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The urban governance of autonomous vehicles – In love with AVs or critical sustainability risks to future mobility transitions

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ABSTRACT

Increasingly guided by the use of ICT, the flow of humans and materials, smart cities and autonomous mobility amalgamate into a game changer in urban planning. This paper critically explores the role of autonomous (driverless) vehicles in plans for urban futures. By looking into the urban plans of 10 European capitals, we investigate the anticipated promises and hazards of autonomous vehicles. Theoretically, the paper draws upon critical urban mobilities studies that invite interlinking carbon reduction, smart cities and mobility planning. By examining these plans, the paper critically evaluates current urban planning for autonomous vehicles by asking whether one can identify any links to the United Nations Sustainable Development Goals of sustainable cities and communities. A practice-based view on automation is then suggested as a pathway to promote a thorough sustainable mobility transition. It is concluded that none of the plans of the 10 capitals studied require AVs to integrate with public means of transport or to be fuelled by renewable energy sources. Hence, AVs are likely to individualise and intensify the existing automobility regime further and emissions are likely to increase, according to the comparative urban analysis. We therefore conclude that urban policy-making needs to contest the existing techno-centric conception of autonomous vehicles if these are to support the sustainable development goals of cities.

1. Introduction: AV planning and the new mobility paradigm

As hopeful as autonomous vehicles may appear, the material turn in mobilities research (Sheller, 2020) reminds us that techno-fixes have not been able to solve the socio-ecological challenges of modern society. Despite significant development in car technologies, cars still stand as a major contributor to CO_2 emissions. Of the total consumption of petroleum products in the EU (Todts et al., 2018), the transport sector consumed 66%, and it continues to increase approximately 2% per year. Although cars have become more energy efficient over the course of the past four decades, net demand has increased 48% since 1985 in the EU alone (Freudendal-Pedersen et al., 2020).

Road transport accounts for approximately one fifth of carbon emissions (Heinold & Meisel, 2018). Current automobility regimes host a car fleet of more than 1.3 billion globally and rising. Across Europe, road transport accounts for 85% of all transport activities (Canzler & Knie, 2016) and continues to grow, both on a national and on an urban scale. Apart from Latvia and Lithuania, car ownership has grown in all European countries by 40 million cars between 2009 and 2018 (Eurostat, 2020). At city level, car ownership continues to increase in many cities at the expense of public transport and other sustainable modes of transport such as walking and cycling (Statistics Denmark, 2019; Statistics Sweden, 2018).[1] But even more salient, the heavy reliance on private vehicles for commuting has not only increased carbon emissions, environmental pollution, harm to health (Crayton & Meier, 2017), congestion and noise, but also besieged urban space (Freudendal-Pedersen et al., 2019). The autonomous car alone will not change this development.

Instead, the new mobility paradigm argues for a crucial need to rethink urban transport and focus on the interconnection between different modes, for instance by moving from ownership to access (Kesselring et al., 2020; Spurling & McMeekin, 2014). This move has

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[1] Overall transport and car ownership, whether EVs or combustion cars, continue to grow (e.g. Statistics Norway, 2019).

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been termed 'Mobility-as-a-Service' (MaaS). In recent years, it has influenced the international policy agenda based on the anticipation of transforming the current resource-intensive, privately owned and car-based transport system into a collaborative, connected and autonomous mobility system (Bissell et al., 2018; Liu et al., 2020). One of the ambitious visions around AVs as part of a MaaS system is to decarbonise the current transport system (Aapaoja et al., 2017; Jittrapirom et al., 2017; Reardon, 2020; Venturini et al., 2019) but concrete initiatives and interventions to implement this are still limited (Agriesti et al., 2020; González-González et al., 2019; Lyons et al., 2019; Porter et al., 2018).

The anticipated potentials and challenges of AVs have long been debated (Acheampong et al., 2018; Agriesti et al., 2020; Brovarone et al., 2021; Nogués et al., 2020; Porter et al., 2018). The urban plans investigated in this article view AVs as a game-changing technology for future city planning (Cugurullo, 2020; Duarte & Ratti, 2018; González-González et al., 2019; Porter et al., 2018). As the City of Amsterdam notes: 'the question is not whether they [AVs] will be a reality, but when. (…) If every vehicle is completely self-driving and is available on call, this will change the entire mobility system' (Appendix 1: City of Amsterdam, 2016, p. 20). And as Porter et al. (2018, p. 755) note, 'amid the uncertainty of what AV will really hold for our towns and cities, the reality of a revolution around the corner is clear.' Others, however, are questioning whether AVs are ever going to be integrated as part of urban mobilities due to the barriers of incorporating them into the 'messiness' of urban mobilities (Freudendal-Pedersen et al., 2019).

