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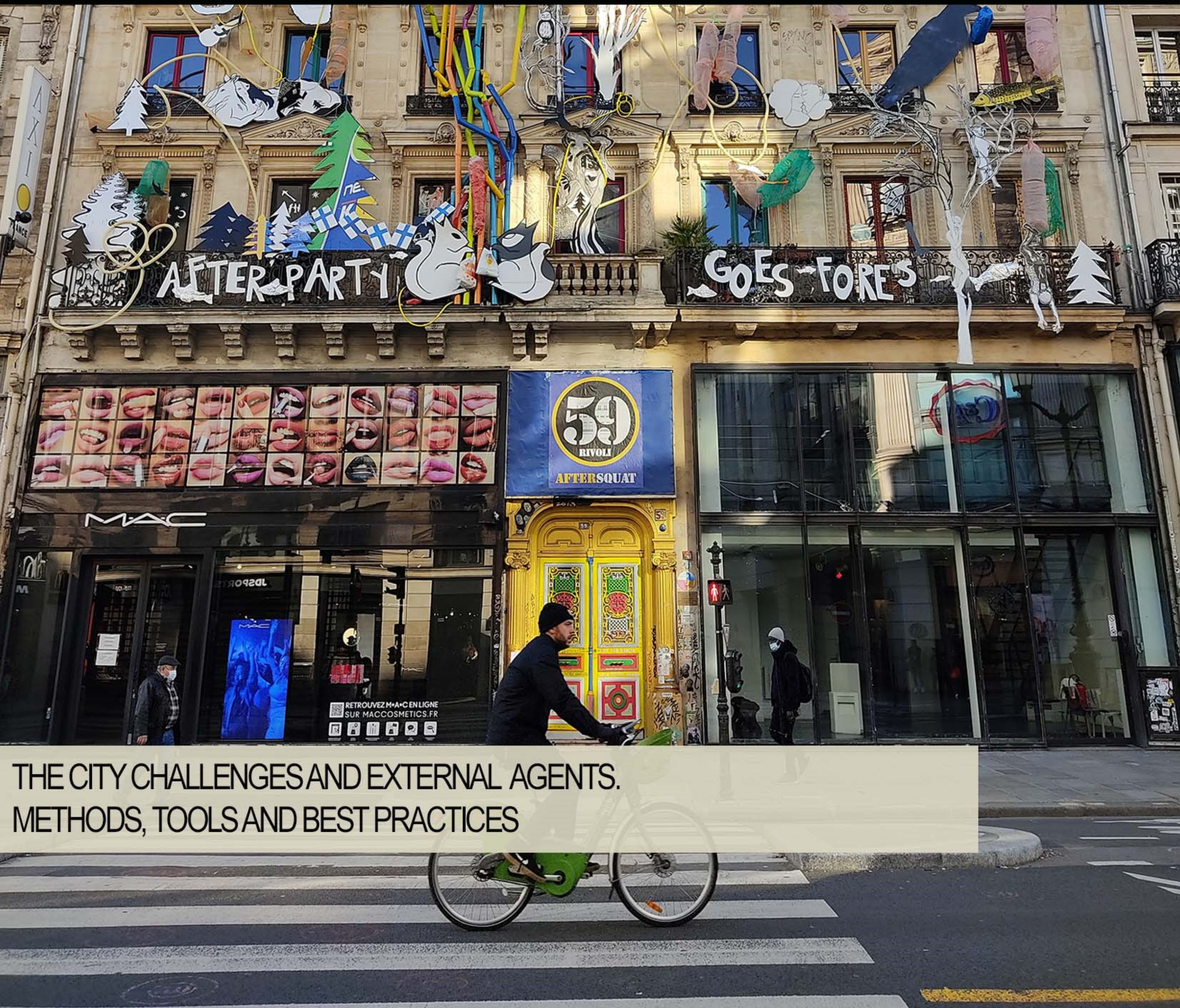

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The cover image is Rue de Rivoli - an emblematic street of Paris connecting Bastille to Concorde – that since May 2020 has been reserved for bicycles and pedestrians, Paris, France, Saturday, Nov. 6, 2021.

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Sustainable Urban Mobility Plan and the electric mobility challenge. First results of the planning process in Genoa

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Abstract
An increased use of local public transport (LPT) is often proposed as an essential contribution to the overall response to the environmental challenges. The major changes in the urban layout are accompanied by an adaptation of the infrastructural settings, necessary so that the movements can take place quickly, safely and efficiently, following to the main exigencies of its citizens. For this purpose, in accordance with the European Directive 2014/94 on alternative fuels, in Italy, the coordinated action at national level supports electricity and other fuels (such as liquefied and compressed natural gas and hydrogen) as priority fields of interventions for the entire supply of the transportation sector. Aware of the current state of Italian urban mobility, in August 2017 the Ministry of Infrastructure and Transport (MIT) introduced a planning tool dedicated to the 14 Metropolitan Cities, the Sustainable Urban Mobility Plan (SUMP) with the crucial objective of the electrification of "Rapid Mass Transport - TRM" systems. In particular, only TRM interventions that create a zero-emission are eligible for funding. Precisely in relation to sustainable electric mobility, this contribution deals with the step-wise project of new 4 trolleybus lines in Genoa, as an initial application of metropolitan TRM systems in Italy. In the paper, author provides the assessment of the electrification project adopted in Genoa and also first results from the case-study planning process.

Keywords
Sustainable urban mobility plan; Electric mobility; Public transport service.

