Back from the future. A backcasting on autonomous vehicles in the real city

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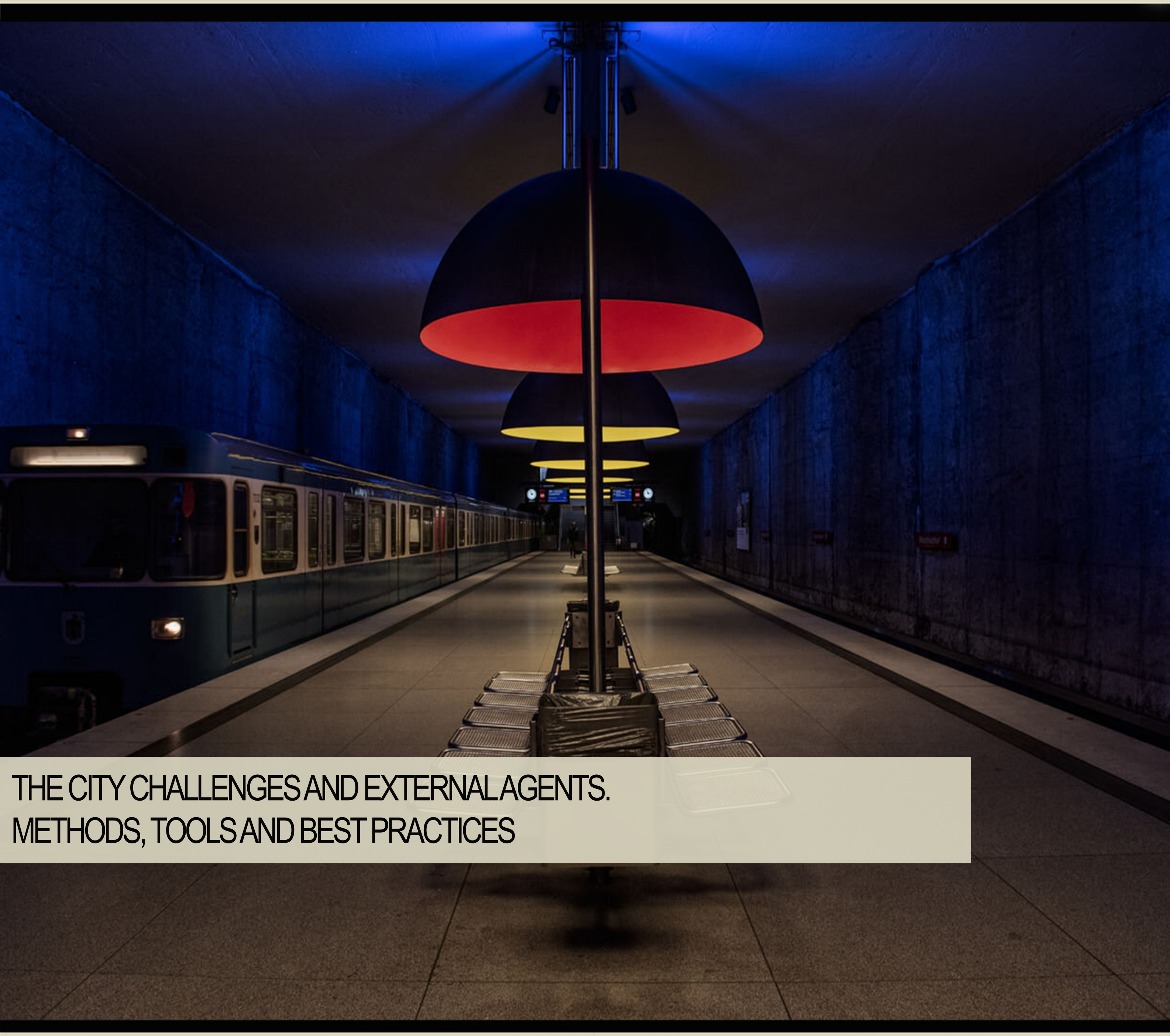

THE CITY CHALLENGES AND EXTERNAL AGENTS.
METHODS, TOOLS AND BEST PRACTICES

Vol.13 n.2 August 2020

print ISSN 1970-9889 e-ISSN 1970-9870
University of Naples Federico II

# TeMA

Journal of
Land Use, Mobility and Environment


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2 (2020)

**Published by**
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realized by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Licence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

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TeMA
Journal of
Land Use, Mobility and Environment

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2 (2020)

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LUME (Land Use, Mobility and Environment)



REVIEW NOTES

TeMA
Journal of
Land Use, Mobility and Environment

TeMA 2 (2020) 209-228
print ISSN 1970-9889, e-ISSN 1970-9870
DOI: 10.6092/1970-9870/6974
Received 9th June 2020, Accepted 4th August 2020, Available online 31st August 2020



# Back from the future. A backcasting on autonomous vehicles in the real city

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**Abstract**
Backcasting is often mentioned as a scenario-building technique that can help decision-makers facing uncertain and complex dynamics, such as the transition to autonomous driving. This article presents a backcasting carried out in the city of Turin (Italy), aimed at defining a policy pathway to steer the transition to autonomous driving towards objectives of sustainability and liveability of the city and its neighbourhoods. It reflects on this exercise and highlights some critical issues that proved to challenge the effectiveness and the potentialities of backcasting when applied to autonomous vehicles (AVs); these issues are mainly related to: factors and levels of uncertainty, contextualization of the vision, involvement of relevant stakeholders, definition of the policy pathway. Nevertheless, the exercise showed that some solutions can be adopted to deal with these challenges, in terms of: reference to existing background socioeconomic scenarios; combination of a range of participatory techniques to broaden the number and type of involved stakeholders; integration of collaborative and think-tank methodologies to review, enrich and systematize the outputs provided by the stakeholders; reference to mid-term planning tools to organize policy packages that are consistent both internally and with the more general mobility strategies. These solutions can support further backcasting exercises for AVs.

**Keywords**
Backcasting; Scenario; Planning; Transition; Autonomous vehicles

**How to cite item in APA format:**
Staricco, L., Vitale Brovarone, E. & Scudellari, J. (2020). Back from the future. A backcasting on autonomous vehicles in the real city. *Tema. Journal of Land Use, Mobility and Environment*, *13* (2), 209-228. http://dx.doi.org/10.6092/1970-9870/6974

# 1. Introduction

Facing the future and its uncertainty is an intrinsic aspect of planning. Uncertainty can be seen as a challenge, but also as an opportunity to question expected trends and envisage alternative (Lyons & Davidson, 2016). In this respect, much depends on the attitude towards uncertainty: planners and policymakers can address uncertainty as an opportunity rather than a complication, and try to steer urban dynamics towards a desired vision. However, some processes display such high and varied degrees and elements of uncertainty that most planners end up adopting a "watch and wait" approach (Guerra, 2016; Legacy et al., 2019; Milakis, 2019).