Either way, the uncertainty about whether driverless vehicles can come to reproduce and accelerate the existing automobility regime or produce new trajectories towards sustainable mobility remains contingent on the urban governance of mobilities systems (Brovarone et al., 2021; Davis, 2018; Fraedrich et al., 2019; González-González et al., 2019; Nogués et al., 2020; Reardon, 2020; Venturini et al., 2019). As Davis (2018) and Reardon (2018) argue, planners need to open up a dialogue not so much about AVs, but about the towns and cities we want. Consequently, Fraedrich et al. (2019, p. 162) note that there is 'a demand for studies that demonstrate how AV can respond to more fundamental challenges and goals that city planner's [sic] face' and Curtis et al. (2019) argue that there is an urgent need to further explore the urban plans of AVs. This paper addresses this discussion by examining the current urban plans for autonomous vehicles (AVs) across 10 European capitals.

The paper is structured in five sections. Section 2 presents the entry point to ascertain city planning documents. Section 3 provides a review of the urban planning AV and policy frameworks that encounter different AV planning framings, their uncertain effects, opportunities, threats and practical consequences. Section 4 presents the results of the synthesis of AV planning across 10 European cities. Section 5 uses the concepts from practice research: recrafting, sequencing and changing in relation to United Nations Sustainable Development Goal 11 on sustainable cities and communities to discuss whether the cities surveyed are moving their present primary technocratic focus on the AV transport planning domain towards a more holistic understanding of city planning and of future mobility practices.

2. Method to ascertain city planning and governance of AVs

This paper builds on a literature review[2] on the urban governance and planning visions of AVs and a comparative document analysis of 39 planning documents across 10 European capitals.[3] As mobility and transport planning documents are often fragmented, interlinked and cross-sectoral, we begin not from bounded planning entities but 'vantage points' where critical document analysis can shed light on intersectional processes, planning dilemmas, planning policy framings and practices (Freudendal-Pedersen & Kesselring, 2017). Although mobility and transport plans are the most comprehensive documents that potentially govern AVs on a city scale, the conjunctural approach invites cross-sectoral understanding whereby smart city plans, climate plans, business development plans, etc. are also included. As such, our interest is not in comparative urbanism of AVs per se; rather, it is oriented around specific processes, dilemmas and framings that both materialise in and are constituted by specific cities. From this perspective, we understand cities as nodes that both respond to and produce practice framings, specific processes, and outcomes (Spurling & McMeekin, 2014).

Drawing from Haustein and Nielsen's (2016) brief screening of the EU's 28 capitals' urban planning documents, 10 capital cities were selected for detailed analysis (see Table 2). The basis for selection was the extent to which the screening indicated that these cities put forward more than just a conventional techno-centric predict-and-provide approach, focusing on the car. Instead, city plans with different backcasting scenarios or visions indicating desired planning goals for a mixed use of mobilities (walking, cycling, public transport, etc.) together with AV implementation were chosen (Rupprecht et al., 2019). This screening was inspired by Flash Eurobarometer 31 (Haustein & Nielsen, 2016, p. 174). Furthermore, the planning documents needed to be publicly available and in English.

To map and analyse planning documents, we used three parameters: recrafting, sequencing and changing, inspired by the mobilities paradigm (Sheller & Urry, 2006) and practice research, especially Spurling and McMeekin (2014). Through these three parameters we translated planning visions and scenarios into policy framings of recrafting, sequencing and changing how mobilities practices interlock. The rows in Table 1 forms the analytical framework of AV governance whereas the colums subdivides the SDG 11 on cities, applicable to the nine core values and goals of future cities identified by González-González et al. (2019). This allows a conjunctural analysis of existing planning and mobility practice intervention, and the extent to which it aligns with or divides from four backcasting scenarios (Agriesti et al., 2020; González-González et al., 2019; Nogués et al., 2020). As can be seen from Table 1, recrafting policy interventions in parameter 1 partly align the unlimited individualistic city with the hyper-mobile city scenario. Parameter 2 on sequencing draws from the restricted individualised city. Parameter 3 on scenarios that change how mobility practices interlock corresponds to images of the liveable and shared city (see also González-González et al., 2019). Finally we score anticipated positive and negative externalities primarily on private or shared AV uptake.

