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Steering disruption: a backcasting approach to govern the spatial impacts of the diffusion of automated vehicles in Turin

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Abstract: The diffusion of autonomous vehicles (AVs) is expected to increase rapidly in the next decades and its impacts can be potentially disruptive. To date, scientific literature on AVs mostly focused on technological innovation, safety issues, ethical dilemmas and normative aspects. A growing number of studies also addressed social aspects and potential demand for AVs. While at first less attention has been given to spatial and territorial impacts that AVs will determine, and on the need to govern their diffusion, concerns and literature on these issues are rapidly growing. Assuming the governance of AVs diffusion as a key aspect to limit their possible negative impacts on urban public space, this paper draws on the preliminary results of a research project led by Politecnico di Torino. The project adopts a backasting approach that considers how circulation and parking of AVs should be differently regulated in various parts of the city. The paper highlights how defining future visions of AV regulation for these backcasting exercises raises issues and questions, that are relevant for implementing policies to control AV impacts on urban public spaces.

Keywords: autonomous vehicles; visioning; backcasting

Introduction

Despite the enthusiasm of media and manufacturers, there is great incertitude about the temporal horizon of the socio-technical transition to fully automated driving. Also the impacts that autonomous vehicles (AVs) will generate on our cities and lives are to a large extent uncertain. After a first phase of enthusiastic optimism, a growing number of scholars are pointing out the possible criticalities and negative impacts of AVs, in terms of car-dependence, decline of public transport, inactivity, sprawl, etc. (Cohen and Cavoli, 2019; Fraedrich *et al.*, 2019; Soteropoulos *et al.*, 2019).

To this respect, an unconditional introduction of AVs, left in the hands of technology enthusiasts and car manufacturers, could lead to severe consequences, raised by conflicts with the sustainability and liveability objectives of urban policies. But while the awareness of the importance to steer the introduction of AVs is raising, how to deal with such an uncertain future remains unclear.

Backcasting is acknowledged as a suitable method to face such uncertainty (Banister and Hickman, 2013; Tuominen *et al.*, 2014; Vergragt and Quist, 2011). Unlike forecasting, which outlines future development visions based on current trends, backcasting moves in the opposite way; it formulates future visions and proceeds backwards, to define the actions needed to achieve them.

Several visions for AV circulation in the future have been proposed in the literature, with various focuses and methodologies (Fagnant and Kockelman, 2014; Fraedrich *et al.*, 2015; Gruel and Stanford, 2016; Marletto, 2018; Milakis *et al.*, 2017; Papa and Ferreira, 2018; Smolnicki and Sołtys, 2016; Thakur *et al.*, 2016). Still, nearly all these visions are a-spatial, in that they hardly refer to the space in which AVs will be circulating and parking.

A research project led by Politecnico di Torino is studying if and how the introduction of AVs should be differently regulated in urban context, and how the rest of the mobility and land use system could be re-organized, so to maximize positive effects of AVs and limit their negative impacts. According to the backcasting participative methodology, the project has been divided into three phases: visioning, policy packaging, and appraisal (Soria-Lara and Banister, 2017). The aim of this paper is to explore a possible spatialization of visions through a diversification of circulation and parking regulations in different parts of the city, and to highlight which potentialities and critical issues it will raise on the use and consumption of urban public spaces.

Section 1 reviews the spatial impacts of AVs as they emerge from the literature; then the importance to steer the introduction of AVs with proactive policies (section 2) is discussed. Section 3 presents three visions that have been defined for Turin (Italy); these visions have been discussed in a focus group with local experts, which insights are discussed in section 4.

1. The impacts of AVs on urban public spaces

A wide range of potential impacts of a future widespread use of AVs has been analysed in the scientific literature (Cavoli *et al.*, 2017). Some of these impacts – which are obviously dependent on the adopted level of technology and the penetration rate of AVs in the mobility system – relate to the spatial urban dimension, in terms of use and consumption of public space.

First of all, automation of driving could reduce radically the road space necessary for car circulation and parking (Metz, 2018; Zhang *et al.*, 2015), as AVs will be able to reduce safe distance among them and to pick up/drop off the riders in front of the door and then park by themselves. On-road car parks could be removed (just leaving some spaces where cars will stop to pick up/drop off) and transferred to dedicated multilevel parking structures (Fraedrich *et al.,* 2018); these structures could be located out of the city where land is cheaper, leaving space in the dense city for new developments (Zakharenko, 2016).