The evolution of mobility, and in particular the transition to autonomous driving, is undoubtedly one of those processes that bring with them a very high level of uncertainty (Lyons & Davidson, 2016; Marchau et al., 2018; Walker et al., 2010). Autonomous vehicles (AVs) are expected to disrupt transport systems and mobility (Fagnant & Kockelman, 2015; Faisal et al., 2019), and generate second and third-order effects in several respects, such as congestion, energy consumption, social equity, economy, land use, etc. (Bahamonde-Birke et al., 2018; Milakis, 2019; Smolnicki & Sołtys, 2016). It is generally assumed that AVs can reduce car accidents (Winkle, 2016), increase road capacity and reduce the amount of space for on-road parking (Metz, 2018; Zhang et al., 2015), improve accessibility for some of those who currently cannot drive a car (Milakis et al., 2018; Papa & Ferreira, 2018). Notwithstanding, concerns about the possible negative effects of autonomous driving are growing. As regards their prospected socio-spatial effects, concerns are related to the increase in travel time, vehicle miles travelled and congestion (Childress et al., 2015), the conflict with pedestrians and cyclists (Gavanas, 2019; Millard-Ball, 2018; Parkin et al., 2018), the reduction of public transport patronage and active mobility (Bahamonde-Birke et al., 2018; Botello et al., 2019), and the risk to foster sprawling processes (Zakharenko, 2016).

Public authorities may play a key role in steering the transition to autonomous driving so to limit their potential impacts and exploit their benefits, improving the quality and liveability of urban spaces (Gavanas, 2019; Guerra, 2016; Papa & Ferreira, 2018; Stead & Vaddadi, 2019). Nevertheless, despite the general consensus about the need to govern the diffusion of AVs, public authorities are reluctant to take the lead (Cohen & Cavoli, 2019; Curtis et al., 2019; Fraedrich et al., 2018). In fact, moving from theory to practice is not an easy task, as many uncertainties surround the transition to autonomous driving. Indeed, a factor of uncertainty regards the timing of this transition. There is no consensus in the debate on this issue, and scholars, automotive manufacturers, public administrations and the general public have different predictions (Bazilinskyy et al., 2019). On the scientific research side, estimates of commercial viability and market penetration rates of AVs are rather prudential and have very wide ranges, from 2025 to 2050 (Litman, 2019; Milakis et al., 2017). According to the European Road Transport Research Advisory Council[1], fully AVs[2] will only be available in the decades after 2030 (ETRAC, 2019). Greater optimism is shown by the automotive industry and by the general public, who expect that AVs will flood urban roads by the 2020s-2030s (Bazilinskyy et al., 2019).

While traditional forecasting methods are not deemed to be viable for dealing with high degrees of uncertainty, backcasting is acknowledged as a suitable method for this purpose (Banister & Hickman, 2013; Bibri, 2018; Robinson, 1990; Tuominen et al., 2014; Vergragt & Quist, 2011). Backcasting proceeds in the opposite direction to forecasting, formulating future visions and going backwards to define pathways to achieve them. Although it is more appropriate than other methods for dealing with uncertainty, backcasting is a challenging process in several respects.

This article reflects on a backcasting that was carried out in Turin (Italy), aimed at defining a pathway to steer the transition to autonomous driving towards objectives of sustainability and liveability of the city and its

[1] European Road Transport Research Advisory Council (ETRAC) is the European technology platform which brings together road transport stakeholders to develop a common vision for road transport research in Europe.

[2] According to the taxonomy introduced by the Society of Automotive Engineers (SAE), AVs can be classified into six levels of automation: no automation (level 0), diver assistance (1), partial automation (2), conditional automation (3), high automation (4) and full automation (5).

neighbourhoods. The results of the first two phases of this experience – visioning and policy packaging – were presented in detail respectively in Staricco, Rappazzo, Scudellari and Vitale Brovarone (2019) and Vitale Brovarone, Scudellari and Staricco (2020-forthcoming). The present article reviews the whole process with the aim of highlighting what challenges and critical issues arise for backcasting when applied to AVs. In detail, section 2 frames and describes backcasting, with a focus on its origins and implementations in the field of transport and on the few experiences related to AVs. Section 3 gives a general overview of the whole backcasting process developed in Turin. Section 4 discusses some key questions that challenged this backcasting experience. Finally, section 5 draws some concluding remarks and directions for future research.

## 2. The backcasting approach

Backcasting is a scenario-building technique that can help decision-makers cope with the uncertainty of the transition to AVs (Li et al., 2018; Marchau & van der Heijden, 2003). Backcasting is an approach used in future studies, which can be classified based on three modes of thinking about the future (Bibri, 2018):

- scenario planning studies, focused on identifying possible futures (*what might happen?*);
- forecasting studies, which try to assess probable futures (*what is most likely to happen?*);
- backcasting studies, focused on preferable futures (*what we would prefer to happen?*).

The main peculiarity of backcasting is a concern with how desirable futures can be attained, rather than with futures that are likely to happen, as in forecasting analyses (Robinson, 1982). Backcasting is a normative approach: it moves step-by-step backwards from a desired future to the present, in order to identify the strategic steps in the policy path that are needed to achieve that specified future (Robinson, 1990).

The backcasting approach has been applied with a wide variety of methodologies, as diverse backcasting traditions and practices have evolved in different countries (Vergragt & Quist, 2011). That being said, backcasting is generally articulated in a sequence of phases, two of which play a key role: *visioning*, aimed at establishing business as usual and alternative visions of desirable futures, and *policy packaging*, to identify pathways and policy measures to pursue the desired vision. Some authors also put an *appraisal* phase at the end of the process, aimed at evaluating the pathways and policy packages (Nogués et al., 2020; Soria-Lara & Banister, 2018b).

The origin of backcasting can be traced back to the 1970s in energy studies, when Lovins (Lovins, 1976, 1977) proposed an approach – which he defined "backwards-looking analysis" – aimed at identifying alternative policy paths to pursue a more efficient use of energy in the long term. The term backcasting was then introduced by (Robinson, 1982), who reflected on the theoretical aspects of this technique. Since the late 1980s, backcasting has been applied to sustainability issues related to geographical contexts – especially cities –, companies and sociotechnical systems (Bibri & Krogstie, 2019; Holmberg & Robert, 2000; Phdungsilp, 2011; Quist, 2007). In particular, in the transport sector "the backcasting approach fundamentally responds to the following question: 'how can a specific transport target be reached (e.g. CO2 reduction, energy efficiency, etc.), when the prevailing structure (e.g. institutional frameworks, legal systems, etc.) blocks necessary changes?'" (Soria-Lara & Banister, 2018, p. 11).

Backcasting has been largely used to address the impacts of transport on the environment (Barrella & Amekudzi, 2011; Dreborg, 1996), and to develop new mobility visions aimed at achieving emission reduction targets and cutting energy consumption (Åkerman & Höjer, 2006; Geurs & Van Wee, 2000; Hickman et al., 2011; Höltl et al., 2018; Mattila & Antikainen, 2011; Olsson et al., 2015; Robèrt, 2017; Robèrt & Jonsson, 2006; Schade & Schade, 2005; Tuominen et al., 2014; Zimmermann et al., 2012).

A recent comprehensive and systematic reflection on transport backcasting scenarios has been developed by Soria-Lara and Banister (2017, 2018a, 2018b), who highlighted a range of methodological issues. In particular, whereas backcasting has traditionally been seen as an expert-led analysis, these authors call for a shift to a more collaborative and participatory approach throughout the whole process (Soria-Lara & Banister, 2018a).