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1. Introduction

Reducing private transport and making urban transport systems greener and more efficient has important benefits: for the health, climate and prosperity of cities. Even today, many of the daily journeys depend on cars and other private motorized vehicles, with a strong impact in terms of air pollution, noise and climate change as in the European Union transport is responsible for a quarter of greenhouse gas emissions. Therefore, new models of transport and urban accessibility, increasingly oriented towards environmental sustainability, must be adopted. The issue of urban mobility is a current issue and is particularly important in European countries where over 75% of the population is concentrated in urban areas and, furthermore, in a moment of growing concern about global warming and other environmental problems, an increased use of local public transport (LPT) is often proposed as an essential contribution to a complex solution (Holmgren, 2013; Mugion et al., 2018).
The choice of the transport solution must be made in relation to not only technical but also economic, social and environmental feasibility. Furthermore, the recent pandemic emergency is influencing mobility attitude and modal choices connected with public transportation (Al-Rashid et al., 2021; Campisi et al., 2020; Tirachini & Cats, 2020; EU Com, 2020).
At European level, Commission indicates the subscription of a planning tool, the Sustainable Urban Mobility Plan (SUMP), which explicitly referred to the policy documents of the sector and in particular in the Action Plan on Urban Mobility of 2009, among the priority actions. Many initiatives have already taken by European cities and the scientific literature about is getting more and more solid Europe-wide (Diez et al., 2018; Campisi et al., 2020; Pisoni et al., 2019).
As known, SUMP was defined as a strategic planning tool (Okraszewska et al., 2018) that, over a medium-long term time horizon (10 years), develops a system vision of urban mobility proposing the achievement of environmental, social and economic sustainability objectives, through the definition of actions aimed at improving the effectiveness and efficiency of the mobility system and its integration with the urban and territorial structure and developments. Evidently, mobility integration does not mean only cars and trains, but also commonly used solutions, meaningfully contributing to sustainable urban mobility goals like bike-sharing or park and ride systems (Macioszek et al., 2020; Politis et al., 2020; Nikiforiadis et al., 2020).
It is therefore evident that the traditional approaches to urban mobility are now outdated and with the SUMP a new concept of mobility has been introduced, with more emphasis on the involvement of citizens and stakeholders (Lindenau & Bohler-Baedeker, 2014), on the coordination of policies and planning tools and integration with various sectors: transport, urban planning, environment, economic activities, social services, health, safety, energy, etc. The main merit of the SUMP was in fact that of not promoting the idea of improving transport through the fluidification of traffic, but of putting at the center the quality of life perceived by citizens: in this sense, participation is not just a duty, but focuses on the sphere of values indicated by the citizens themselves, which is in fact detected by surveys in the first phase of SUMP (Maltese & Mariotti, 2011). The SUMP is also a fundamental tool for the integration into urban policies oriented towards the "smart city", supported in the European framework of Sustainable Urban Development. It intends to favor actions to combat climate change, production of clean energy, risk prevention, accessibility with a view to social and economic inclusion, safety and health, entrusting a new role to communities as real actors in urban transformation processes.
Many cities Europewide have already adopted a SUMP, as a coordinate way to organize internal transportation (Mozos-Blanco et al., 2018) but also to be competitive in a wider scene for obtaining UE funds, according to communitarian rules, which strongly suggest to adopt the plan. Around the tool, a meaningful debate arose, too (Niglio & Comitale, 2015; Arsenio et al., 2016; May et al., 2017; Jordova et al., 2021).

The SUMP is a strategic superordinate tool, hierarchically binding in respect to the other planning tools of the transport sector, because it takes into consideration all the needs of the core city and its hinterland, overcoming municipal administrative boundaries.

It is a dynamic tool, not limited to providing a list of interventions but it defines also measurable objectives, types of actions and proposes a program. On the basis of the objectives set, a two-year monitoring process and regular evaluation of the results are activated and, therefore, of the ongoing review of the measures adopted. Best cases can be represented by Manchester, Bilbao, Dresda, Grenoble, to cite a few. In particolar, SUMP Guidelines underlined how comprehensive sustainable urban mobility planning has proven to be an effective way to tackle the climate, energy and environmental challenges that cities face in relation to transport, giving also a greater emphasis on participatory process; in fact, in the document, SUMP concepts were explained to readers who are not necessarily professional planners, but want to understand the principles and basic elements for an active role during the drafting.

The Ministerial Decree 4 August 2017 of the Ministry of Infrastructure and Transport "Identification of guidelines for Sustainable Urban Mobility Plans-SUMP entrusts the Italian Metropolitan Cities with the drawing up their plans, as a condition to have access to State funding. They were specifically devoted to new interventions for Rapid Mass Transport-TRM, such as metropolitan rail systems, metro and trams.

The Decree starts from an assumption: the travel speed of the Italian metropolitan LPT is about half that of the large European metropolitan areas. The Italian anomaly compared to other European countries is especially visible in the undersizing of the rail mobility network (trains, trams, subways): in Italy the number stops at 3.8 km per million inhabitants of the underground network, half of that of Germany and a third of Spain. Therefore, political priority is assigned to the investment in infrastructures which favor electric transition: they must have an impact on the city as to considerably reduce gas pollution, to allow an increasingly decisive modal shift towards collective transport and to justify heavy costs in the long-medium term (Gargiulo et al., 2012; Ghosh & Schot, 2019; Guno et al., 2021; Ryghaug & Toftaker, 2016; Yao et al., 2020; Bakker & Konings, 2018).

The main target areas of this initiative are, as mentioned, the metropolitan cities, because they are places in which pollution levels are most critic. In relation to sustainable mobility in the Italian context, the paper deals with the assessment of the project of new trolleybus lines (as an application of the TRM system) in the Metropolitan City of Genoa, designed in accordance with Ministerial Decree and SUMP EU Guidelines.

Genoa is a densely populated area located at the center of the Liguria coast, where a complex geomorphological situation forces the urban mobility system to be extremely diversified: so that, it is an ideal test-bed for the application of the Italian and European regulatory apparatus in the field of transport of great interest. LPT service has buses, trolley buses, vertical and horizontal lifts, funiculars, racks, underground and marine transport. More specifically, Genoa has the lowest density of cars in Italy, compared to other metropolitan cities and a quite high share of non-motorized internal movements; for that, the increase in the use of the LPT is even more challenging.

The work is structured as follows: section 2 briefly outlines the planning process which boost electric mobility within the Italian context, trying to explain peculiar elements of the “Italian way to transport electrification process” (in accordance to the EU one); section 3 describes the project of Rapid Mass Transport system conceived in Genoa and its SUMP. Sections 4 is dedicated to the process’ results and the assessment of the electrification projects adopted in Genoa, while section 5 is devoted to general conclusive remarks where also critical points from the Genoa case are summarized.