At the same time, there is a risk that these benefits may be limited to the short term, and turn into negative impacts in the longer term (Childress *et al.*, 2015; Legacy *et al.,* 2018). Actually, AVs could increase vehicle miles travelled (Metz, 2018), for several reasons. First, they could reduce the value of travel time, as riders will not have to drive and could use this time to carry out other activities; this could foster sprawling processes, increasing average travel distances (Meyer *et al.*, 2017). Second, AVs will allow car-less citizens (such as elderly, disabled, young people) to ride a car, improving their accessibility but also resulting in an extreme car dependence (Papa and Ferreira, 2018). Finally, automation of driving could increase the effectiveness of cars to the detriment of public transport and non-motorised mobility; in particular, active mobility could be adversely affected (with negative consequences for health) also because conflicts could arise between AVs and pedestrians and cyclists (Millard-Ball, 2018).

Not only the magnitude, but also the (positive or negative) direction of most of these impacts will probably depend on the diffusion of sharing in AV use. Some researches consider the possibility that a relevant part of the current fleet of privately-owned cars could be replaced in the long term by shared vehicles, increasing the positive effects of AVs or at least reducing their negative outcomes (Alessandrini *et al.*, 2015; Fagnant and Kockelman, 2015; Fraedrich *et al.,* 2018).

2. Visioning and backcasting for policies

Urban and transport planning can play a relevant role in the transition to automated driving, in order to influence the direction of the above-mentioned potential impacts (Li *et al.*, 2018). At the same time, given the uncertainty about the timing and scale of these impacts, policymaking for AVs at the local and metropolitan level is quite complex, and successful advance planning may seem excessively difficult (Marchau *et al.,* 2018).

Some authors have provided policy recommendations for local governments, in terms of transport and land use policies that cities and regions could implement in the short and medium term to guide the transition to AVs in their local environments in the long term (see, for example, González-González *et al.,* 2018; Guerra and Morris, 2018; Papa and Ferreira, 2018). Most of these policies can be considered as "no regret" policies; indeed, they contribute to increase the sustainability of present mobility systems and, at the same time, their short and medium term effects could be useful to prevent negative AV impacts on the longer term. In some respects, these recommendations are quite general. Backcasting and visioning can offer useful insights for implementing them in a specific local context.

Backcasting is acknowledged as a suitable method to deal with the future by setting normative visions (Banister and Hickman, 2013; Tuominen *et al.,* 2014; Vergragt and Quist, 2011). While forecasting investigates probable and possible futures, backcasting goes the other way, from future to present. It identifies desirable futures and goals, and then defines policy pathways to achieve them.

Backcasting is normally structured in three phases (Soria-Lara and Banister, 2017): visioning, in which the baselines of business as usual and alternative visions of desirable transport futures are set; policy packaging, which elaborates a set of policy measures and the pathways to steer development towards the desired result; and appraisal, through which the impacts of the policy pathways are assessed against a set of criteria (environmental, social and economic impacts, as well as feasibility and acceptability, etc.). Moreover, the backcasting methodology can be combined with participative tools, i.e. focus groups, workshops and interviews, in order to provide external stakeholder inputs (Carlsson-Kanyama et al., 2008; Svenfelt et al., 2011)

Defining the visions that will be subject to policy packaging and appraisal is therefore a crucial step. Several authors developed visions for AV development, with various focuses and methodologies, and the literature on visioning for AVs is rapidly growing. However, nearly all these visions are a-spatial, meaning they do not refer their envisaged AVs development to the space in which they will be circulating and parking. Parkin *et al.* (2017) propose four visions that are somehow spatialized, as they are referred to the space in which they will be allowed to circulate: segregated network for AVs, AVs only on main network mixed with human-driven cars, urban network, shared space. Nevertheless, also in this case, space is considered mainly as a container, and the focus is on the interaction of AVs with other users.

3. A visioning exercise

3.1 Aims and methods

This paper presents a visioning exercise that introduces a spatial dimension in the prefiguration of future AV visions to be used in backcasting, namely with reference to the Italian city of Turin. The proposed visions are "spatial" as they consider how circulation and parking of AVs could be differently regulated in various parts of the city.

At first a brainstorming exercise was carried out by the research team to define possible future visions, all referred to a long term horizon when all circulating vehicles will be fully connected, autonomous (SEA level 5) and electric. Based on the authors' own analytical thinking, this first phase led to the elaboration of three visions, characterised by different regulations in terms of AV circulation and parking.