In this sense, they extend to transport a more general recommendation in the literature about backcasting (Carlsson-Kanyama et al., 2008; Quist & Vergragt, 2006), since stakeholder engagement is seen as crucial to bridge the gap between the conceptual elegance of scenario-based research and the practicalities of its actual implementation through policies (Banister & Hickman, 2013).
Backcasting is often mentioned as a suitable method to deal with the transition to autonomous driving (González-González et al., 2019; Li et al., 2018). Indeed, this transition displays the conditions which, according to Dreborg (1996), make backcasting an appropriate method:

- the problem to be studied is complex;
- there is a need for major changes;
- the dominant trends are part of the problem;
- the problem to a great extent is a matter of externalities;
- the time horizon is long to allow considerable scope for deliberate choice.

Moreover, backcasting puts particular emphasis – more than other categories of futures studies – on the definition of the policy pathways to achieve the desired scenario (Robinson, 1990). It can be then considered especially appropriate for the elaboration of policy packages for steering the transition to AVs.
However, most of the studies that dealt with the diffusion of AVs were just focused on the visioning step. Several authors have developed visions and scenarios about AVs, focusing the socio-technical transitions (Fraedrich et al., 2015), expected implications of AVs (Papa & Ferreira, 2018), user friendliness (Smolnicki & Sołtys, 2016), combination of technological innovation and policy support aspects (Milakis et al., 2017), impacts on urban form (Stead & Vaddadi, 2019); yet, most of these studies do not elaborate concrete policy pathways and do not refer to real-world cases. The most advanced exercise of backcasting about AVs was proposed by González-González et al., who first identify some potential measures to steer the transition to AVs toward a range of urban development policy goals (González-González et al., 2019), then focus on parking policies (González-González et al., 2020) and finally present the results of the evaluation of the scenarios and policy packages defined in the previous phases of backcasting (Nogués et al., 2020). Finally, to the authors' knowledge, to date the backcasting process that is discussed in this paper is unique of its kind, as it is applied to a real-world case study (Staricco et al., 2019; Vitale Brovarone et. al., 2020-forthcoming).

# 3. Backcasting the diffusion of AVs in Turin

This article reflects on a two-step backcasting for the diffusion of AVs in Turin (Italy). The aim was to define a policy pathway toward a future vision (to 2050) in which AVs will be integrated in the mobility system of the city so to preserve the liveability and quality of public spaces. The visioning and the policy packaging phases of this process can be found respectively in Staricco et al. (2019) and Vitale Brovarone et al. (2020-forthcoming), where they have been described in detail. Here a summary overview of the whole process is offered, as a basis for the methodological reflections in section 4 on the application of backcasting to AVs.

## 3.1 The case study

Turin is the fourth most populated Italian city (around 886,000 inhabitants at the city level and 2.3 million in the metropolitan area); it is located in the north-western part of Italy. The choice of Turin as a case study was due to several reasons.
First of all, Turin is heavily car dependent, so it is particularly exposed to the potential negative impacts of the transition to AVs, if this transition is not properly governed. It has one of the highest car ownership rates in Europe (639 cars/1000 inhabitants), and the modal share of private motorised mobility is nearly 40% (source: EMTA Barometer 2015, Istat). Car traffic is scarcely discouraged; only one restricted traffic zone (covering 2% of the municipal area) and few small 30 km/h zones are active in the city. Public transport (one metro, 8 tram

and about 90 bus lines) and the cycling network are poorly used; their respective modal shares are 24.3% and 3% (source: EMTA Barometer 2015, Agenzia mobilità Piemonte).

In 2018, the city launched a pilot project to test AVs in a real-world environment, on a 35-km route along its road network. In this way, the city aims to position itself at the forefront of the transition to AVs and renew its long-standing economic specialization in the automotive and ICT sectors.

Finally, Turin is now elaborating its new Sustainable Urban Mobility Plan (hereinafter, SUMP), since the previous one, adopted in 2010, is now coming to the end of its 10-year validity period. Therefore, the city is developing the vision of its mobility system for the next decade, and if it wants to govern the transition to AVs, in this moment it has the opportunity to define which short- and medium-term measures for AVs can be integrated into the new SUMP.

## 3.2 The visioning phase

The visioning phase of the backcasting process was aimed to explore different visions for AVs in Turin, and to select the most advisable one, in terms of sustainability and liveability. Different ways of regulating how AVs can circulate and park in Turin, and of integrating them in the overall mobility system of the city (taking into account the real structure of its road network, its neighbourhoods, etc.) were explored.

In this visioning phase, a combination of the think-tank method and the participatory method was applied. Both are widely used for designing future normative visions (Börjeson et al., 2006; Carlsson-Kanyama et al., 2008; Dreborg, 2004). In the think-tank model, visions are generated back-office by a multidisciplinary research team. In the participatory model, a larger number of (expert and non-expert) stakeholders are involved in developing the visions.

The visioning phase entailed three different steps (the first two based on the think-tank model, the third on the participatory model):

1) development of three possible future visions of Turin, referring to a long-term time horizon (2050) in which all circulating vehicles are expected to be fully connected, autonomous (SAE level 5), and electric. These visions were defined by the research team (composed of urban and transport planners, transport engineers and sociologists) through a brainstorming meeting, grounded on a previous systematic review of the scientific and grey literature about the impacts of AVs on cities. The team identified fourteen key elements to regulate AV circulation and parking and to integrate AVs into the offer of other modes of transport and mobility[3]. These fourteen items were developed and combined differently by the researchers, according to three scenarios that are frequently conjectured for AVs in the literature (Papa & Ferreira, 2018):
    - An optimistic and technology-centred scenario, which assumes that the impacts of AVs on the city will be largely positive. A "Strong deregulation" vision was developed, in which the fourteen items were devised on the assumption that AVs could solve most of the current transport problems in Turin.
    - A pessimistic scenario, which presumes that the negative impacts of AVs on the city will prevail, if not properly managed. A "Strong regulation" vision was elaborated, by implementing the fourteen items according to the general policies that are recommended for AVs in the scientific literature.
    - A neutral scenario, in which the diffusion of AVs will not be explicitly governed, nor their positive or negative impacts. A "Business as Usual" vision was proposed, in which the fourteen items were

[3] The fourteen key elements were: road hierarchy - main roads; road hierarchy - local roads; limitations to vehicle circulation; on-road parking and pick up/drop off areas; multi-storey parking; intermodal parking; main public transport lines (trains, metro, streetcars); feeder capillary network (buses); lanes reserved to public transport; motorized AV sharing; non-motorized AV sharing (bike sharing); pedestrian areas; cycling facilities; modal split.

developed in a sort of inertial prolongation of the current planning conditions of the mobility system in Turin[4].

