of these "alternative" means of transport are that they:

- allow short trips to be made quickly and practically (home–school or home–work);
- provide the possibility to avoid both car traffic and crowded public transport, thereby saving time;
- are ecological and do not pollute;
- are a very economical alternative when compared to using a car or a motor-driven vehicle;
- can even be fun to drive (see Table 11.5).

It is very interesting to note that the average speed of travel with micro-mobility over a distance of up to 2–3 km is often even greater than that for an underground railway trip, all access times being avoided. Micro-mobility can therefore be integrated in a significant manner with collective transport.

All the micro-mobility means are also connected, and it is therefore possible to reconstruct from their displacements the origin/destination matrices for the first and last mile, which in turn can suggest changes to the collective transport system.

It is therefore suggested that local authorities authorise micro-mobility providers to request constant data transmission. If it transpires that there are major source/destination relationships in the volumes and constancy thereof during the hours of the day, it could be the case to implement a collective service.

As mentioned in the introduction, micro-mobility, in particular electric vehicles such as scooters, segways or assisted and non-assisted bicycles, is opening a relevant regulatory issue that can be divided into two macro-categories:

Table 11.5 Benefits and problems of micro-mobility

Benefits and problem	Description
First/last mile access to transit	Small. Lightweight vehicles increase access to transit stations
Satisfy short trip making	Micro-mobility can satisfy trips under 5 miles with scooters, bicycles and e-bikes. In addition, e-mobility works in hilly areas where biking can be a challenge
Low-impact transportation	These no or low power vehicles have a smaller carbon footprint and make more effect use of parking and infrastructure as compared to an automobile trip
Expansion of mobility to traditionally underserved areas	Early data shows an expansion of options to mobility deserts (not well served by transit and/or with low auto ownership)
New avenues for transportation data	Shared use mobility and opt-in data collection from riders through mobile apps provide information on the performance of the mobility system, in particular when trips are carried out with multiple modes

- road safety;
- damage management and related insurance coverage.

As far as road safety is concerned, very clearly these vehicles are particularly suited to the cycle paths, thus separated from car and larger vehicle traffic. One would imagine that the overwhelming development of micro-mobility will finally lead to a greater development of urban cycle paths even in countries where the culture of the bicycle use has never really taken off. On this point, it is hence advisable that local governments/councils continue to invest in their cycle path networks, bearing in mind that they will serve as an infrastructure for the entire micro-mobility system.

With regards to damage management, understood as damage resulting from accidents between people moving by any means of transport or on foot, the authors believe that the only solution, for which indeed, among other things, some insurance companies already envisage coverage, is to move from insurance of the means of transport to insurance of the person by the mere fact that he or she moves, therefore with any means of transport.

Obviously, dependent upon the profile of each one, the insurance will assess the level of risk that will depend on whether they have a license or not, the type of driving license and therefore the vehicles which they are permitted to drive, the fact that they use *the bicycle, the scooter or the car*, whether they fly or go by train. In short, how their mobility is assured. This seems to be the only way to avoid the grotesque insurance of an electric scooter or bicycle.

11.3.3 Charging Infrastructure

From an infrastructural viewpoint, in order to correctly outline how electric mobility can develop, it is necessary to put oneself in the shoes of the user and analyse the different usage scenarios, from which different requirements in terms of necessary infrastructures are established (Longo et al. 2018a; Engel et al. 2018; Lunz and Sauer 2015). Three different scenarios for the development of a national charging network should be considered:

- **Scenario 1—Long stay**. This scenario identifies the places where cars stop for long periods such as, for example, parking spaces at the workplace, individual parking lots in garages, condominium parking lots and parking lots for company fleets occupied for overnight stops or throughout the day. The charging systems suitable for this service are those with low power in AC (slow type charging up to 6 kW) for a prolonged period of time (even 4–10 h). This type of recharge meets the "primary" needs of the user of electric vehicles and, with some exceptions, guarantees the daily journey of the vehicle (if it is less than 150 km/day and meets 95% of the needs of European daily journeys); individual recharge wall boxes in the garages of a block of flats are usually rated at 3 kW which, in some countries, involves increasing the householder's base supply from 3 to 4 kW.
- **Scenario 2—Short stopover**. This scenario describes the typical stop in shopping centres, cinemas and restaurants where parking typically varies between 30 min and 2 h. This type of recharge meets the need to supply the vehicle with additional mileage during the day to give the user more flexibility. This category includes accelerated charging systems such as roadside columns. These charging infrastructures involve higher costs than the battery charger on the vehicle but extend the range of action of the EV.
- **Scenario 3—Stop for recharging** or stopover less than 30 min for the sole purpose of recharge. The "stop for recharging" scenario does not respond to the needs of the home–workplace, but to those who must quickly recharge (a few tens of minutes) the EV (taxis, delivery vans, buses, etc.). It is also the scenario that allows the autonomy of exceeding 450 km to be significantly increased. Fast charging is also useful in cities because it gives reassurance to the driver and guarantees flexibility in case of unforeseen needs.