In a second phase, seven local experts and practitioners in the transport field, ranging from politicians to managers and technicians, were invited to discuss and assess these three visions in a focus group. More in detail, these experts represented the main institutions and companies which are in charge of transport planning, managing and operating in the area of Turin:

- the Transport Department of the City of Turin;
- the Land use and transport Department of the Metropolitan Area of Turin;
- AMP – Agenzia della Mobilità Piemontese, the public transport Authority of Piedmont (the Italian region where Turin is located);
- 5T – Tecnologie Telematiche Trasporti Traffico Torino, a public company providing info-mobility and Intelligent Transport Systems for the whole Piedmont region;
- GTT – Gruppo Torinese Trasporti, the main public transport company operating in Piedmont region;
- Blue Torino, a full electric car-sharing provider operating in Turin since October 2016;
- Bike Pride, a local association focused on sustainable (in particular non-motorised) mobility.

The focus group was articulated in two steps. First of all, the three visions were presented to the participants, who were asked to fill in a questionnaire to assess (on a 1-10 scale) their "plausibility" and "sustainability" with specific reference to fourteen issues. An open discussion followed, aimed on the one hand at exploring possible further aspects not included in the visions, and on the other hand at investigating participants' concerns about how AVs will integrate (or replace) other modes of transport.

3.2 Case study

Turin – the fourth most populated Italian city (about 886,000 inhabitants in the city, 2.3 millions in the NUTS-3 province), located in the North-Western part of the country– was chosen as a case study, for several reasons.

Turin is heavily car-dependent. It has one of the highest car ownership rates in Europe (639 cars / 1.000 inhabitants), and the modal share of private motorised mobility is quite significant (39%) (source: EMTA Barometer 2015, Istat). Car circulation is poorly moderated; only one restricted traffic zone, covering 2% of the municipal surface, and few small 30 km/h zones are active. Public transport (one metro, 8 tramway and about 100 bus lines) and the cycle network (nearly 200 km of cycle lanes and paths) are underused; their respective modal share are 24.3% and 3%. In the case of a mere transition from human- to self-driving cars, prospective negative impacts of AVs can then be particular significant in this city.

In 2018 the Public administration of the city launched a pilot project for testing AVs, initially in a closed, "simulated" urban area, and at a later stage on a 35-km route along the real road network. This street test is mainly aimed at placing Turin at the forefront of the transition to AVs, thanks to its economic specialization in the automotive and ICT sectors.

The Sustainable Urban Mobility Plan (hereinafter, SUMP) adopted by the city in 2010, is now at the end of its 10-year period of validity, and the elaboration of the next plan is starting. So, this is a right moment for the city to assess if and which short and medium term measures can be integrated in the new SUMP to try to steer the transition to AVs.

3.3 The three spatial visions

The three spatial visions were identified and articulated by the authors with reference to fourteen themes and sub-themes, namely:

1. road hierarchy, based on articulation into main roads (1.1) and local roads (1.2);
2. limitation to vehicle circulation;
3. parking areas, with specific focuses on street parking and areas to pick up/drop off the passengers (3.1), multilevel parking (3.2) and intermodal parking (3.3);
4. local public transport, with specific focuses on main lines (4.1), feeder capillary network (4.2) and reserved lanes (4.3);
5. sharing mobility, differentiated between motorised services (5.1) and non-motorised ones (bike-sharing, 5.2);
6. pedestrian areas;
7. bicycle facilities;
8. modal split.

Vision 1, called "Business As Usual" (BAU), is typified as the result of a sort of inertial interpolation of the transport policies set by the current SUMP of the city, which pursues a sustainable mobility, encouraging the use of public transport and soft modes and moderately deterring the use of private cars. In this vision, no tailored policy to assist and regulate the transition from human to autonomous driving has been implemented, so the conversion occurred in a rather inertial way. Road hierarchy is the result of the current revision process of speed limits: 50 km/h for main roads, 30 km/h for local roads. Vehicle circulation is banned in few restricted traffic zones. As regards car parks, they are partially transferred from roads to new intermodal and multilevel parking areas; the freed road space is devoted to AV circulation and ad hoc platforms to facilitate AVs' passengers getting on and off the vehicles. The public transport supply is articulated in main lines and a feeder capillary network; reserved lanes are provided for main lines. Sharing (both motorised and non-motorised) mobility is provided by multiple companies. Some new pedestrian areas are added to the existing ones. As regards bicycle facilities, the vision complies with that of the current Bike Plan (adopted in Turin in 2013), which pursues the completion of ten radial and four circular cycle paths. The deployment of the BAU vision is assumed to lead to a modal split in which the use of private and shared motorised transport and of the bike will increase, the use of public transport will slightly decrease, while pedestrian mobility will consistently decrease as a consequence of the use of AVs for door-to-door trips.