As can be seen from Table 1, the different themes of SDG 11 form

[2] The literature review consists of an abstract search in Science Direct, Scopus and Google Scholar. The abstract search in Science Direct produced 9 results and combined the following key words: ("AV" OR "autonomous vehicles" OR "driverless vehicles" OR "automated vehicles") AND ("urban governance" OR "urban planning" OR "city planning" OR"mobility planning"). The abstract search in Scopus produced 10 results following the same method. A broader search including Google Scholar on "autonomous vehicles" "new mobility paradigm" produced 57 papers, none of which surveys the urban planning of AVs across cities. The literature review was inspired by Wee and Banister (2016).

[3] The 39 urban planning documents are so-called 'soft laws' (declarations of intent) that are not legally binding. Nevertheless, planning documents are the most concrete documents on a city scale, which direct future framings.

Table 1
Data collection tool and the new mobility parameters.

SDG	Public transport (SDG 11.2)	Liveable city and transport mix (SDG 11.3)	Sustainable urbanisation (SDG 11.3)	Environmental/climate impact (SDG 11.6/SDG 11.9)	Urban/rural transport links (SDG 11.8)
Parameter 1 – Recrafting scenarios	Replace buses with more efficient autonomous buses/ trams etc.	Transport mix between soft mobility public transport and cars remains unaffected by AV governance	Replace existing cars with AVs and favour AV infrastructures to ensure more efficient land use, parking, etc.	Require AVs to be fuelled by renewable energy	Faster transport connections and corridors via AVs
Parameter 2 – Sequencing scenarios	Increase travel by public transport over other modes of transport. Allow AVs for public transport only	City planning favours soft mobility and sets sequencing AV frameworks to regulate transport mix	Manage AVs to reduce overall number of cars, car ownership, congestion, trips (AV lanes and/or barriers)	Carbon standards produce policy frameworks of ownership, smart modal shifts and MaaS	Smart modal shifts, differentiation between AV high- and low-speed networks
Parameter 3 – Change how practices interlock	Only allow AVs if shared mobility, MaaS solutions integrated into public transport. AVs feed passengers into the public transport network	Transport mix favours the vulnerable, elderly, disabled, etc. via AV policy frameworks mobility (standards for access)	AV policy intervention favours MaaS and shared mobility with fewer modal shifts, fewer trips over shorter distances	AV policy framing regulates the need for mobility and AVs in securing maximum CO_2 reduction	AV policy intervention: fewer modal shifts, fewer trips over shorter distances, but mainly for inner urban connections rather than greater suburban links
Policy framing scenarios of positive/ negative AV externalities stated in the plans	AV policy intervention implies growth/reduction in overall transport and public means of transport	AV policy intervention implies growth/reduction in soft mobility, modal shifts, number of trips, distance per trip	AV policy intervention implies growth/reduction in travel time, congestion, etc.	AV policy intervention implies growth/reduction in CO_2 emissions.	AV policy intervention favours long-distance travel over short-distance AV connections, e.g. connection to mobility hub

categories in which the planning document analysis identifies specific arguments for a given AV policy intervention.

Second, it shows if the implementation of AV is to be organised as individualised, semi- or quasi-shared or fully intermodal interventions. Thus, policy framings around car ownership, quasi-private, shared and MaaS solutions translate into categories of how AVs are thought of in relation to recrafting, sequencing and changing mobility practices.

Third, the categorisation criteria involve policy framings of non-motorised mobility combined with motorised mobilities (whether AVs or not) to examine policy framings around mobility mixes.

Fourth, the categorisation employed in Table 1 includes modal shifts, number of trips and policy framings of access to AV mobility including disabled or vulnerable groups, and organisational framings. These constitute the AV planning parameters under which the 39 planning documents of the 10 cities were categorised.

The categorisation criteria consider planning and policy interventions with regard to AVs in the selected climate, smart cities and transport planning documents (Appendix 1), regardless of the stages of advancement in the planning of AV and/or MaaS solutions. This goes for the spatio-temporal outcome (modal shifts, distance, number of trips) and climate impact, as well as anticipated positive and negative externalities as indicated in planning documents. Externalities, whether positive or negative, are context-specific and may vary considerably from city to city. In the following we review AV planning, focusing particularly on planning uncertainties, planning dilemmas, visions and risks.