These scenarios are not intended to be limited to vehicles for passenger transport but can also be applied to freight vehicles (vans, etc.) to allow the development of the so-called "last mile". Electric vehicle charging technologies are divided into: conductive and inductive. The conductive recharge allows the charging of the battery of the electric vehicle through the connection to the power supply grid in alternating current (AC) of the charger on boarding the vehicle.

An alternative method for charging the vehicle is to use an external battery charger that supplies direct current (DC) to the vehicle. Both charging methods are characterised by a physical connection (through the power cable) between the vehicle and the charging infrastructure.

Within the conductive recharge technology, a fairly complex articulation is then to be found between slow recharging (single-phase or three-phase) and fast recharging (in AC or DC), strictly related to the technological evolutions that are characterising this sector. With inductive charging, the energy transfer to the battery takes place through the electromagnetic coupling between two coils: one mounted under the vehicle and the other supported or even buried in the vehicle parking area (Arancibia and Collins 2018; Foiadelli et al. 2017).

This technology is divided into stationary, which can also be activated automatically at the time of the stop, or dynamic, an application perhaps a little more futuristic which consists of charging the vehicle while driving (i.e. smart road). The first two types of recharging are accompanied by the battery swap technique, i.e. battery replacement, which can be considered comparable to a recharge technology. In Fig. 11.6, the charging technologies currently used are represented in a schematic way, in relation to the time taken for recharging.

Cities and towns tend to favour the first two recharge scenarios, that of low power in residential areas and workplaces and that of medium power for fast recharges. Ultra-fast recharges, for very long-distance needs, can be met outside the city, particularly in motorway service areas. Exceptions are recharge islands dedicated to electric taxis or electric commercial vehicles which need to minimise downtime from service on the road.

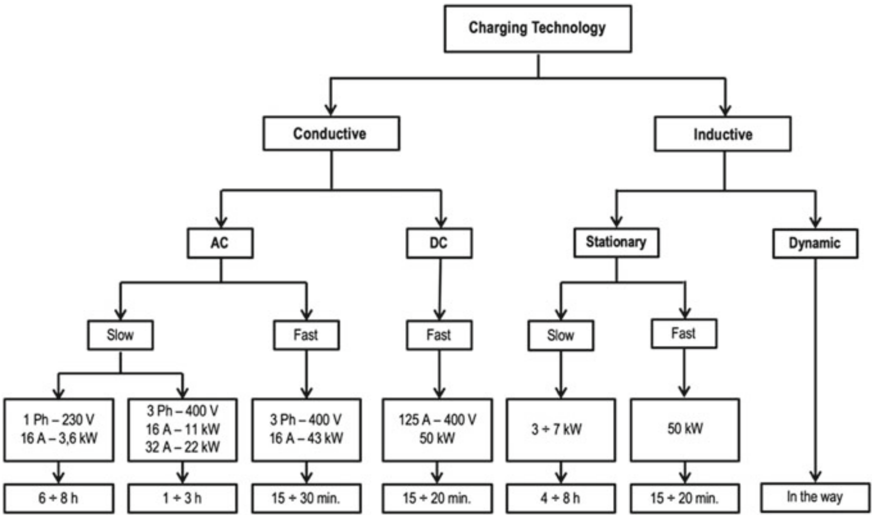

Fig. 11.6 Schematisation of the different charging technologies (Ancitel Energia e Ambiente 2016)

11.3.4 Charging System Requirements

Given that the infrastructure locations must privilege the intermodality criterion, the municipalities must ensure that the public access charging systems present on their territory adopt payment systems which are:

- functional;
- simple to use;
- readily available;
- updated and based on the latest technological solutions available on the market, with particular reference to Web/smartphone applications and digital payment systems;
- "open", or that allow the provision of the service to occasional customers through contextual payment as defined by Directive 2014/94/EU, in order to allow the use by occasional users (e.g. using common credit cards) without the need to enter into contracts.

It is also important to ensure that the charging stations are not illegally occupied by internal combustion engine vehicles or electric vehicles that are not under charge (Longo et al. 2017a, b, 2018a), having them removed when infractions occur.

11.3.5 Criteria for Planning the Charging Infrastructure Available to the Public

The charging infrastructure accessible to the public must be characterised by "high" or "high power" charging systems (greater than 22 kW), in order to guarantee the best coverage of the multiple needs of users and, in particular, a reduction in waiting times for vehicle being recharged, maximum 10–15 min. However, the charging infrastructure for private usage must be characterised by an adequate combination of "standard" or "normal power" (7.4–22 kW), or indeed household (3 kW), since, in this case, the recharge will be done in the night hours.

Standard recharge
It is preferable to install the "standard" "accelerated" charging systems in the following locations:

- *ALONG THE ROADSIDE*: with the main objective of providing the possibility of charging from the network during the overnight stop to those users of rechargeable vehicles who are not equipped with private parking/garage with a wall-box recharge.
- *PARK AND RIDE*: the main objective is to provide the possibility of charging users during daytime parking who reach the park-and-ride hubs of large urban centres by private car. They enable home-to-work commuting by electric vehicles even to those who do not have company parking lots equipped for recharging.

