A New Vision on Smart and Resilient Urban Mobility in the Aftermath of the Pandemic: Key Factors on European Transport Policies

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Abstract. Recent events related to the COVID-19 pandemic event highlighted some criticalities of transport systems, especially the public sector. The respect for social distancing and a widespread fear of contagion have reduced travel on public transport. In addition, the new trend to reduce daily long-range mobility needs due to the increase in teleworking is present. Following the pandemic, there has been a paradigm shift, from smart cities to smart and sustainable cities (SSCs) in which a new concept of resilience is contemplated. Among the various changes, a reversal of the trend has occurred with respect to the transition to the use of public transport. The growing density of car traffic causes an increase in external costs, in terms of atmospheric pollution and waste of time, with negative consequences also for the balance between private life and work. In this regard, the focus of this paper is to analyse the European policies promoted in the aftermath of the pandemic in the field of urban and suburban mobility. An exploratory analysis of key factors for active mobility, public transport and shared services has been carried out highlighting possible actions and strategies to be implemented in the light of the recent pandemic and the defined restrictions. Among the European policies implemented, the redevelopment of public spaces for the promotion of various forms of active mobility, such as cycling and walking, are considered. Among the possible transport solutions, which allow medium and long-range travel, demand responsive transport (DRT) services can reduce the use of private vehicles. In fact, they are implemented for two purposes: both to connect the centres with

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low demand for transport often lacking an adequate supply of travel choices and to cope with the pandemic, strengthening the service on the routes with greater demand for transport.

Keywords: Urban Mobility · Transport Policies · COVID-19 · DRT · Key factors · PUMS · SUMP

1 Introduction

The pandemic has significantly transformed the concept of spaces, wellbeing, relationships and it is no longer possible to hypothesize a city without analysing the new paradigms that look at respect for the environment, accessibility, inclusion, health, and the future in general [1]. This has led policy makers to define more focused objectives, designing short- and long-term strategies in an attempt to achieve an urban sustainability associated with a new concept of resilience [2]. This new concept of resilience overlaps with the concept of smartness and, despite having different roots and missions, they have many similarities and present key characteristics to both concepts, some of which are: efficiency, sustainability, flexibility, learning and innovation skills, participation, awareness, etc.

In this regard, the literature has highlighted how the smartest cities are sustainable and resilient cities [3], because the monitoring of the city through smart infrastructures leads to the acquisition of deep knowledge and the timely decision-making process and the execution of actions, particularly considering the new strategies to be adopted with the pandemic. With this new meaning, in this article the authors consider the concept of Smart and Sustainable Cities (SSCs) [4, 5]. As far as the development of sustainable cities is concerned, in the eleventh Sustainable Development Goal (SDGs) named "Sustainable Cities and Communities" it is specified that most of the urban challenges not only related to environmental issues, but also to social and economic issues, making that the success of the implementation of the SDGs depends on the local authorities [6]. The connection between a smart city and sustainability requires smart city approaches to produce sustainable and liveable places in urban centers [7, 8]. Cities can be considered smart if investments ensure sustainability in urban areas through the use of modern technologies [9] that allow access to more and smarter solutions based on knowledge and innovation [10]. Particularly in recent years, the SSC has been focusing on the transformation of conventional cities and their processes into resilient and smart cities, by considering the interdisciplinary challenges that involve different scientific fields, at the level of urban growth [6], modelling, design and implementation [11–13]. An analysis on SSCs revealed a human centered approach [14, 15] and most of the services focused mainly on the dimensions of mobility, compared to the rest (environment, economy, governance and living) [16]. In fact, particularly with the pandemic, a high quality of life in cities is wanted to ensure, trying to make the same cities more accessible, clean and competitive. The authors will focus in this paper on transport field, by analysing a necessary modal change, and by also considering the shift to sustainable modes of transport.

Based on these premises, the aim of this paper is the understanding and investigation of how cities have made themselves smart and sustainable, starting from an analysis of European policies promoted in the aftermath of the pandemic in the field of urban mobility. This paper is divided into 5 sections: Sect. 2 considers the methodological framework based on European Transport policies towards SSCs. Section 3 and Sect. 4 focus on identifying the key factors for the promotion of strategies and actions respectively in favour of active mobility and public transport with shared services; finally, Sect. 5 concludes the paper with some remarks and laying the basis for further research.

2 Materials and Methods

As stated in the previous section, the research area of this paper is on SSCs, particularly focusing on European policies that both at the local and international level that have been promoted also following the pandemic.