3. Review of AV planning and the new mobilities paradigm

Research on AVs and city planning covers a vast spectrum of topics including backcasting scenarios (Brovarone et al., 2021;González-González et al., 2019; Nogués et al., 2020), planning ethics and transport responsibilities (Baumann et al., 2019; Borenstein et al., 2019; Sparrow & Howard, 2017), routing systems, among others, for shared mobility planning or MaaS (Agriesti et al., 2020; Liu et al., 2020; Reardon, 2020; Venturini et al., 2019). Other studies on transport justice (Bissell et al., 2018; Mladenović, 2019) anticipated impacts on environmental and urban sustainable transport (Aapaoja et al., 2017; González-González et al., 2020; Heard et al., 2018; Jittrapirom et al., 2017; Nogués et al., 2020), land use patterns and modelled or backcasting scenarios on urban spatial structures (Agriesti et al., 2020; Cavoli et al., 2017; Gyergyay et al., 2019; Legacy et al., 2019; Smolnicki & Sołtys, 2016), the discrepancy between planning authorities at different governmental levels (Davis, 2018; Fagnant & Kockelman, 2015; Fraedrich et al., 2019), travel behaviour and artificial modelling (Acheampong & Cugurullo, 2019; Inder et al., 2019) and more. Following Wee and Banister (2016), while conducting the literature review we came across a total of 57 articles, most of which seem aligned with guidelines for sustainable mobility planning (Rupprecht et al., 2019). Relatively few studies related to the new mobilities paradigm.

González-González et al. (2019) and Nogués et al. (2020) studied backcasting approaches to investigate how the potential positive and negative consequences of AV implementation may help urban policy decision-makers to subordinate considerable AV uncertainties in supporting urban development policy goals (González-González et al., 2019; Nogués et al., 2020). Venturini et al. (2019) and Reardon (2020) studied AV and MaaS solutions in a climate context. Although they stress uncertainty about carbon effects, they found that MaaS solutions and shared automation potentially have significant decarbonisation impacts, depending, however, upon the actual planning and policy scenarios. By contrast, Kent (2018) finds that AVs will lead to increased car ownership and increased road traffic, whereby automating private motorised travel appears not to match municipal planning perspectives (Fraedrich et al., 2019; Nogués et al., 2020). Reardon (2018) and Porter et al. (2018) ask what good planning and governance are and call for critical analysis of what is 'sold' to politicians in terms of (green) growth, sustainability or related and discursively negotiated benefits. Within this context, Stone et al. (2018), Fraedrich et al. (2019) and Curtis et al. (2019) find that planning issues and the importance of AV planning are currently underplayed. Cohen et al. (2018) study stakeholder workshops on planning for AVs in the UK. They conclude that there is an urgent need for public planning debate and find that 'the possibilities of self-driving cars suggest the need for a more active form of governance for responsible innovation' (Cohen et al., 2018, p. 257). Likewise, Cugurullo (2020) finds the autonomous city is a city where autonomous cars, robots and city brains are increasingly envisioning non-human actors in the city performing particular politics on its own. Against this, Wood and Flinders (2014) suggest that the urban planning of AVs has been discursively depoliticised, with little public debate. In a similar vein, Fishman et al. (2018) calls for government action, as no action due to the great uncertainty about causes and consequences may lead to planning inaction, as González-González et al. (2019) note. Davis's (2018) case study of San Francisco and Stockholm identifies a situation of 'lingo planning'. Lingo planning of AVs, she argues, produces dysfunctional planning and a 'collective action problem' as smart technology actors achieve their own singular priorities over coordinated planning. Similarly, Fagnant and Kockelman (2015) study the preparation for AVs in the US, its policies, problems and potentials. While AVs, they suggest, may lead to safer roads and reduced parking, the forecast is that overall traffic demand will increase. They suggest that planning at state and city level, rather than nationally, is inconsistent with addressing such challenges. Moreover, lack of data privacy for personal travel is worrying. Mladenović's (2019) study of AV planning in Helsinki focuses on the potential society-wide disruption, as well as the redistribution of benefits and burdens. Despite fruitful planning efforts based on modelling and forecasting, the understanding of AVs as a socio-technical phenomenon remains unresolved. He suggests that a participatory expansion of planning processes is essential to supplement existing modelling approaches, as they cannot be disentangled due to the uncertain nature of AVs. Consequently, González-González et al. (2019, 2020) – the latter published in this journal – points to AV backcasting scenarios as a means for urban planning decision-makers. Insofar as planning conflicts and conflicting estimates and opinions may lead to planning inaction, she calls for strategic urban planning, through which backcasting scenarios may accommodate productive decision-making tools. As Davis (2018) and Reardon (2018) argue, planners need to open up a dialogue not so much about AVs, but about the towns and cities we want. Consequently, Curtis et al. (2019) argue that there is an urgent need to further explore the urban planning of AVs. While planning is discussed in various case studies (Davis, 2018; Fagnant & Kockelman, 2015; Fraedrich et al., 2019; Mladenović, 2019), as is the need for strategic planning and scenario tools (González-González et al., 2020), we found no studies examining planning documents across city levels and planning documents' subordination of anticipated opportunities and risks, urban integration, its planning principles, urban visions or dilemmas. In what follows, we look at AVs across 10 European capitals in connection with the new mobility paradigm. In particular, we examine whether and to what extent current urban planning documents integrate AVs with public transport and MaaS solutions.