2. Electric mobility planning process in the Italian context: a brief review

In recent years, many Western European urban public transport systems have undergone major reorganisation. While organisational forms differ between cities, there are common features that can examine as structural changes in urban public transport.

Within changes of this magnitude, *electric traction* is one of the most promising technologies, capable of improving the quality of life in metropolitan contexts, reducing emissions -that alter the climate- and dependence on fossil fuels (Chowdhury et al., 2019; Jorgensen, 2008; Drofenik & Canales, 2014).

The paradigm shift in Italy is not so timely for now: at the close of 2018, with 14,000 electric cars in use, the peninsula ranks among the tail-lights of Europe, even if the technology providers are gearing up to respond to the demand and the tendency to promote electric mobility in urban areas, starting from a not good position.

It is interesting to investigate how and from what basis the introduction of electric mobility is evolving In Italy.

Economic and Financial Planning Document (DPEF) of 2016 mentions the major criticalities of the Italian transport system and starts from there to propose solutions.

In particular:

- modal imbalance;
- reduced road capacity;
- insufficient last mile connection;
- reduced accessibility to main nodes.

The Annex of the same Document integrates, in 2017, its objectives and strategies with the analysis of medium/long-term infrastructure needs, identifying interventions and programs of significant national interest: it represents the document of "synergy" between the Italian infrastructure planning and the EU strategies, with which it shares the time horizon to 2030. As far as the completion of the EU Core network challenge is concerned, to better understand the logical steps in the adoption of electric mobility in Italy, a conceptual milestone is represented by the implementation of the EU Directive 2014/94 into the National Decree n. 257/2016. If the shared goal is to mitigate the effects of greenhouse gases and other pollutant components' concentration, the question is how to ensure that this cultural change takes place with the inclusion of everyone and contributes to an increased competitiveness of the transport system of the Country.

The IT Legislative Decree 2016/257 gives the precise definitions of what is meant by alternative fuels and allocates targeted funding to them: according to it, "alternative" are fuels or energy sources which serve, at least in part, as substitutes for fossil fuels in the supply of energy for transport and which can contribute to its decarbonisation and improve the environmental performance of the transport sector. Alternative fuels include:

- electric energy;
- hydrogen;
- biofuels;
- synthetic and paraffinic fuels;
- natural gas, including biomethane, in gaseous form, called compressed natural gas (CNG) and liquefied, called liquefied natural gas (LNG);
- liquefied petroleum gas (LPG).

Furthermore, the Decree instituted the so-called PNIRE (National Plan for the recharging of vehicles powered by electricity), that is finally more specifically related to the electric topic (IT Transport Ministry, 2020).

The National Plan concerns the creation of infrastructural networks for the recharging of vehicles powered by electricity as well as interventions for the recovery of the building stock aimed at the development of the same networks. The Plan supports the policies that incentivize the development of electric mobility by monitoring and / or promoting involvement in the following areas:

- revision of SUMPs;
- participation in European projects;
- involvement of end users through information campaigns and policies sharing of national and regional strategies of the sector.

But not only. Further measures, for the private sector, are:

- development of a national electric charging network, both in terms of quantity and location of the *charging infrastructures*, their characteristics and development trends, including public and private fleets, two-wheeled vehicles and residential areas;
- reference models on which to base the spread of electric charging infrastructures;
- minimum *standard characteristics* of the components of the charging process mainly constituted from sockets and charging methods, communication protocols and forms / tools for accessing infrastructures.

To better implement a dissemination model whose criteria are guaranteed by standards decided at national level, the Decree also establishes the PUN (United National Platform) which therefore has the objective of ensuring, throughout the national territory, uniformity and homogeneity of the information relating to the contents of the National Infrastructure Plan for the recharging of vehicles powered by electricity.

This Platform is exactly in line with the European initiative of DG Move and in particular of the European Electro-mobility Observatory (HyER), which provides for the establishment of a single platform for the control and monitoring of public charging infrastructures aimed at control (for managing bodies) and the provision of information (for end users) as well as integration with mobility policies sustainable to be developed locally and nationally.

Moreover, the National Decree of 257/2016 builds an "ideal bridge" between the PNIRE and SUMPs. This peculiar "graft" of electric mobility plans on SUMPs, in addition to the TRM systems promoted by the 2017 MIT Decree, has ensured that the main "room" in which the national electricity grid (and related services) is developed are the SUMPs drawn up on a metropolitan scale, combining in an overall vision private and public sectors' investments for electrification. Fig.2 shows the archipelago of regulatory references and related policies that make up the peculiar architecture of "sustainable mobility transition in Italy". As better explained in section 3, this "way" was crucial in the case of Genoa transport service design, so that can be considered as a methodological starting point.

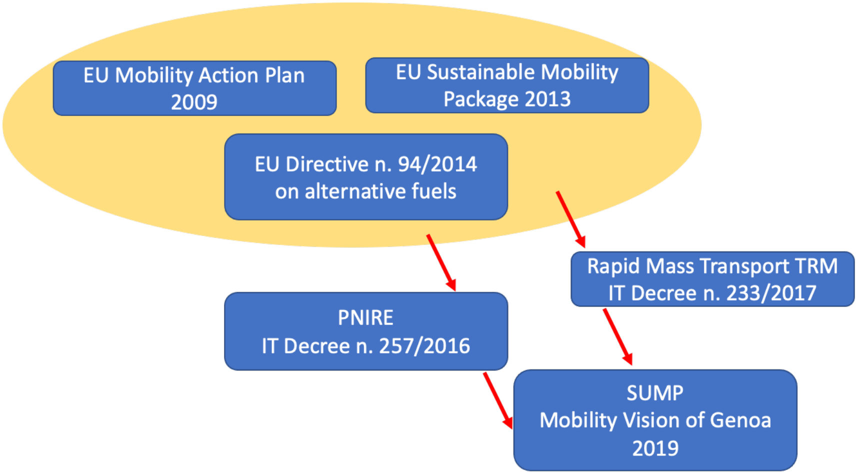


Fig.1 Main legislative pillars in the EU and IT planning process for electrification of transport sector which lead to Genoa SUMP

In the PNIRE, there are many national and local measures active in the transport sector and aimed at reducing consumption and emissions. Preliminary estimates about the impact of these measures lead to a total of 12.1 cumulative Mtoe of final energy in the period 2021-2030. These are (Fig.2):

Finally, to fully understand the legislative and planning framework it is still necessary to include a further document which refers to the diffusion of electric mobility: PNIEC - Energy and Climate Plan 2030, which final version of which was released at the end of 2020 (IT Economic Development Ministry, 2020).