2) Validation of the three visions, in a focus group which involved seven local experts (ranging from politicians to managers and technicians) of the transport sector. These experts were selected so as to represent the main institutions and companies which are in charge of transport planning, managing, and operating in the area of Turin. They were invited to debate each item of each vision, to confirm it as proposed by the research team or to suggest how (and why) to develop it differently. The recorded results of this discussion were finally analyzed by the research team. The participants did not propose significant changes to any of the three visions; each vision was then considered validated. All the three visions corresponding to the three above-mentioned scenarios could have been built in different versions; however, the participants to the focus group judged that the three visions proposed by the research group (and in particular their articulation according to the fourteen key items) were appropriate developments of the three scenarios to the city of Turin[5].
3) Selection of the most advisable vision. In this third step, the seven experts who participated in the focus group and other 44 local stakeholders[6] filled in a questionnaire to evaluate the advisability of each of the fourteen items of each vision on a scale from 1 ("absolutely not advisable") to 10 ("absolutely advisable"). The stakeholders were chosen so as to represent automotive companies involved in car manufacturing and sales, providers of ICT and mobility services, research centres, public administrations, and environmentalist or professional associations. The "Strong regulation" vision turned out to be considered the most advisable by 45 of the 51 respondents, and recorded the highest values for 13 out of 14 items; only one respondent preferred the "Strong deregulation" vision, and five preferred the "Business as Usual" vision.

## 3.3 The selected vision

The "Strong regulation" vision is focused on improving quality and liveability of public spaces at the neighbourhood level by reducing the circulation of private AVs and promoting the use of shared AVs, public transport and active mobility (fig. 1 and 2). The vision is inspired by the superblock model (Scudellari et al., 2019), which in turn traces back to the concept of neighbourhood unit launched in the United States after World War I and reinterpreted over time (Brody, 2016; Mehaffy et al., 2015; Patricios, 2002; Perry, 1929; Zali et al., 2016), to reduce the negative impacts of the diffusion of human-driven cars in the urban environment. According to this model, the road network is hierarchized into two levels: a main network of thoroughfares (with a speed limit of 50 km/h) supports cut-through traffic; the meshes of this network are re-thought as superblocks, in which every road is classified as local (with a speed limit of 20 km/h) and reserved to access traffic of shared AVs and AVs belonging to the residents of the superblock. As a result, in a trip from home in neighbourhood A to a destination in neighbourhood B, drivers can run their (private or shared) car in A, then have to run along the main road network, and finally, leave their car (if private) at the border of B or ride just to destination inside B if they are using a shared car. In any case, both private and shared AVs cannot ride through an intermediate neighbourhood between A and B. In this way, volumes of car traffic inside neighbourhoods are reduced.

Parking is completely removed from road and concentrated in multilevel facilities provided around each superblock and at the terminals of each public transport line. The freed-up road space is partly devoted to

[4] A fourth "critical" scenario could have been assumed, in which the inevitability of transition to AVs is questioned and a city can actively block the entrance of these vehicles in its roads (see, on this issue, the comments by Legacy et al., 2019). This scenario was not considered, as the city of Turin is already committed in testing and promoting the introduction of AVs in its roads.

[5] For more details about the validation process in the focus group, see Staricco et al. (2019).

[6] 62 stakeholders were interviewed with semi-structured interviews, but 11 of them did not fill in the questionnaire.

platforms for picking-up/dropping-off passengers, partly to favour non-motorised mobility and improve the quality of the public space.

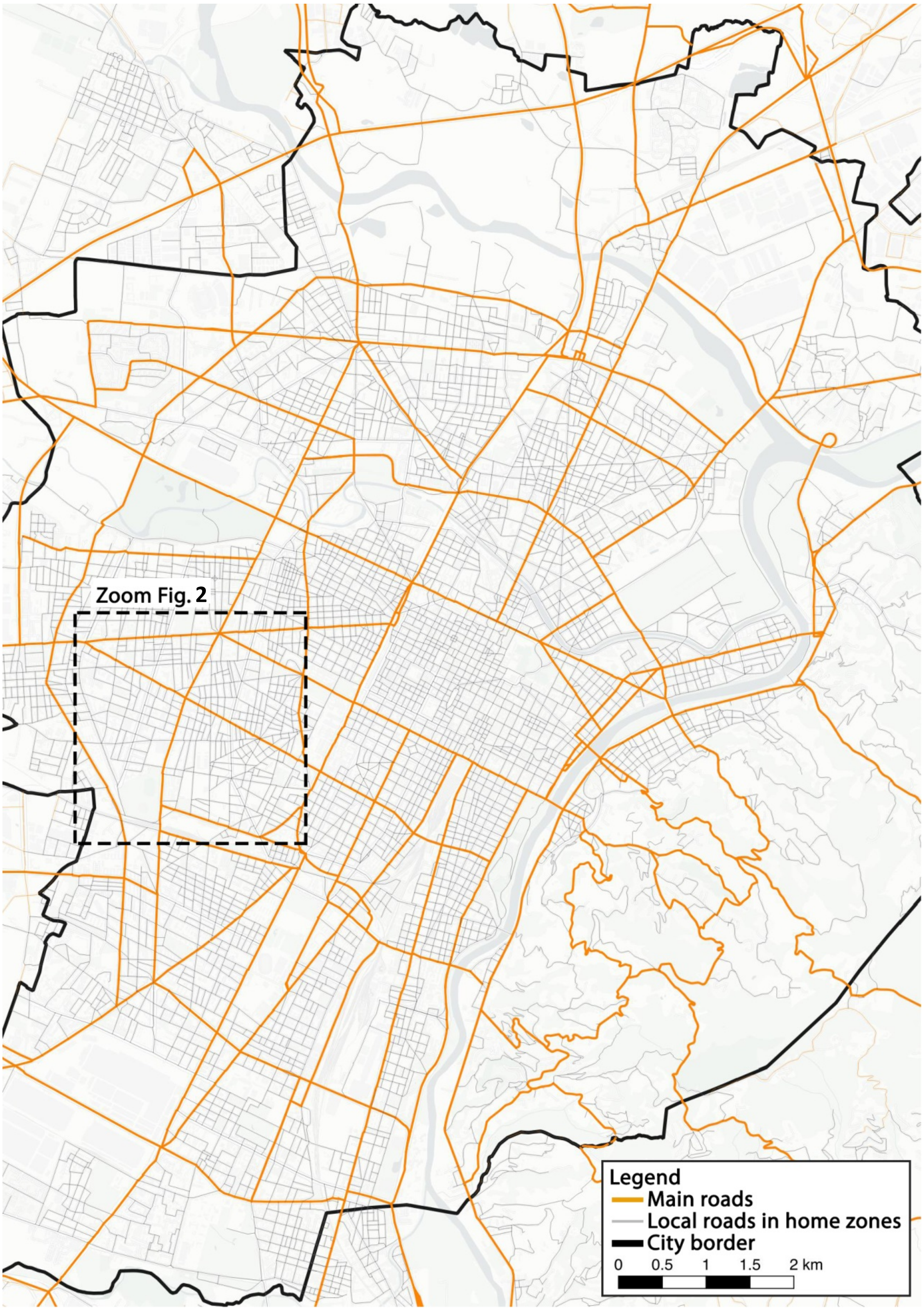


**Fig. 1 Road hierarchy in the "Strong regulation" vision**

As regards public transport, the service is concentrated on the main network and underground. Trams and streetcars run on reserved lanes on all the thoroughfares of the main network; the metro and the metropolitan

railway service are provided at high frequency. Inside superblocks no public transport service is provided, except in the larger ones, where autonomous shuttles circulate to feed the main lines.
The supply of car and bike-sharing services is spread throughout the city. Cycle paths are provided on the whole main road network, and cyclists are allowed to freely ride on local roads inside superblocks. Within each superblock, the road space is organised as a shared space having walking priority.
As a consequence of these regulations, the modal split is assumed to result in a significant increase in all alternative modes to private AVs; the latter would be strongly hindered, while car sharing services would be boosted. The share of public transport and bikes would slightly increase, and walking would grow thanks to the shared spaces in the home zones.