Whereas Vision 1 continues the regulation approach currently adopted by the city of Turin, Visions 2 and 3 take this approach to two opposites.

Vision 2, called "Strong deregulation", is based on a widespread liberalisation in the name of a complete confidence in the great outcomes of technological development; it assumes that AVs will enhance road safety, solve congestion problems, decrease the levels of air and noise pollution. In this vision, any speed limit is removed; AVs are able to circulate everywhere in the road network, with the exception of few pedestrian areas. Parking is possible only in ad hoc multilevel buildings, homogeneously distributed in some areas along the road network and in intermodal parking areas located at the termini of the public transport lines; on-road parking is completely removed and the freed space is devoted to AV circulation and ad hoc platforms to facilitate AVs' passengers getting on and off. The public transport network is reduced to the metropolitan railway service and the metro line 1; all surface public transport is dismantled (as considered not competitive with respect to AVs) freeing up additional space for AV circulation. Sharing mobility services are enhanced. Pedestrian areas are only kept in the historical city centre and overruled in the rest of the city. Also cycle paths are removed, reserving the saved space to AV circulation. As a result, in Vision 2 the modal split will entail a great increase of private motorised transport and a slight increase of car-sharing; the use of both public transport and soft modes will decrease.

Opposite to the “Strong deregulation” is Vision 3, called “Strong regulation”, which is characterised by a robust regulatory approach; strict policies concerning AV circulation and parking are planned to take advantage of AV benefits and limit their negative impacts. The road network is more distinctly hierarchized in main roads (having a speed limit of 50 km/h) and local roads, whose speed limit does not exceed 20 km/h. The meshes of the main road network are sort of “home zones”; inside each of these zones, every road is classified as local and only shared AVs or AVs belonging to the residents in the zone are allowed to circulate. Street parking are completely removed and the saved space is devoted to non-motorised transport; multilevel parking are built around each home zone, both for residents and visitors, and intermodal parking areas are realised at the termini of public transport lines. As regards public transport, streetcars run on reserved lanes on all the main roads; transport systems with exclusive right of way (metro and metropolitan railway service) are reinforced, whereas current bus services are banned within the home zones and replaced in the largest zones by autonomous shuttles. Sharing mobility is strongly encouraged, to the detriment of privately owned AVs. Bike-sharing services are enhanced as well. Furthermore, pedestrian facilities are improved and shared spaces having walking priority are systematically extended within all home zones. Cycle lanes are present on all main roads and bikers are allowed to freely ride on the local roads inside the home zones. As a likely outcome of the strict regulation lying behind the transport policies in Vision 3, the modal split will entail a consistent increase of all modes alternative to privately owned AVs, the latter being strongly hindered, whereas use of car sharing services will be boosted. The use of public transport and bike will slightly increase, and walking will record a more consistent growth thanks to the shared spaces in the home zones.

4. Discussion

4.1 Sustainability vs. plausibility of the three visions

Participants to the focus group were asked to evaluate and validate through the questionnaire the three proposed visions, with respect to their plausibility and sustainability, and to express possible concerns or changes to be made to each of them.

Overall, the three visions were validated, as no significant changes were proposed by the participants to any of them.

As regards plausibility, the overall average of the scores assigned in the questionnaire by all participants to each of the 14 themes and sub-themes shows that Vision 1 is - not surprisingly – the most plausible. It gets an average score of 7 out of 10, and it records the highest values for all the 14 sub-themes, except for traffic restrictions. Visions 2 and 3 were assessed almost equally plausible in terms of average score (respectively 5.5 and 5.3), but they perform very differently in relation to the sub-themes; Vision 2 is generally considered more plausible than the third concerning regulation of AV circulation and parking, and vice versa as regards the relation with public transport and non-motorised mobility.

The results are quite different for sustainability. Vision 3, which was judged the least plausible, is considered as the most sustainable; it scores 7.6 out of 10 on average, and records the highest values for 11 out of 14 subthemes. Vision 1 ranks second, with an average score of 6.2. Finally, Vision 2 is deemed as the least sustainable, with a low score both in overall average terms (4.4) and specifically for subthemes related to public transport and non-motorised mobility.