The PNIEC foresees 5 lines of intervention - decarbonisation; efficiency; energy security; development of the internal energy market; research, innovation and competitiveness - which should guarantee a 56% decrease in emissions in the large industry sector, a 35% reduction in the tertiary sector and transport and bringing the share of energy from RES in Gross Final Energy Consumption to 30%.

Fig.2 List of measures contained in PNIRE (Piano nazionale infrastrutturale per la ricarica dei veicoli alimentati ad energia elettrica, 2020)

Italy intends to accelerate the energy transition from traditional fuels to renewable sources, promoting the gradual abandonment of coal for electricity generation, in favor of an electricity mix based on a growing share of renewables and, for the residual part, on gas. The document states that the realization of this transition requires the planning of the plants' replacement and the construction of necessary infrastructural network.

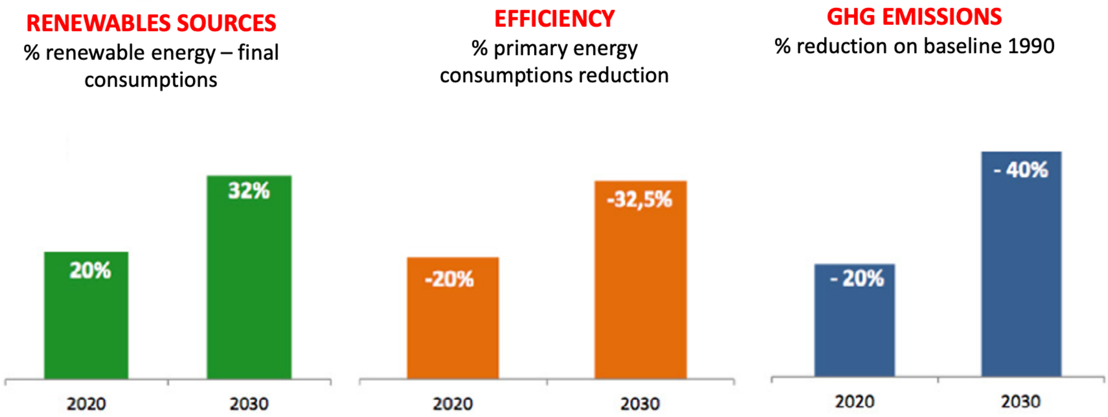


Fig.3 PNIEC - Energy and Climate Plan 2030 Reduction Goals (Source: elaboration from PNIEC, 2020)

According to the PNIEC's objectives -which targets are represented in Figg.3 and 4-, the power generation park undergoes an important transformation thanks to the objective of phase-out of coal generation by 2025 and the promotion of the extensive use of renewable energy sources.

The increasing contribution to the renewables derives from the growth of electricity sector, which by 2030 reaches 16 Mtoe of generation from RES, equal to 187 TWh. The strong penetration of renewable electricity production technologies, mainly photovoltaic and wind, allows the sector to cover 55.4% of Gross Final Electricity Consumption with renewable energy -all sectors-, compared to 34.1% in 2017.

Trajectory of Renewable Energy Sources share in the Transport Sector (recorded and projected)																			
2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
4,6	5,6	4,8	4,3	5,7	6,5	5,5	6,7	7,8	8,9	9,9	11	12,1	13,2	14,4	15,8	17,2	18,6	20,1	22

Tab.1 Increase of Renewables in energy consumptions in the Transport Sector (recorded and projected)

This last objective is directly linked to the SUMPs and attributes to this kind of plans the driver role in the planning process, both from the transport and environmental point of view.

3. The project of the trolleybus lines in Genoa: materials and methods

In this paper, the materials and methodology refer to what has been done in the planning process of the city of Genoa, as a reference example for the planning of sustainable mobility supported by the Directives.

Genoa adopted its SUMP in August 2019, after a long period of discussion around alternative solutions for a better mobility in the city. Focusing on the case-study, Genoa is a densely populated area, but only 30% anthropized: the rest of the municipal area is not accessible and is covered by uncultivated vegetation and is characterized by steep slopes.

Evident is the morphological uniqueness that characterizes the city: it is precisely this complexity that forces the urban mobility system to be extremely diversified. In order to meet passenger demand, the LPT service has buses, trolley buses, vertical and horizontal lifts, funiculars, racks, underground and marine transport. These factors significantly affect the way people move around the city. In fact, the data reported on the Municipality of Genoa show how the rate of use of LPT by residents is 32%, a rather high percentage for the Italian scenario and also the share of non-motorized internal movements, i.e. on foot or by bike, is 22%, an extremely high score for a city that is not exactly flat, third only after Turin (32%) and Bologna (28.2%) in which the contribution is made by bicycles, not by pedestrians. However, an emblematic data for Genoa is the density of cars (car fleet per 1,000 inhabitants) of 492.94, the lowest compared to other metropolitan cities.

Starting from an accurate knowledge of the territorial contest, basically the SUMP of the Metropolitan City of Genoa proposes 4 LPT "core routes" (mainly on a dedicated lane) that unfold on the municipal area, intercepting the most important directions of city mobility, as showed in Figure 5. Then, it, leveraging on "mass" transport and on speed and punctuality by ensuring the protected lane along almost the entire route. Basically, the SUMP prioritizes LPT over private transport, intercepting the greatest number of users on the entire area.

Considering the experiences underway in other European cities that are dealing with the same problems and the same SUMP tool, it can be noted that Genoa, through its transport vision, is in line with the major European cities, reaching a hypothesized target of pollution reduction within a range of 5-10%. However, differently from other cases, Genoa has not focused its strategy of change either exclusively on the technological upgrade, nor on the push to intermodality, nor on the realization of missing infrastructures. It proposed an organic idea in which the design of the new public transport framework did not concern a particular aspect or place, but reached all the places of greatest demand, promoting a strategical and not a tactical approach. This fact underlines once again that the focus is on the quality of life of metropolitan citizens and not only on the technical choice of a particular technology.