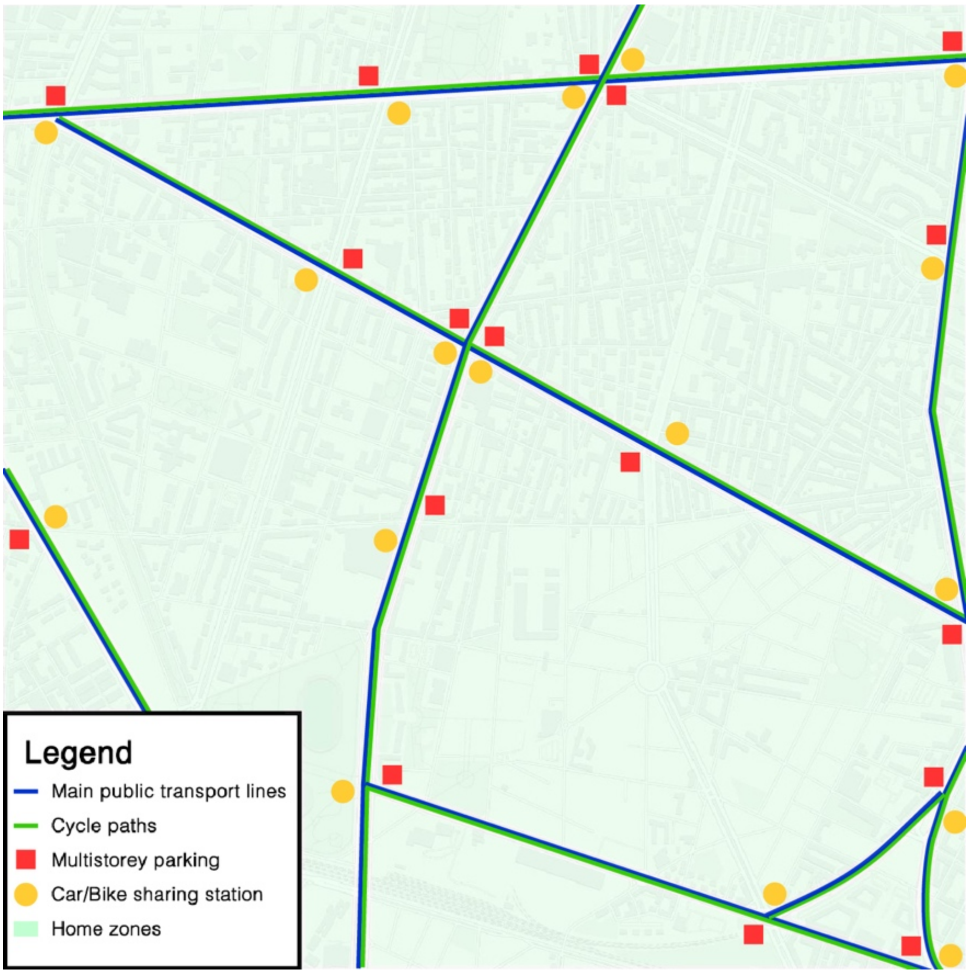


**Fig. 2 Public transport, cycling, sharing stations and parking along the network of the main roads in the "Strong regulation" vision (zoomed-in view of figure 1). Each mesh of this network is a superblock**

## 3.4 The definition of the pathway

Once the vision for Turin in 2050 had been chosen, a second phase of the backcasting process was aimed at defining milestones and actions to pursue it along the 30-year timeline. Again, think-tank and participatory methods were combined to frame the actions and organize them in policy packages.
As mentioned in paragraph 3.2 (note 4), in the phase of selection of the vision, 62 stakeholders were interviewed with semi-structured interviews, so to collect their points of view on the diffusion of AVs and the three visions.
During the interviews, participants were asked to identify and suggest possible measures to pursue the most desirable vision. First, a list of 18 measures was set by the research team, combining and clustering the measures emerged during interviews and questionnaires. Thereafter, a workshop was organized, in which 8

stakeholders[7] – split into two groups – were invited to discuss this list, add new actions if needed, and distribute all the measures along the timeline from 2020 to 2050. The two groups were facilitated by members of the research team, who provided support when needed but did not steer the discussion, so to leave the floor to the participants. The mobility and socioeconomic scenarios set at the regional level to 2050 by the Regional Transport Plan of Piedmont Region[8] were assumed as a reference framework. The participants were chosen so to represent different stakeholders' views on AVs (automotive companies, providers of ICT and mobility services, research centres, public administrations, environmentalist, professional or citizens' associations). During the workshop, questions and discussions were raised by the participants, especially about overarching measures and conditions and on the need to further detail some of the 18 actions, splitting them into sub-categories and setting them at different points in the timeline. Overall, around 45 elements were set on the timelines, including overarching measures, actions and sub-actions.

Finally, the research team reviewed the results of the workshop and further integrated them based on inputs from the scientific literature. As a final result, 33 key actions were streamlined and distributed along the timeline[9] (Fig.3). For the sake of clarity, actions were referred to six clusters summarizing the fourteen items that, as mentioned above, were used to frame the vision (Tab.1). Actions were specified in terms of type (articulated in three main categories – policy, technology, physical transformation of the urban space), main public or private actors in charge of implementation, and decade of implementation.

The SUMP was assumed as the key planning tool to pack the main actions towards the vision. As already mentioned, in 2020 the city of Turin will deliver its new SUMP, which will be valid for ten years. Hence, the three SUMPs that the city of Turin will develop in 2020, 2030 and 2040 were set as milestones in the timeline, and all the actions were related to one of these plans.

The SUMP 2020-2030 was envisaged to start setting up the city for the upcoming changes and to test the technology. In this decade, the road network is organized in the two levels – main and local roads, so to delimit the superblocks and set them as 30 km/h zones. Parking space is reduced inside the superblocks, and the space that is freed up is redesigned with light, low-cost temporary interventions, so to reclaim public space for pedestrians. The public transport services and the cycle network are reorganized, the main lines of the public transport and cycling network are concentrated on main roads. Preliminary tests of AVs are conducted in few target areas, and the main road network is provided with technological V2I (Vehicle-to-infrastructure) connection infrastructure. In the following decade (SUMP 2030-2040) autonomous public transport services and shared AVs are allowed to circulate on the main network. On-road parking space is reduced, especially inside the superblocks, and new multi-storey parking facilities are located on the main network. Temporary interventions to reclaim public space for pedestrians are progressively extended and replaced by permanent interventions. The provision of the V2I connection infrastructure is progressively extended also to the inner roads of the superblocks. In the third decade (SUMP 2040-2050) the superblocks are converted in restricted traffic areas. Only shared vehicles and residents' private ones are allowed to circulate and cut-through traffic is completely prohibited. On-road parking is completely removed and public spaces inside the superblocks are structurally redesigned to prioritize active mobility.