4.2 Key issues for policies

The elaboration of the three spatial visions and their discussion in the focus group let emerge some key issues for AV regulation that are not yet deeply investigated in the scientific literature, but are crucial to short and medium term policy making.

Circulation

A first issue concerns how private AVs are allowed to circulate in the road network, in particular in light of their feared impact on modal split (less use of public transport, less active mobility). Should they be let free to move on the entire road network, as in Vision 2? Or should their circulation be free only in a portion of the network (e.g., the main roads), and discouraged in the rest of the network, such as the secondary roads inside home zones? In this second case, different levers could be used to deter private AVs from entering these zones. The first one is differentiating speed limits, e.g. 50 km/h in the main roads and 30 or 20 km/h in secondary roads. Another possibility is to completely forbid privately owned AVs to access the secondary roads inside home zones (except the zone in which the owner of the AV resides), as in Vision 3. In this case, AVs could reach the border of the area in which the destination of the trip is located, but the final link in the travel chain should be made by foot, bike sharing etc.

The above-mentioned regulations could be used also to promote a transition from ownership to sharing, which is often identified in the scientific literature as a key factor to reduce potential negative impacts of AVs. Vision 3 for example applies restrictions to circulation only to private AVs and not to shared AVs, which are let free to enter secondary roads. As highlighted in the focus group, Vision 3 could also favour community car sharing services, organised just at the home zone level.

Parking

One of the potential impacts of AVs on the city, that is often cited in the literature, is the reduction of parking need. This reduction will concern the absolute number of car parks (if AVs will be most shared) and, in particular, the number of parks on roads, as AVs will be able to drop off the passengers at their destination and then travel empty to reach the nearest vacant parking space. The possibility of freeing up space on roads by gathering parking in dedicated structures (multilevel parking) raises questions on the location of these structures and the maximum distance that AVs should be allowed to travel empty to reach a parking. This question can be relevant in the short and medium term, as vacant lots in dense central urban areas are generally rare: should they be used for new residential or tertiary buildings, or for multilevel parking so to begin to reduce parking on road?

Finally, if parking on street will be removed, areas for picking up/dropping off passengers will probably be necessary: how many areas for each block and where to locate them will be issues for urban planning and design.

Multimodality

One key issue about AVs is how to avoid they increase their modal share to the detriment of non-motorised mobility (and its health benefits), also because they will make unnecessary even the short trips on foot from origin to parking, and from parking to destination. At the same time, as highlighted in the previous sections, AVs will probably allow to reduce car parks on road; this freed up space could be dedicated to pedestrians and cyclists. Vision 3 tries to combine these two issues: it forbids privately owned AVs from entering home zones, where all local roads are re-designed as shared space (without parking) having priority for pedestrians and cyclists; in this way, drivers should be fostered to walk or bike to their final destination.

As regard public transport, diffusion of AVs questions its spatial organisation. Will a hierarchical structure, based on main underground and tram lines and secondary feeder bus lines, still work? Or could feeder buses be replaced by shared AVs, robot-cabs and so on? This perspective is particularly relevant for a city like Turin, which – due to financial constraints – is now restructuring its public transport supply, and is deciding whether to linearly cut frequencies of all lines or to boost main lines to the detriment of secondary feeder buses.

Concluding remarks

The elaboration and discussion of the three visions for the city of Turin has shown that the spatial approaches in regulating AV circulation and parking are likely to play an important role to govern the impacts of AVs on the city. As just one case study has been considered, any claim to exhaustiveness and systematicity must be excluded. However, most of the emerged issues are not specific to Turin, but concern transport and urban factors that are relevant in every urban context, such as road hierarchy, speed limits, restrictions to circulation, parking location, multimodal integration, home zones and shared spaces.

The visions are currently being evaluated by 50 interviewees through in-depth interviews, and the one that will result the most preferable (as a combination of its sustainability and its plausibility) will be the objective for the backcasting exercise. At the same time, using such spatial visions, that expressly address the use of urban roads and public space, in participative exercises, can help to identify which measures could be adopted in the short and medium term. The involvement of different stakeholder can be useful to emphasize the possible strategies that the Public Administration should undertake in order to address the AV transition. This can be particularly important for cities (such as Turin) that are elaborating their SUMPs; indeed, these plans generally cover a time horizon of at least ten years, which is a plausible time-horizon to expect an initial appearance of AVs.

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