The work focuses on a methodological framework based on a detailed examination of case studies and literature review characterized by 3 steps (Fig. 1): the preliminary phase is of the research is fundamental in order to be able to clearly identify the key objectives related to the Sustainable and Smart Mobility Strategy; then, is it possible to focus on the main strategies promoted in the aftermath of the pandemic in the field of urban mobility, in particular regarding active mobility and public transport innovations; finally the key factors for the promotion of these strategies and actions are highlighted.



Fig. 1. Methodological framework – Research steps (Our elaboration)

2.1 Research Framework: European Transport Policies Towards SSCs

One of the aspects that most affect cities and the transport sector is addressing the decarbonization of urban areas in the long run [17]. Among the main European strategies, the Green Deal Commission includes as a main target to reduce transport-related greenhouse gas emissions by 90% by 2050. The European Commission intends to adopt a comprehensive strategy to achieve this and ensure that the EU transport sector is fit for a clean, digital and modern economy. The objectives include:

- increasing the uptake of zero-emission vehicles;
- making sustainable alternative solutions available to the public and businesses;
- supporting digitisation and automation;
- improving connectivity and access.

The Sustainable and Smart Mobility Strategy is structured around three key objectives (Fig. 2). These targets will enable a 90% reduction in greenhouse gas emissions from transport by 2050 as defined in the European Green Deal [17].

Through the implementation of 10 action areas defined as flagships, the European Commission has proposed concrete policies for 2030 and 2050:

– at least 30 million zero-emission cars will be in operation on European roads;
– 100 European cities will be climate neutral;
– collective trips planned for less than 500 km should be carbon neutral;
– automated mobility will be widespread.

By 2050:

– almost all cars, vans, buses and new heavy-duty vehicles will be zero-emission. Emissions;
– a fully operational multimodal trans-European transport network (TEN-T) for sustainable and intelligent transport with high-speed connectivity.

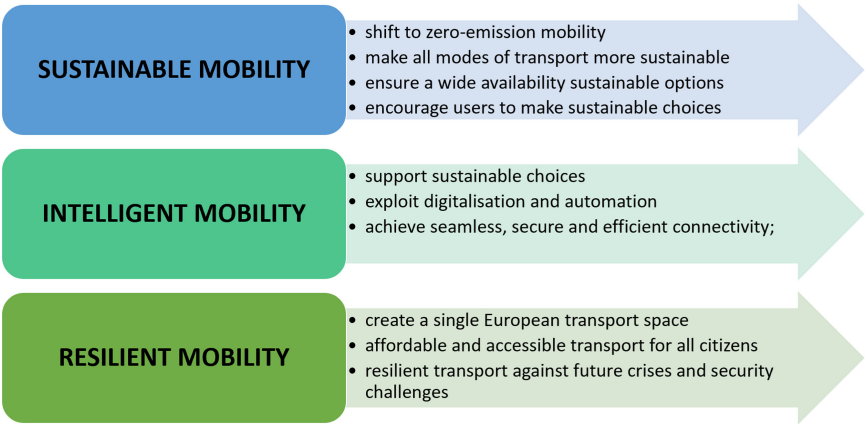


Fig. 2. Key objectives of the Sustainable and Smart Mobility Strategy (Our elaboration)

The development of digitisation and technologies (i.e. IoT or the Cloud) with the development of ITS systems [18] and also the implementation of digital mobility platforms MaaS (Mobility As a Service) [19] can be a best practice for upgrading the whole system, making it even more efficient. This will enable the EU to maintain its leadership in transport equipment production and services and improve our global competitiveness [20]. Unfortunately, the recent COVID-19 pandemic has affected several economic sectors including transport, and the crisis has caused healthy companies to lose jobs and revenue. To stem the crisis, several strategies have been promoted in accordance with the above-mentioned targets and to implement the recommendations for reducing contagion such as social distancing and limitation of seats on board [21]. Several studies

in the literature show the need for more sustainable and resilient policies and strategies to reduce the impacts of catastrophic events such as climate change and pandemics [22, 23].

To ensure a rapid recovery, a series of bottom-up actions have been disseminated that directly involve citizens and administrations. These actions allow to have a better analysis of critical issues and travel habits so that strategies can be implemented that are best suited to the urban realities under investigation. The EU works with cities to develop a sustainable urban mobility policy, including efficient public transport systems and good connectivity at national level [24, 25]. It also aims to improve the quality of life in cities by promoting active mobility solutions, such as walking and cycling, and ensuring good accessibility for residents and commuters [26, 27]. Therefore, the next two sections will present the policies that EU has promoted and implemented in various cities regarding soft/active mobility and local public transport with the integration of shared services.