7 The 8 experts who participated to the backcasting focus group were selected among the 69 who were involved in the previous phases, according to their experiences (to have expert representatives from the mentioned categories) and their willingness to be further involved in the project.

8 The main mobility targets to 2050 set by the regional plan are: zero fatalities due to road traffic accidents; public transport offer serving 100 per cent of the potential demand; no consumption of fossil fuels. Regarding the modal split, private motorised transport should decrease from 63% in 2011 to 31% in 2050, whereas public transport, cycling and walking should increase respectively from 20% to 36%, from 3% to 17% and from 14% to 16%. The socioeconomic scenario to 2050 describes a society that is highly differentiated in terms of lifestyles, an economy focused on innovation and in particular on the use of big data, an environment that has overcome the dependence on fossil fuels, a territory whose peculiarities are given value through a place-based policy approach.

9 For more details about the policy packaging process, see Vitale Brovarone et al. (2020-forthcoming).

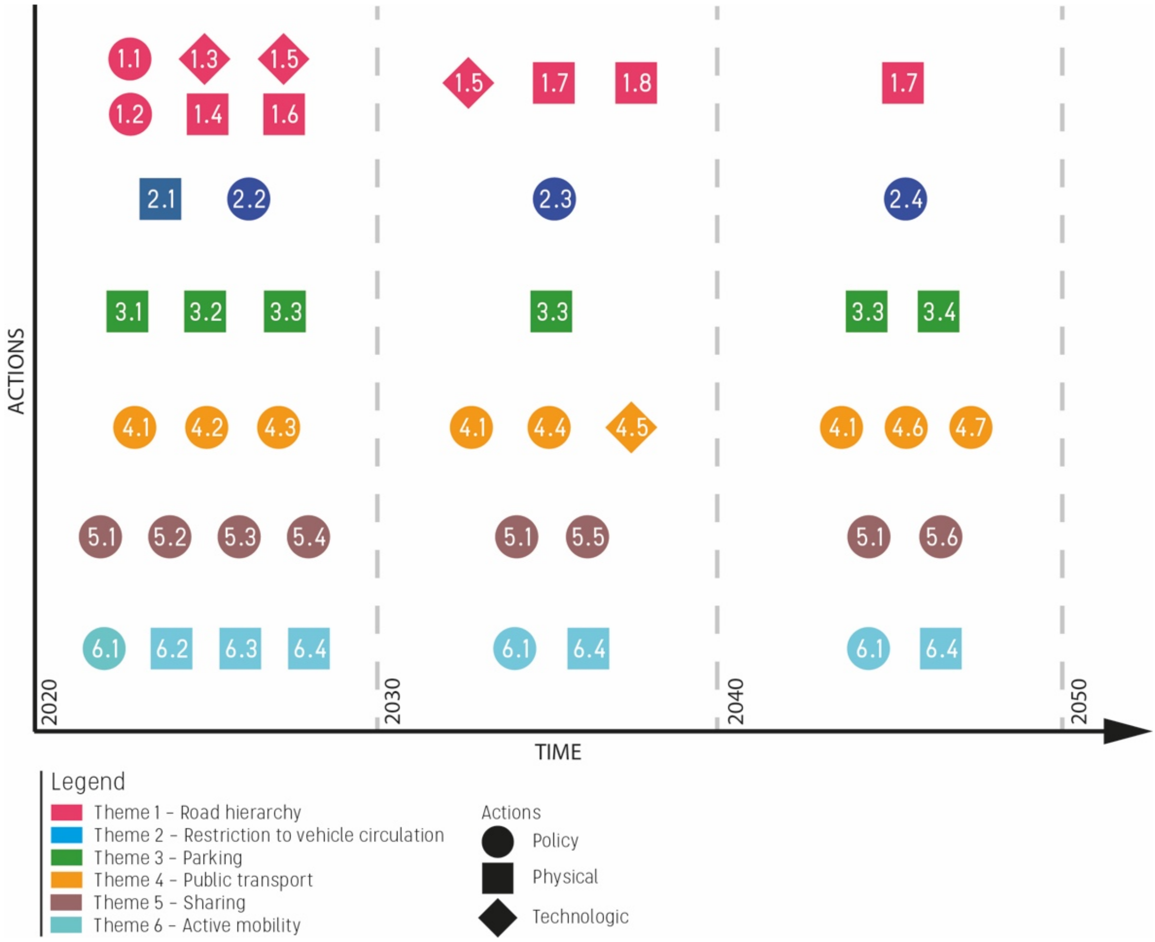


**Fig. 3 Distribution of the policy packages on the time-line**

| | |
|---|---|
| | **Theme 1 – Road hierarchy** |
| 1.1 | Classify the roads (main roads, local roads) and identify the main thoroughfare networks and the superblocks |
| 1.2 | Identify target areas (including main and local roads) to promote AV tests in real urban environment |
| 1.3 | Provide test areas with the technological infrastructure for connection (V2I) |
| 1.4 | Ensure road maintenance of test areas to ease the circulation of Avs |
| 1.5 | Provide main roads with V2I connection infrastructure |
| 1.6 | Ensure maintenance of the main road network to ease the circulation of Avs |
| 1.7 | Provide local roads with V2I connection infrastructure |
| 1.8 | Ensure maintenance of the local road network to ease the circulation of Avs |
| | **Theme 2 – Restriction to vehicle circulation** |
| 2.1 | Design superblocks as 30 km/h zones through traffic calming elements |
| 2.2 | Enhance limitations to private car traffic in the central restricted traffic zone |
| 2.3 | Ban private cars from the central restricted traffic zone |
| 2.4 | Transform superblocks in restricted traffic zones where circulation of private cars is prohibited |
| | **Theme 3 – Parking** |
| 3.1 | Reduce parking space for private cars and increase parking lots for shared vehicles |
| 3.2 | Develop new park&ride facilities |

| | |
|---|---|
| 3.3 | Build multi-storey parking structures along the main road network |
| 3.4 | Eliminate everywhere on-street parking |
| | **Theme 4 – Public transport** |
| 4.1 | Promote the use of public transport (incentives, communication campaigns, etc.) |
| 4.2 | Reorganise the public transport network (trams on main roads, buses on local roads) |
| 4.3 | Promote automation tests on public transport means along the main road network |
| 4.4 | Boost autonomous trams along the main road network |
| 4.5 | Integrate local public transport and car sharing in a MaaS system on the main road network |
| 4.6 | Remove bus lines inside the superblocks and provide small autonomous shuttles in larger superblocks |
| 4.7 | Integrate public transport in a MaaS system on the whole road network |
| | **Theme 5 – Sharing** |
| 5.1 | Promote the use of sharing services (incentives, communication campaigns, etc.) |
| 5.2 | Enhance sharing services (fleet, spatial coverage, etc.) |
| 5.3 | Support the renewal of the car sharing fleet with new ADAS |
| 5.4 | Promote automation tests on car sharing along the main road network |
| 5.5 | Boost shared AVs along the main road network |
| 5.6 | Integrate sharing facilities in a MaaS system on the local road network |
| | **Theme 6 – Active mobility** |
| 6.1 | Promote active mobility (incentives, communication campaigns, etc.) |
| 6.2 | Develop a cycling network on the whole main road network |
| 6.3 | Expand and improve pedestrian paths and areas |
| 6.4 | Improve liveability and quality of public space in local roads |

**Tab.1 List of the 33 actions subdivided for policy packages**

# 4. Challenges and critical issues of backcasting AVs

This backcasting process is one of the first applications of the backcasting method to the transition to AVs, and to the authors' knowledge the first application in a real-world context. A set of critical questions, challenges and methodological issues emerged. This section aims to reflect on such key issues and on possible ways forward, to support further backcasting studies for planning the transition to autonomous driving.