At this point, however, the technological choice of "how" and "with what" to equip the lanes arises: Genoa decided to invest, according to the SUMP objectives and the TRM funding, in the building up of 4 trolleybus lines in reserved lanes, as an infrastructural intervention that best matches the urban situation.

The goal was to realize a set of axes (therefore not a single line, like Bologna, Firenze, Brescia proposed), but using a less impactful technology from the point of view of times and costs. With the same investment, it would have been possible to build a tramway, but only along 2 lines and not 4. The "systemic" choice was the crucial point on which the political and technical side of the research team involved found a meeting point.

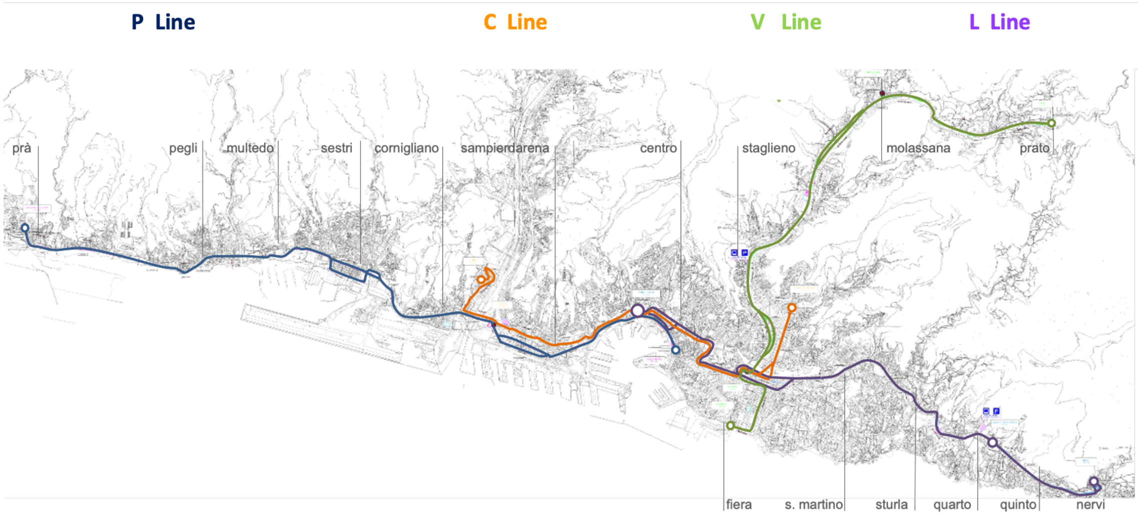


Fig.5 Map of the 4 priority LPT lines (P, C, V, L) crossing all districts of Genoa conurbation (Source: elaboration from SUMP 2019)

The target is to achieve, in the long term, the official type approval of trolley buses on three carriages, 24 m. long, already present in other countries of Europe but which in Italy currently cannot circulate. In this sense, Genoa acted as a frontrunner: the pushing force of Municipality and Liguria Region contributed decisively to the circulation permission to the 24m long buses, accorded by the Ministry in 2021.

Specifically, the LPT lines must have characteristics of high hour capacity (3000 pax / h per direction) and excellent interconnection with the rest of the public network (train and metro), with private traffic (interchange parkings with cars and two wheels). In addition, in support of the design of the 4 lines, an overall rationalization of the city LPT supply will also be carried out, with reorganization of the hilly lines, in addiction to priority axes. In this regard, it should be noted that the technologies existing to date, capable of providing a reliable, punctual service (and electrified) are numerous and in continuous evolution.

The solutions considered valid today could quickly lose their competitive advantage with the arrival of new decisive improvements in the offer of new vehicles and infrastructure. In order to be able to evaluate the different alternatives offered by today's market, a multi-criteria evaluation[1] was used in which the construction of an "all trolleybus", "all tramway" and network organized on "thermal buses" scenarios were compared (on 15 selected criteria). The results show better advantages - not only economic - in the choice of trolleybus (Hamacek, 2014; Mwambeleko et al., 2015; Borowik & Cywinski, 2016): a simplified comparison between tramway and trolleybus is reported in Figure 6. The "thermal bus" scenario was immediately set aside as it cannot be financed as TRM.

The complete conversion of all urban public transport to electric traction will represent, in the near future, the most visible sign of sustainable urban transformation and, at the same time, will drastically reduce air and noise pollution (Pisoni et al., 2019); but the Plan provides a gradual conversion of collective urban transport to electric traction. The next generation of buses will be predominantly electrified.

The technologies for recharging and storing electricity are rapidly evolving. Currently, if the relatively low volume of traffic does not justify the infrastructural cost of a power supply such as the overhead line (catenary), the most important alternatives are:

- the night-time or fast-charging electric vehicle;

[1] Criteria used for the evaluation were: costs of investment, times of realization, impact in phase of construction site, urban redevelopment involved sites, impact on management, minimum frequency in operation, capacity of vehicles, distance between stops, travel comfort, impact on the city centre, impact on the roads hierarchy, environmental benefits, interactions with the ordinary roads (overlapping), flexibility of the management, intermodality ed expandability.

- the "classic" hybrid vehicle (thermal engine and electric motor);
- the plug-in hybrid (the electric motor can operate either by a thermal engine or by a rechargeable battery).

In the Genoese metropolitan area, the Plan assumes the gradual replacement of the entire fleet by 2025 (reference year is 2019). At present, the replacement of the existing fleet can be around 500-550 vehicles. The replacement must therefore be gradual and prudent, for obvious financial reasons (operating costs), and in order not to expose the transport company to high risks due to rapidly evolving technologies. These aspects will be studied in depth in the following stages of elaboration of the SUMP and during its biennial monitoring process which is expected for the end of 2021.

For better organizing the electric transition and providing a structured manner to control results of strategic choices, SUMP procedure implies the building up of a set of scenarios in which alternative solution are represented and evaluated by a traffic simulator (Lindenau & Bohker-Baedeker, 2014).

These scenarios must include an economic-financial plan that supports their programmatic sustainability in terms of investment and management costs. Each alternative has to be evaluated with respect to the "reference scenario", which includes all the interventions under construction or already financed, which will be completed within 2028.