3 Promoting "Active Mobility" in Urban Areas

Several strategies have been implemented by European countries to promote active (soft) mobility. This includes all ways of getting around under one's own steam (cycling, walking, skating, etc.). These options are often faster and cleaner and make short-distance travel easier [28–32]. The modal choice of transport has been widened by the advent of e-scooters, bikes and car sharing. In congested urban centres and on blocked main highways, many road users are opting for alternatives to single occupancy vehicles. After individual cars and public transport, soft/active mobility is the third most used mode of transport for daily travel [33]. This form of mobility is increasing, especially in urban centres, and has many advantages: it saves time, often money, and of course reduces the overall environmental impact. Many cities and communities are encouraging these new modes of transport with the aim of reducing emissions and freeing main roads from traffic congestion.

In general terms, active mobility is part of the ecological transition, with a clear trend: fewer internal combustion engine cars and more electric cars [34]. Several studies have focused on the dissemination of good practices and the analysis of the impact on users [35].Different forms of mobility other than ownership have spread over the last decade, including both renting [36] and sharing [37–39]. The distribution of vouchers for the purchase of micro mobility has recently been one of the European practices respecting the social distancing due to the pandemic together with the encouragement of new design and improvement of cycling and walking infrastructure [40]. Several research studies investigate transport demand habits and the frequency of use of different modes through surveys and interviews [41–43] in order to foster a bottom-up view and in several cases the democratic participation of people in urban planning activities [44–47]. The dissemination of good practices that encourage walking for short distances (<1km) [48] and at the same time reduce the gender gap [49] and limitations of people with disabilities [50] will increase the demand for mobility in urban areas, allowing everyone to move around easily.

At the urban planning level, the drafting and revision of Sustainable Urban Mobility Plans (SUMPs) should be a strategic priority [51, 52], considering the recent Italian

Recovery Plan strategies, encouraging the construction of cycle paths and the opening of new construction sites for metro and tram lines. The spread of the new urban planning with the development of 15-min and compact cities favours sociality and short-distance travel, ensuring the concentrated location of services and an increase in Wi-Fi technology for greater connectivity [53, 54]. Therefore, it will be necessary to build a new local welfare system that includes individual mobility, in communities, with schools, universities, companies, public bodies and communities (neighbourhoods, apartment blocks) becoming places where environmentally and socially sustainable mobility is defined. For each macro area, i.e. the transport offer (service and infrastructure), the transport demand (the user) and the environment, it is therefore necessary to define the key factors in order to improve the impacts by defining ad hoc strategies and actions. In Leipzig (Germany), for example, bicycle parking spaces were created instead of car parking spaces, thus reducing the availability of car parking spaces and making cycling more convenient [55]. In several cases, however, parking policies were not coherent with policies for sustainable urban mobility: in Poland, and especially in Warsaw, the fine for not paying for a parking space is lower than the fine for not paying a ticket on public transport; and in Poland, even where parking on the side of the road is prohibited, it is still possible to park on the pavement, thus reducing the space available for pedestrians [56].

Other ways to discourage the use of private vehicles include the creation of pedestrian zones and the use of the congestion charge as happened in 2018 in Madrid which introduced a 472-hectare restricted traffic zone resulting in a reduction in NO2 pollution. Barcelona has removed cars from the streets by creating "superbills" (macro isolates), which include nine residential blocks, with an area of 400 m x 400 m, surrounded by streets where traffic, including bus traffic, is concentrated. In the inner streets, cars are banned or speeds are limited [57]. "Supertiles" are an example of how cities can give priority to pedestrians and cyclists, taking public space away from parking and giving it back to citizens. In Italy, pedestrian zones of 4 hectares have been established in Palermo and the local administration plans to double the size. It also intends to reduce the space available for cars to extend the tram network. Table 1 summarizes the above the key factors to be taken under consideration to propose strategies and actions related to active mobility:

4 The Impact on Public Transport and Future Scenarios

The adopted strategy by Europe proposes a roadmap towards sustainable mobility and a series of targets to be achieved: among the main objectives defined by the new plan is the increase in the efficiency of the transport system through the enhancement of digital technologies and intelligent systems [58–60]. The European Commission also intends to accelerate the distribution of sustainable mobility alternatives, favouring elements such as advanced biofuels, electricity, hydrogen and renewable synthetic fuels and removing the obstacles in the transport electrification. [61]. In addition, several strategies have been implemented by various European countries to reduce the use of private vehicles. A series of incentives have been implemented for the use of electric mobility, encouraging the dismantling of cars with traditional power supply and in some cases eliminating toll

Table 1. Key factors linked to discourage the use of private vehicle and promote active mobility (Our elaboration).