## 4.1 Factors and levels of uncertainty

As explained in section 2, backcasting is considered as a suitable tool to deal with problems that display high levels of uncertainty and complexity. Still, in the case of the transition to AVs these levels are so relevant to significantly challenge the effectiveness and implementability of the backcasting approach.

A first factor of uncertainty concerns the technological evolution of AVs. Full automation of driving will be the result of a number of key enabling technologies (radars, sensors, in-vehicle embedded computer units, V2X communication technologies and so on), some of which are currently competing with each other, and it is far from clear how fully autonomous vehicles will actually work (in particular, how much they will depend on communication with other vehicles and the infrastructure) (Medina et al., 2017). This is particularly true for public transport, which could evolve toward more flexible systems completely different from the existing ones (for example, through the connection of individual modules to form platoons on the road; Nguyen et al., 2019).

A second element of uncertainty is the time horizon of the transition to autonomous driving. Indeed, fully autonomous vehicles are the ones that can generate the epoch-making changes in mobility patterns, but as anticipated in section 1, there is so far little consensus among scholars, automotive manufacturers and public authorities on when they will be ready to circulate on real-world roads (Bazilinskyy et al., 2019). This complicates the definition of the visions and the transition pathways, which depend on when cars with different SAE levels of automation will be introduced in the market. Moreover, the renewal of the vehicle fleet will take several years, and in the transition phase, the co-existence of AVs and human-driven cars would raise some conflicts that are being explored by some scholars but remain to a large extent uncertain and difficult to foresee (Fraedrich et al., 2015; Parkin et al., 2018).

Deep uncertainty also surrounds the effects of other potential innovations in the transport sector. Some of these innovations are already appearing on the market, such as smart micro-mobility solutions that are progressively flooding the roads of many cities (Chang et al., 2019; Maiti et al., 2019; Mathew & Bullock, 2019; McKenzie, 2019). Others, such as urban air mobility, may have a disruptive effect on urban mobility, yet the diffusion of this technology in urban skies is surrounded by several elements of uncertainty (Thipphavong et al., 2018).

Finally, the emergence of new disruptive business models and new mobility paradigms, such as sharing and Maas, may produce massive changes, which are to a large extent uncertain, and could even question the distinction between private and public, collective and individual mobility in the future (Mulley, 2017; Sheller & Urry, 2006, 2016).

During the backcasting exercise, the involved stakeholders often highlighted how all these factors of incertitude make it rather complex to define an acceptable and shared vision, as well as the policy pathway to achieve this vision. In this sense, the combination of the think-tank method and the participatory method proved to be positive: a pre-definition of the visions by the research team reduced the degrees of complexity the stakeholders had to face in the process (albeit at risk of reducing the disruptive potential of these visions).

## 4.2 The contextualization of the vision

Beyond the above-mentioned factors of uncertainty, other issues make the backcasting process complex. In fact, the vision of AVs circulating in Turin in 2050 is part of a broader framework that comprises further elements, including: the distribution of land uses, hence of generators and attractors of mobility; the availability of vacant spaces, i.e. where to locate parking facilities along the main road network, at the boundaries of the superblocks; the transition to electric mobility, when and how it will occur and how it will reshape the road space (e.g. charging infrastructures); the demographic and societal trends (ageing, depopulation of core cities and growth of metropolitan belts, etc.) [10]; the evolution of the economic structure of the city.

All these factors, and many others, constitute the territorial, environmental and socioeconomic scenario in which the diffusion of AVs will take place. Indeed, these scenarios are in themselves complex to be elaborated over a 30-year time horizon, and even more complex if their interrelations with the evolution of mobility systems due to the transition to AVs are taken into account. In this respect, it is probably appropriate to refer to existing scenarios that have already been elaborated and validated on other occasions. In the present research, the socioeconomic scenario defined at the regional level for the transport plan by Piedmont Region was assumed as the reference framework. This scenario has its limitations but was adopted as-is both for simplifying the backcasting process and for facilitating the development of a policy pathway in Turin which would be consistent with the measures defined in the regional transport plan. This approach was positively assessed by the focus group participants in the second phase of the backcasting process, as it allowed them to integrate the specific measures for AVs into a more general set of measures for governing regional mobility toward 2050.

10 For a comprehensive review of the public and social attitudes that will influence the transition to AVs, see Cohen et al. (2020).

Therefore, the availability of a socioeconomic reference scenario could be considered a critical pre-condition that should be verified when planning backcasting processes, as it simplifies their development.

## 4.3 The involvement of relevant stakeholders

As anticipated in section 2, a shift to a more collaborative and participatory approach to backcasting is called for in the scientific literature. This expectation can be extended to the transition to AVs: its inherent high levels of uncertainty and complexity suggest to broaden the range of stakeholders to be involved in the backcasting process. A wide and varied representation of stakeholders would allow to address the different possible respects, and the participatory process facilitates the integration and exchange of knowledge. In addition, the different perspectives and roles in the definition of the vision and of the pathways to pursue it can be put together and possible conflicts or criticalities can be identified.

Willingness to be involved in participatory processes cannot be taken for granted. Not all the cultural contexts show the same enthusiasm in participation processes, due to administrative traditions, institutional factors, national cultures but also subjective factors such as personal perceptions, beliefs, norms and values, or previous experiences in similar processes (Enserink et al., 2007; Huxley et al., 2016; Wassenhoven, 2008). Thus, participation in workshops, focus groups, living labs, etc. can be quite weak in some contexts. As the backcasting experience presented in this article has shown, engaging stakeholders can be very challenging. And in the case of this project, the most reluctant actor to participate turned out to be the public administration, that on the one hand was supposed to be the recipient of policy pathways and the main actor at stake; on the other hand, it proved to conceive the transition to AVs as a problem too far away to deserve real attention at the moment.

Moreover, general knowledge on the topic can be a critical factor for the involvement of stakeholders. The project expressly targeted expert stakeholders in the mobility field, while no in-depth knowledge on AVs was required, in order to avoid narrowing the sample too much. Notwithstanding, scarce knowledge of the subject by some of the participants raised some criticalities. In this respect, the involvement of private citizens turned out to be very difficult, as general knowledge on AVs is very low, and engaging a limited number of private citizens would have raised some issues of representativeness. To address this criticality, citizens' associations involved in the process were considered as representatives of private citizens' views.

Integrating different participatory techniques, as suggested by Soria-Lara & Banister (2018a), proved to be a solution to partially remedy this criticality. In this backcasting process, brainstorming, focus groups, workshops, semi-structured interviews, questionnaires were combined and offered the possibility to deepen, combine and exchange stakeholders' perspectives and knowledge.