The identification of the best scenario has been carried out through the comparative assessment of the economic, financial and managerial sustainability of the proposed interventions and the synergies generated by all the strategies implemented by the SUMP. The way in which strategic options affect performance, scope, safety, investment costs, operating/maintenance costs, urban planning and aesthetic impact depends crucially on ongoing and rapid technological evolution. The comparison between different transport systems must therefore take these aspects into account.

In particular, the SUMP of the Metropolitan City of Genoa presents 3 alternative scenarios -modal shift performances are showed in Fig.7- which, starting from the comparison with the reference scenario by means of a core of selected indicators, allowed the identification of the selected scenario.

- Scenario 1 includes the almost complete list of interventions considered as a priority by the Administration. They include both works to be developed in the capital and in the metropolitan area and refer to multimodal actions (LPT on rail and road, private traffic, pedestrian and cycling, sharing and pooling) and intermodal ones (interchange parking lots, LPT terminals organization) (see Fig.8).
- Scenario 2 presents the same interventions as scenario 1, but with the exclusion of the LPT lines of Center C and Ponente P. This scenario was constructed in order to assess the impact on the total of the sole two lines and to verify the added value resulting from the synergy of the LPT system if fully realized.
- Scenario 3 proposes the construction of the 4 lines, but unlike scenario 1, it does not consider new interchange parking lots in the metropolitan area, an essential part of the mobility system. Scenario 3 was built to identify the contribution of the interchange system of the metropolitan area and to evaluate the differences between its actual and non-realization.

The little difference among scenarios is due to the strategical vision adopted which was articulated in many aspects: the scenarios showed that if a tessera of the mosaic is changed, the same benefits that would be obtained with synergistic actions could not be achieved.

The scenarios differ from each other not so much in terms of number of interventions, but they intend to simulate, on the one hand, the contributions of each intervention on the overall system, so that to provide elements for the political decision.

4. First results: electric mobility choices and scenarios assessment

Genoa started its planning process just after the legislative update reported in section2. According to that, the electric mobility "architecture" of Genoa is substantially composed by the TRM system, equipped with trolleybuses -for the public sector- (and financed by MIT, according to 2017 Decree) and by the investments for the construction of recharging infrastructure -for the private sector-, as envisaged by the Government in the PNIRE.

Focusing on public transport service, two important motivations in support to the extension of the LPT lines along the coast (L, P, C) and the principal valley (V) are confirmed in the Regulatory Master Plan of the Municipality of Genoa: first of all, the morphology of the conurbation which implies the river implies a high population density (about 300-400 inhabitants per hectare), with a road network converging on a single direction "west-east". Secondly, the importance of a reserved LPT lanes, characterized by a high users' attractiveness, which is therefore considered as the ideal solution to satisfy significant amounts of demand.

The technological choice on the type of vehicles used and their characteristics was not trivial and accompanied by a broad citizen debate and a careful evaluation of the various solutions.

As known, trolleybus systems are based on the use of electrically-propelled road vehicles (Brunton, 1992), which are powered by an electrical energy distribution infrastructure. Generally, the collection of electricity takes place through electrical conductors by means of devices called "trolley rods" or "collection rods".

The trolleybus network has the following advantages:

- it integrates the existing trolleybus section in the city center (C), which, however, will need to be improved by implementing, where possible, further portions of reserved lanes;
- it takes full advantage of the existing axis in the eastern part of the city (L), minimizing the impact during the construction phase in this portion of the city;
- allows a high flexibility in operation.

Furthermore, the implementation of the routes dedicated to LPT crosses prestigious squares and boulevards, connecting them in a branding new way, as an important landmark for urban regeneration actions.

The overhead line consists of a two-wire: it is a double wire hung by a system of tension cables that allow the overhead line to remain in the assigned position even under the strain of its own weight or other climatic conditions, such as the presence of wind. As known, the need to have a two-wire and not a single wire, as occurs in trams or trains, derives from a question of the composition of the electrical supply circuit system. In fact, vehicles such as trams or railway engines have a circuit formed not only by the overhead line, but also by the metallic track with which they are in contact via the wheels. In the case of a trolley-bus, this is not possible because the line does not has rails.

The overhead line is positioned at a height of about 5-6 meters from the roadway, so as not to hinder the normal circulation of other vehicles (such as trucks or vehicles with particular vertical protrusions) and to ensure greater safety of the entire plant.

The definition of a trolleybus, as it was introduced before, has been undergoing a transformation of concept in recent years, abandoning the close link with the term "wire", towards new innovative technologies in the field of sustainability and environmental protection.

For now, the regulatory reference is the Italian Decree no. 238 of 10/07/2003 "Provisions concerning the homologation procedures for trolleybuses for the transport of people" (IT Dec., 2003), which contains rules to which new trolleybuses and those still in use must refer and, where missing, adapt to the current law.

The selected technical solution for Genoa was the "In Motion Charging-IMC" Trolleybus System (Wolek et al., 2021), a system with free-driving cars all electric, able to travel up to 45% of the route without power supply from overhead contact line (the above mentioned two-wire system). According to Bartłomiejczyk (2017), point-to-point contact charging or induction charging at the station or stops are the two most common systems for charging electric buses, but they extend the stopping: the alternative which combines the advantages of trolleybus transport and of electric buses is to charge vehicles in motion: the main supply source are traction batteries and the charging is performed in motion, without the necessity of stopping the vehicle. This system allows short realization times with a medium-low impact in terms of possible inconvenience during the construction phase. When fully operational, it allows sufficient frequencies, compensated by the absence of

constraints on the distance of the stops and a high flexibility. Positive is the physical impact of the system (visual of the overhead line where present, practically no impacts due to noise and vibrations) and interactions with the ordinary roads (no rails) and good travel comfort.
As for investment costs are concerned, the trolleybus solution is decidedly inferior to the other technological options and high possibility of both integration with other systems and expandability later in other directions. The economic framework provides, as a first approximation, an amount overall equal to 450-500 million / euro.