Areas	Key factors	Strategies and actions
Road pavement	Greenways, Pedestrian area or ZTL, Shared space, Bike and micro mobility parking, Road pavement	Reduction of road space for cars (parking and carriageways) Dedicated lanes Electric charging station Route hierarchy Regularizing and restoring the road surface
Service	Frequency, Shared service type	Incentive to transport multimodality Special rates Green-vehicle (e-mobility) Gender equity/equality
User	Behaviour, Habits, Economical aspects, Barriers	Incentives single user Democratic planning Survey and interview campaign
Environment	Reuse of spaces, New urban planning	Ensuring respect for historical and cultural diversity present on the territory Promoting cross-border cooperation at local and regional level Define and implement policies on landscape also through the involvement of communities Consistency with policies traffic and transport policies Enhancing the urban centre by improving its usability, safety and accessibility Incentives for buying bikes and micro mobility Promoting slow tourism Compact cities and 15min cities development

road costs and Limited Traffic Zones costs [62]. But one of the major innovations is the advent of sharing mobility, which is a phenomenon in constant expansion and which continues to change the world of traditional transport, making it more innovative and eco-friendlier. The sharing mobility represents a choice: each person can decide not to travel with their own private vehicle (i.e. car, bicycle, scooter, etc.) and use shared vehicles. Thanks to the development of technology, sharing mobility makes it possible to share both vehicles and journeys, making transport more interactive and efficient and

significantly reducing costs and consumption related to the vehicle ownership [63]. The sharing mobility is characterized by numerous transport services based on the use of different modes. Among these, the most well-known type is the car sharing, that allows to rent a car, alone or with others, to make a trip by paying only the linked travel costs. It can present different forms of service, such as traditional or electric power supply, station based, free floating and peer-to peer [64, 65]. Electric car sharing has also become an integral part of urban landscapes and thanks to the increasing spread of charging areas, it will be possible to reduce the number of combustion engine vehicles in the coming years [66]. Instead, carpooling is not configured as a transport service realized by organizations or companies, but it is made available by private individuals. In fact, carpooling is a shared service based on the use of private cars between two or more passengers who must perform the same journey. The driver makes the vehicle available and the passengers contribute financially to fuel and travel costs. The carpooling model currently most used is the real-time one, realized thanks to digital platforms and apps for smartphones that allow to connect the driver and passengers [67]. It is possible to mention the so-called On-demand Transport Services, which are characterized by shared journeys that take place at the specific request of one or more users. Taxis, for example, belong to this transport category, but there are also the most innovative services (e.g. the American Uber) that allow to book a ride in just a few minutes via smartphone. The implementation of this type of service, also identifiable with the term of Demand Responsive Transit (DRT), is envisaged in areas with low mobility demand to replace low-utilization scheduled services and characterized by considerable dispersion spatial and temporal. In this context, the need that emerges is to identify innovative solutions capable of offering a widespread coverage of the territory, guaranteeing the movement of citizens from their residences to the main "transportation hubs" (main bus and train stations) or to the main point of interests (schools, hospitals, urban centres, sports centres, etc.) [68].

Furthermore, the changed transport conditions resulting from the need to cope with the pandemic caused by COVID-19, make it essential to strengthen the service on the routes with greater demand for transport [69]. Its main features are:

- user-oriented (flexibility/adaptability of the route, times and frequency based on transport demand);
- accessibility to the service via web, through specific platforms available for smartphones, apps, PCs;
- versatility of use with reference to the areas and users to be served (more calibrated vehicles and mileage).

In a post-COVID scenario, the availability of resources and technological innovations seem to create the ideal situation to lay the foundations for a new model of mobility, which intercepts the strong social interest in the issues of safety and environmental sustainability. In this sense, close collaboration between private actors and the public sector becomes essential, which constitutes an enabling and coordinating role in the functional planning processes of cities with a view to intermodality between the different transport solutions. This full integration between different mobility services is achievable through the MaaS platforms: the idea is to integrate various forms of transport services

into a single access point for mobility services [70]. Thanks to the availability of new digital technologies, users can plan their journeys in real time, taking advantage of mobility services provided by different operators (public and private) using a single platform and a single payment method. With the technological platforms for DRTs it is possible to achieve: the travel optimization; the use of cashless payment systems; the possibility of integrating booking and payment systems through MaaS for a better synchronization of the modal interchange. Similarly, to what has already been studied for the strategies and policies aimed at active mobility, with reference to the different macro areas, it is essential to highlight the key factors that allow to identify and implement strategies and actions for the improvement of public transport and discourage the use of private vehicles, thanks to technologies and new forms of shared mobility. For example, in the city of Copenhagen a model was developed to study the accessibility of the metro network. Considering the simultaneous choice of residential location and car ownership by households, the impact of an extension of the metro network has been studied. he results showed that with an extension of the metro network in the Greater Copenhagen Area, the car ownership decreases by 2–3% [71].