- *POINTS OF INTEREST*: the main objective is to provide the possibility to recharge during the stopover (average duration 1–2 h) at particular points of interest characterised by a strong influx of people.

High recharge
It is necessary to favour the installation of charging systems accessible to the general public in the following places:

- *SERVICE AREAS*: with the main objective of providing the ability to quickly recharge the vehicle on a route to be completed which is greater than the vehicle's maximum range. Wherever, due to problems of competence, it is not possible to intervene directly on the motorway, recharging service areas located near the entrance/exit toll gates should be the preference. It is also believed that the installation of recharging columns in such locations would ensure excellent capillarity but, above all, would lead the consumer to refuel in the same places previously used, presumably when he/she made trips with an internal combustion engine car. This system would improve the availability of charging stations without the need to have a specific App or interactive maps, also facilitating tourist activities, guaranteeing those who come from other towns and cities the certainty of being able to recharge their electric vehicle;
- *RAILWAY STATIONS, AIRPORTS AND KNOTS OF LOCAL AND EXTRA-URBAN PUBLIC TRANSPORT*: the main objective is to provide the possibility of quickly recharging the vehicle with access modalities such as to be able to guarantee the mixed usage of the recharging installations (by taxis, fleets in sharing, private vehicles);
- *GOODS LOADING/UNLOADING AREAS*: here, the main objective is to provide the possibility to quickly recharge from the network those rechargeable vehicles destined for the delivery of goods in urban areas, using parking bays compatible with commercial vehicles with loading up to 3.5 tons.

11.3.6 Analysis of the Actual State of Mobility

In order to plan the development of electric mobility as close as possible to the needs of anyone in possession of vehicles powered by electricity (be they residents, tourists, traders, taxi drivers or local public transport operators or other public services), a careful analysis of the existing scenario is advisable. An evaluation methodology is proposed hereunder.

First of all, it is necessary to carry out a georeferenced mapping of all the electric columns present on the municipal territory, distinguishing them on the basis of:

- locations;
- type of vehicles for which the infrastructures are destined (i.e. cars, quadricycles …);

- type of socket supplied in each column;
- distinction between "standard" or "normal power" charging systems and "high" or "high power" charging systems (CSs);
- if the CSs are intended for the public or if they are totally or partially intended for specific subjects (i.e. car-sharing operators, buses, taxis) and to what extent.

In order to allow the adequate development of electric mobility, in line with the objectives set by the European Union at 2030, which in urban transport plans to halve the use of cars "powered by traditional fuels" by that year and eliminate it by 2050 altogether, each municipality should estimate the growth volumes of the quantity of electric vehicles in circulation (private, public fleets, companies and sharing services) and calculate a recharging infrastructure requirement, including a green zone in a strategic area, well-connected with other types of mobility.

Of these top-up points, it will be noted that the majority, roughly 85% will be installed on private land (business, shopping centres, parking lots, garages and private garages/boxes) and the remaining 15% on public sector land. It is suggested to consider the following main indicators: population density (population and active population); density of economic activities and business demography; density of demand for private mobility; density of services of public interest.

If possible, and compatible with the size of the municipal territory and its morphological characteristics, it is suggested to aggregate the information, represented on a cartographic basis, by geographical area.

The process of analysis must first consider the resident population, both total and active: this first step, using the data related to the surface of each territorial area, allows the definition of the areas characterised by the highest population density. A similar criterion must be followed for production activities and their location. Subsequently, an analysis must be made of the displacements (origin -> destination) in order to determine the areas of greatest affluence. Thereafter, the location of public utility services has to be considered, in particular schools and universities, hospitals and other health facilities, sports facilities, theatres and auditoriums, museums, community centres, pharmacies, places of worship, post offices, public transport stations and stops. Finally, by assigning the same weight to each indicator, a summary table is drawn up indicating, for each selected areas, the average of the values corresponding to the classes defined above, identified as overall indicators. This synthesis, elaborated by comparing each theme, makes it possible to identify the areas for which it is estimated that there may be greater demand for infrastructure.

Considering the recharging network within the municipality of reference, it is considered appropriate to define the percentages, divided according to reference criteria normally employed (i.e. districts), to be used for the location of the new recharging infrastructures, in order to guarantee the service on the territory where, today, it is less present.

Finally, relying on the above analyses and considering the total needs of recharging points previously calculated, it is possible to proceed by making hypotheses of how to distribute them in the medium-long period among the various municipal areas.

In order to guarantee an effective use of the public top-up system by users, the infrastructure hypothesised must include a mandatory mix of AC recharging points and DC recharging points.

11.4 Conclusions

It is now fully recognised and a well-established viewpoint that terrestrial mobility can be 100% decarbonised by 2050. In metropolitan cities, the good starting point is the historical presence of many electric means of transport: the underground, trams and trolleybuses. The extension of the use of these vehicles, together with the widespread electrification of buses, commercial vehicles and cars is now a matter of time but no longer of technology.

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