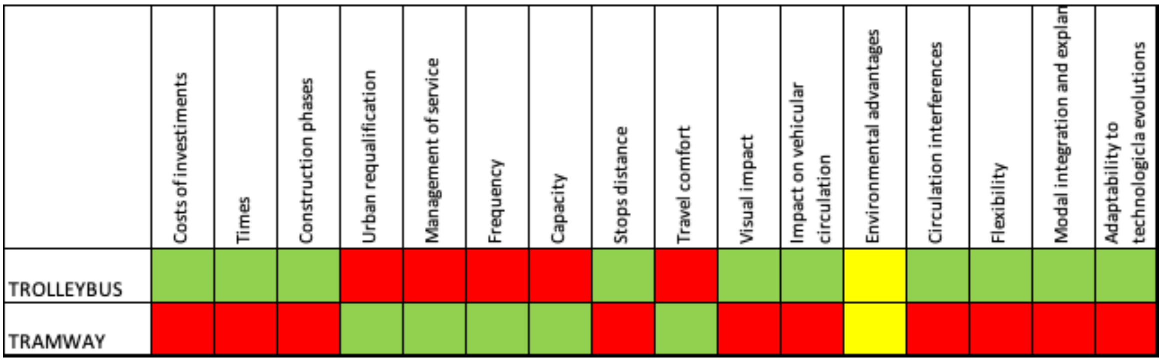


Fig.6 Performances of tramway and trolleybus, in an intuitive comparative framework (Source: PUMS, 2019) Legend: reds are the disadvantaged aspects of the solution, greens advantaged ones

As shown in Fig.8, scenario 1 shows comparatively better performing modal share than alternative scenarios. In the table, it is also possible to appreciate the improvement compared to the reference scenario "business as usual" to 2028 (scenario 0). In this regard, scenario 1 demonstrates a strong acceptance of citizens: the scenario proposes a strong identity, clearly characterized and complete in all its parts, in accordance with the strategic guidelines of the Administration and the results of the participation process.

Modal Share	0 Scenario (business as usual)	1 Scenario (all interventions)	2 Scenario (without P and C lines)	3 Scenario (without interchange parkings)
% cars	44.8	39.4	40.6	40.5
% LPT	25.4	31.4	30.0	30.3
% bike or foot	23.2	23.2	23.1	23.0

Fig.7 Comparison among performance indicators related to Reference Scenario, Scenario 1, 2, 3

Moreover, for the scenario 1, the benefits that can be quantified through the simulation show, with respect to the reference scenario:

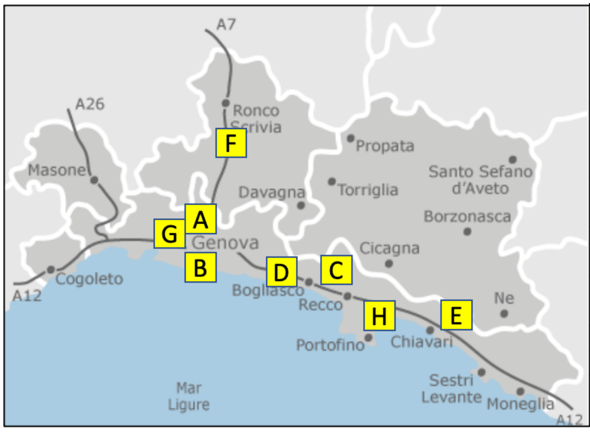
- an increase in local public transport users of approximately 52 thousand people / day (+ 22.5%);
- a reduction of over 511 thousand km / day in private journeys.

These forecasts allow to estimate the following environmental effects:

- a decrease in CO_2 emissions in public transport estimated at about 8,700 tons per year1 with consequent savings in external costs of the order of 780,000 euros per year;
- a decrease in polluting emissions in public transport with consequent savings on external costs of the order of 87,000 euros per year;
- a decrease in noise emissions in public transport with consequent savings on external costs of the order of 450,000 euros per year;

— a decrease in CO_2 emissions resulting from the reduction of kilometers traveled by private vehicles, estimated at about 15,000 tons per year with consequent savings on external costs of the order of 1,350,000 euros per year;
— a decrease in polluting emissions resulting from the reduction of kilometers traveled by private vehicles, with consequent savings on external costs of the order of 750,000 euros per year;
— a decrease in noise emissions resulting from the reduction of kilometers traveled by private vehicles, with consequent savings on external costs of the order of 2,300,000 euros per year.

Estimates are based on the Handbook on external cost of transportation, available at the link of DG-MOVE, MOVE Directorate-General for Mobility of the European Union (EU Com DG Move, 2014).
To sum up, considering the inevitable uncertainty existing in the external cost estimation models, it can be concluded that the benefits for the community generated by the implementation of scenario 1 are in the order of € 5.7 million per year.



MAIN INTERVENTIONS SCENARIO 1
A) extension of the Brin-Brignole underground line with the construction of three new stations; to the east: Terralba; to the west: Pallavicini and new Corvetto station (LINE "M")
B) four axes of force of the TPL electrified: VB, C, L, P large interchange car parks (Levante, Val Bisagno, Sampierdarena, Val Polcevera, Ponente)
C) new interchange car park in Recco near the A12 exit new interchange parking near the Rapallo tollgate A12
D) new interchange car park near the railway stations of Bogliasco and Pieve L.
E) new Chiavari / Carasco interchange car park new Cogoleto interchange car parks
F) new interchange car parks in Busalla and Ronco Scrivia
G) TPL connection Erzelli's technological hub
H) TPL Rapallo - SML - Portofino realization of networks for urban mobility infomobility interventions

Fig.8 List and map of the main interventions of Scenario 1 (dark grey: Genoa Metropolitan Area)

5. Discussion and conclusions

What can be seen from the significant example of Genoa is that a TRM system, that constitutes the general architecture of public transport influences the modal choice and generates effects from the point of view of vehicular congestion and - above all - from the point of view of concentrations of harmful gases, which was the main ambition of the Alternative Fuels Directive. As told in the paper, the planning of sustainable mobility through a dedicated tool, such as the SUMP, strategic, updatable and common throughout Europe, is certainly a positive aspect in urban governance, as well as being a point of comparison between the different experiences of European cities.
The capacity of Genoese governance was to have correctly interpreted the process of SUMP (as a strategic element of the city and not just as a sector plan), and to have it correlated with the opportunities offered by national funding. Often, especially in terms of energy planning, these elements are reported as conflicting, especially for electricity and the use of renewables (about, see Joint Research Centers publications).
Considering the initial application of a metropolitan TRM system in Genoa, first elements of discussion can be shared, in order to support urban policies' applications that are still reflecting on their electric transition model (or developing it):