Another important aspect is represented by the presence of an appropriate electric charging infrastructure. In Turin, a model to study the performance and costs of fleet charging management, with reference to an Electric Free-Floating Car Sharing. To maximize the number of trips of users, and at the same time minimize the cost of relocating cars for charging, it emerged that the better solution is represented by a distributed set of charging poles around the most-used zones, where users can eventually contribute to plug cars [72]. Regarding the type of service, many cities have investigated the propensity of users to share the means of transport [73–75] and, also in light of the new mobility needs deriving from the pandemic, innovative mobility services have been implemented such as the DRT in the city of Ragusa (Italy) [76]; the fully flexible and true door-to-door DRT experiment implemented in Oberharz (Germany) [77] and the e-mobility bus fleet application in Sorrento (Italy) [78]. In these cases, the complementary extension of the existing public transport service through the DRT should meet mobility needs of rural areas to redeem car dependency and improve mobility for all population groups. In this regard, it is important to implement strategies and actions shared with the population, through bottom-up procedures, which take into account the preferences of users and stakeholders, as implemented for example in the city of Enna (Italy) [79, 80] and Manchester (UK) [81] and in rural areas of the Netherlands [82]. However, the use of sensors and simulation models also constitutes a valid support for comparing different scenarios and monitoring the effects of certain strategies [83]. In Italy, the city of Catania implemented a traffic monitoring and forecasting system equipped with radar sensors [84, 85]; while in France, the city of Marseilles realized a machine learning model to estimate driving behaviour as a function of traffic conditions and road infrastructure coupled with a physics-based microscopic emissions model [86].

Following the analysis of these case studies and the literature review, Table 2 summarizes the emerging key factors linked to the strategies and actions to discourage the use of private vehicle and promote the use of shared transport services.

Unlike the analysis carried out in the previous section, referred to transport modes with a single user, in this case it is possible that the shared vehicles are also used by

Table 2. Key factors linked to discourage the use of private vehicle and promote the use of shared transport services (Our elaboration).

Areas	Key factors	Strategies and actions
Infrastructure	Parking areas, Bus stop location, Recharge infrastructure, ICT infrastructure	Redesign of parking areas Identification of virtual stops Location of recharge infrastructure Clear identification of the delimitation of areas
Service	Frequency of the service, Type of service, Number of users, Social distancing, Load factor	Digital platform to transport multimodality Integrated ticketing Encourage the E-mobility Innovative shared transport services (DRT) Territorial network planning
User	Behaviour, Travel habits, Economical aspects, Incentives for safety	Democratic planning User preferences investigation Awareness campaigns Establishment of the Green pass
Environment	Continuous monitoring, Reuse of spaces, Environmental emissions, Acoustic emissions, Travel time optimization	Implementation of sensor networks (smart road) Use of green vehicles Big-data applications Charges to discourage the use of private vehicle

several users simultaneously. They are all alternatives to single occupancy vehicles and enable the development of sustainable mobility in line with decarbonization policies.

5 Conclusions

Sustainable urban mobility under the SSC recent paradigm is one of the main challenges that European cities have been facing for the past decade, although recently the pandemic has overturned the concept of mobility and imposed various restrictions. It is necessary to conceive solutions designed not for a transitory phase, but rather to offer a vision and tools that are inspired by a completely new perspective. It would not be correct and extremely insufficient to face only to immediate financial and sectoral needs and not making the effort to propose a systemic approach. Therefore, it is necessary to rethink the mobility system through an integrated and human centered oriented design.

In this perspective, various considerations and strategies for the decarbonization of mobility up to 2030 and 2050 have been disseminated through the definition of the Horizon 2020 and Green Deal strategies. Cities are adopting a series of initiatives to encourage "active mobility" by combining with the creation of models (i.e. 5 min city) and to increase the quality and availability of public transport in order to meet the new

transport demand mobility needs. In view of a trend that could be lasting, the preparation of SUMPs is essential for planning adequate strategies and actions.

This work, through a detailed examination of case studies and literature review, has made possible to identify the key factors, strategies and actions aimed in these directions. The results will constitute the basis for future research aimed at the critical analysis of the drafting of SUMPs at both National and European level, focusing on the topics about the regeneration of urban spaces and the use of technologies for the promotion of innovative shared forms of mobility.

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