## 4.4 The definition of the policy pathway

Despite a predefined list of actions was proposed to the two groups of participants in the second workshop, the pathways they proposed turned out to be quite different (Fig.4). Two members of the research team moderated the work of each group, but the outcomes differed in terms of rationale, number and priority of the actions, etc.. Hence, concerns arose about the relevance and reliability of the two pathways, and about the significance of the participatory backcasting process in itself.

A remedy could be increasing the number of participants and multiplying the focus and working groups, so to enhance the representativeness, reliability and relevance of the outcomes. Nevertheless, the low attendance rates and difficulties in stakeholder involvement mentioned in the previous paragraph raise some doubts on the feasibility of such a process, and on its cost/benefit ratio.

As a consequence, the definition of the policy pathway was not an easy task. In this sense, the combination of the collaborative approach with the expert-led predefinition of the vision and definition of the policy pathway seems appropriate. In fact, the integration of elements emerged in the literature review, in the interviews and during the focus groups helped to define the pathway and strengthen its relevance.

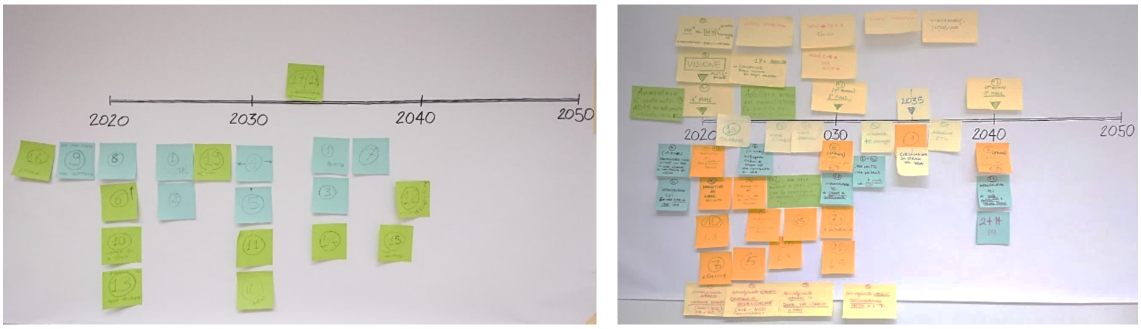


**Fig. 4 The pathways proposed by the two groups during the backcasting focus group**

The allocation of the proposed measures on the timeline turned out to be quite complex for the workshop participants; familiarity with long-term reasoning through concrete actions cannot be taken for granted, and the high level of uncertainty did not help. Most of the actions were set in the first decade of the timeline; this can be an expression of the difficulty of dealing with long-term horizons, but also of the fact that many actions must be taken now to pave the way for the desired vision. The choice to refer the packages of actions to SUMPs, which is valid for 10 years, can facilitate the scheduling of the actions and allow to verify the internal consistency of the packages of measures, as well as their integration with the other general measures proposed by the SUMPs. Moreover, it allows for a certain degree of time-framing flexibility, as the measures envisaged for the second and third decades in SUMP 20430-2040 and 2040-2050 can be revised on the basis of the results achieved in the first ten years.

As mentioned in Section 2, backcasting sometimes includes a third phase appraisal (after visioning and policy packaging) for assessing the feasibility and barriers of the proposed policy pathway (Soria-Lara & Banister, 2018b). The backcasting process described in this paper involved a wide range of experts, which at least partially allowed to preliminary verify the robustness, consistency and feasibility of the measures included in the pathway. However, a more quantitative appraisal of the pathway could be useful to assess the effectiveness of the measures (for example in terms of modal diversion, multi-storey parking structures that are needed to eliminate on road parking etc.) and their efficiency (with relation to costs of operating the reorganized public transport lines and sharing services, of building the parking structures etc.). In this way, it could help identify if proposed measures (and related scheduling) have to be rethought, or alternative measures are needed.

## 5. Conclusion

The transition to AVs is expected to have a disruptive impact on the urban environment, and urban planning and policies are increasingly called for addressing this challenge already in the short and medium-term. At the same time, the uncertainty and complexity of this transition make it difficult for public administrations to introduce the issue of AVs in their planning processes. Backcasting is often reported in the scientific literature as an appropriate technique for scenario building on AVs, but very few applications have been implemented so far.

This article discussed a participatory backcasting exercise for defining a vision and a policy pathway to steer the transition to AVs towards the liveability of cities and neighbourhoods. The backcasting was applied to a real-world context, the city of Turin, in Italy. To the authors' knowledge, very few similar researches have been published previously. Hence, this paper aimed to contribute to fill a gap in the literature, and support further research on the subject.

One single exercise is not sufficient to explore all the crucial issues of the application of backcasting to AVs, nor its multifaceted aspects. The backcasting process that was discussed in this paper explored how AVs could be integrated into the mobility system of the city while preserving the liveability and quality of roads and public spaces. The process raised some criticalities and showed solutions to address them were found. While the visioning and the policy-packaging phase of the backcasting were described elsewhere (Staricco et al., 2019; Vitale Brovarone et al., 2020-forthcoming), this article presented the whole process and its criticalities.
The transition to AVs displays very high levels of uncertainty and complexity, which are related, among other factors, to the different possible technological evolutions of AVs, the time horizon of the transition, other potentially disruptive innovations in the transport sector, the emergence of new business models and mobility paradigms. In the case presented in this article, these elements proved to challenge the effectiveness and the potentialities of implementation of the backcasting approach.
In the face of high levels of uncertainty, referring to socioeconomic scenarios that have already been developed for other local plans or policies allowed to simplify the backcasting process, as the elaboration of these scenarios is a further element of complexity. Moreover, it facilitates the integration of the specific policy pathway for AVs into a more general set of measures for the whole mobility system.
The involvement of a wide range of stakeholders in the backcasting process is essential to take full account – through their different perspectives and roles – of the complexity of the transition to AVs in the vision and policy pathways, as well as to reduce the implementation gap. Engaging stakeholders can be difficult: some countries are less keen than others on active involvement in participatory processes; moreover, AVs are often seen – in particular by public administrations – as something that has yet to come, premature to be considered. In our case, the combination of a range of participatory techniques – brainstorming, focus groups, workshops, semi-structured interviews, questionnaires – proved important to broaden the number and type of involved stakeholders.
At the same time, precisely because of the uncertainty and complexity of the problem, the outputs of these participatory phases can be partial, biased, controversial or even contradictory. In the backcasting presented in this paper, the integration of participatory and think-tank techniques allowed to review, enrich and systematize the outputs provided by the stakeholders, particularly in the definition phase of the policy pathway.
Finally, a long time frame makes it difficult for most stakeholders to allocate the proposed actions along the timeline. The reference to mid-term planning tools, such as the 10-year long SUMPs, can be an effective way to organize the pathways into policy packages that are consistent both internally and with the more general mobility strategies.
The application of backcasting on AVs in a real-world case study in Turin and the analysis of its critical issues can support further researches. This research contributed to improve knowledge on the potentialities and constraints of using backcasting to define policy pathways to steer the diffusion of AVs towards a desired vision. Applications in other real-world contexts will confirm to what extent the issues presented in this article can be generalized and provide further insights.

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## Image Sources

Fig. 1: authors' own elaboration

Fig. 2: authors' own elaboration

Fig. 3: authors' own elaboration

Fig. 4: authors' own elaboration

## Author's profiles

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