— for a successful planning, capable of being effective in responding to the electric mobility challenge, a commitment is also required in setting up a series of boundary conditions that can favor the change of the mobility paradigm, as all international policies in the field hope. A systematic approach to electric mobility, testified by the union of European Directives and National Plans as PNIRE and PNIEC, is very important, but it must also be inserted within a city vision that involves other related aspects. In this perspective, SUMP is crucial to implement policies to a lower scale;

- taking into account practical implications, the increasing public service and electric private mobility systems encourages sharing mobility and puts the user in a position to have other needs: for example, knowing the localisation of recharging points and the time needed for it. For this reason, it is essential to advance the design of the electrification of the LPT lines, in parallel with the application of the concept of MaaS (Mobility as a Service) which provides information and integrates the services to users. This also involves a parallel evolution of the ITS (Information Technology System) architecture;
- as showed, the traffic simulation is quite central in the assessment of the benefits generated by the selected scenario and its results claim to strongly guide choices. Nevertheless, the results obtained through the simulation are only one of the parameters used in the SUMPs Guidelines and contented in the National Decree. This means that, even today, the plan objectives are usually focused on the fluidification or mitigation of congestion and not, for example, on the number and surface of urban regeneration spaces that such a transformation brings with it. In other words, the parameters not deriving from the simulation are in any case considered but are not considered rights: that is, the final decision is not played on them;
- nevertheless, it must not be forgot that the lowering of the concentrations of polluting emissions and greenhouse gases also passes through the reduction of the demand for vehicles' parking and therefore how the planning of quality cycle-and-pedestrian routes encourages the demand for sustainable mobility (which is currently growing all over the world). These long-term objectives place SUMP within the most innovative actions carried out by metropolitan areas in favor of sustainability and attribute to it a pivotal role from the point of view of strategic planning;
- the results of a plan such as the SUMP cannot be parameterized only through the reduction of emissions: to change the face of the urban mobility system, other improvements and innovations are clearly needed and this is only the first step. This opens up new spaces for discussion on other solutions that have only been hinted at in this paper and which constitute just as many new directions of investigation and research.

To briefly report main points underlined in the paper, the great originality of the Genoese choice in the drafting of its SUMP were:

- the attention paid to the city context, such as described in section 3, and focused on mobility attitudes (strong propension towards LPT, difficulties in infrastructures building up, consolidated tradition in pedestrian mode for interchange,…): starting from the social terrain is a good point for successful initiatives that have solid acceptance; in this case, the design of the 4 LPT lines sounded on this robust base, so that to facilitate ecological transition and urban transformation but according to shared social assumptions;
- the overall design of an interconnected network of service, which is not linked "a posteriori" but conceived "a priori" as unitarian; the 4 lines were thought as a unique system like a skeleton in which all other modes are added. The strong meaning attributed by the SUMP strategy to the public service wanted also to induce a mind-shift, limiting the demand of private cars;
- as reported before, the SUMP Guidelines stressed a lot on the strategical contents of the plan; nevertheless, SUMP is considered an "enlarged Traffic Plan": that strategical orientation is sometimes neglected or juxtaposed. In this case, the choices are derived by a unique methodological choice: not to invest in single interventions, but in a general revision of the LPT network, which is be able to reach important ecological targets, expected by the metropolitan population and demonstrated by the computer-science simulation of congestion and pollution production;
- the SUMP is not centered in a technological choice, but in a strategy that can be supported -at this particular stage- by a functional way of transport. The choice of the electric buses is related to the boundary conditions (accessibility to funds, market, technicalities, competences) but the technological

choice is not considered as the unique solution; actually, the trolleybus were selected from their flexibility and because they allow Administration to equip the LPT lines in a different way, if conditions were to change;

- Genoa followed the strategy carried out by PNIRE and TRM systems orientations, in order to think about the transformation of the urban area from the mobility point of view. Metropolitan governance did not ground on its own perspective to build up a new vision, but follow the Italian way to ecological transition, giving also a contribution to it as a frontrunner (in many aspects, as the often used expression "Genoa Method" contributes to underline). In this sense, it is a best-case not only from the transport point of view but also from the multilevel governance angle.

The present article therefore intended to show a practical application of electric mobility planning at a local level, in accordance with the regulatory framework, whose decisions have been illustrated and argued. It revealed how both the current moment of great economic support for ecological transition, and the consideration of the geographic constraints of the place, were the "guide" for the realization of an all-encompassing project.

The urban transport planning, in fact, nowadays cannot ignore urban regeneration as one of the main challenges that all cities in the world have to face: the need of conversion of ex-industrial spaces that quickly become inadequate and obsolete, the simultaneous creation of "full spaces" in which urban expansion is concentrated and that of "empty spaces" in which it progressively goes towards depopulation and decay, the modern "design for all" policies that largely involve the transport systems' project for an increasingly accessible and inclusive city.

Transport planning will increasingly have to go hand in hand with the urban regeneration of metropolitan cities to be truly effective: the merge of these two aspects - although desired by many - is not so taken into consideration by current research. In this sense, this vision that brings the two elements together in an effective way - and not only programmatic - will clearly be a very prosperous line of research in the future, in accordance with the goals of Agenda 2030.

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Image Sources

Fig.2: Elaboration from PNIRE (Piano nazionale infrastrutturale per la ricarica dei veicoli alimentati ad energia elettrica, 2020);

Fig.3: Elaboration from PNIEC (Piano Nazionale Energia e Clima , 2020);

Fig.4: PNIEC (Piano Nazionale Energia e Clima, 2020);

Fig.5: SUMP-Sustainable Urban Mobility Plan, Genoa, 2019;

Fig.6: SUMP-Sustainable Urban Mobility Plan, Genoa, 2019;

Fig.7: Elaboration from SUMP-Sustainable Urban Mobility Plan, Genoa, 2019.

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