4. Result: synthesis of AV planning across 10 European cities

The 39 climate, smart city and transport planning reports (see Appendix 1) in the 10 capital cities surveyed demonstrate different stages and levels of advancement in relation to the integration of AVs. Whereas half the cities reflect nothing on AVs in either transport plans or in climate and smart city plans, two cities mention AVs in one sentence (Stockholm, Helsinki), but have extensive policy framings of transport mix and shared mobility. A summary of the data collected is presented in Table 2. This table shows how planning provisions and planning goals for AVs are still rather limited.

Three cities (London, Amsterdam and Copenhagen) contain brief analyses and policy scenarios on the planning and implementation of AVs in the city. They stress the importance of AV planning due to the potential positive and negative effects and highlight the importance of planning so that AVs support the overall city goals. No standards, visions or planning goals, however, are set particularly for AVs either in London, Amsterdam or Copenhagen, or across the cities surveyed. Results demonstrate that none of the planning documents across the 10 cities set standards that require AVs to fulfil urban goals. The plans do not set AV standards and goals for a certain level of transport mix and number of vehicles, as is the case with the combustion car, standards or goals that ensure integration with public means of transport, or sharing standards, nor do they require AVs to be fuelled by renewable energy sources, as is the case for electric vehicles and combustion cars. The lack of standards and AV goals seems to support Kent's (2018) finding on increased traffic and Davis's (2018) findings of 'lingo planning'. Similarly, the planning document analysis finds that the lack of AV standards and goals is consistent with González-González et al.'s (2019) planning inaction. AVs are likely to individualise and accelerate the existing automobility regime and emissions are likely to increase, the current level of planning suggests when exposed to backcasting scenarios from the review. The uncertain nature of AVs, however, should not limit cities to developing planning standards, which seem a necessity if AVs are to support the sustainable development goals of cities. In the following, results from the document analysis are presented through the three 'vantage points': urban visions, planning dilemmas and practice.

5. Analysis: recrafting, sequencing, and interlocking practices of AV planning

5.1. Urban visions

First of all, the review shows that AVs in general are expected to be a successful technology to accommodate sustainable mobility transition in cities. Five capital cities have planning documents that address AVs (Helsinki, Stockholm, London, Copenhagen and Amsterdam), signalling urban futures with AVs. Data collected during the study illustrates that planning of AVs is still at an early stage, with remarkably few concrete plans and little outlining of AV goals and scenarios. While London, Amsterdam and Copenhagen reflect urban planning principles, no transport plan or equivalent regulatory planning framework requires AVs to be fuelled by renewables, integrated with MaaS and public transport systems, or to meet similar conditions. Thus, recrafting scenarios (parameter 1) seem prioritised in most planning strategies, whereby combustion cars are replaced with AVs.

While most of the 10 cities surveyed state the importance of increasing public transport as the overall means of transport in the mobility planning documents, e.g. to support cities' goal of sustainability, the bundle of mobility provisions does not seem to require the bundling of mobility practice interventions in subsequent planning documents, apart from four cities (Helsinki, London, Stockholm and

Table 2
AV policy interventions in climate change, smart city and transport planning documents.

City	Analytical problem framings				
	Do the Climate, Smart City and/or Transport Plans mention AVs?	Does the city require AVs to be fuelled by renewables?	Do planning documents require AVs to integrate with means of public transport?	Fewer modal shifts, shorter distances, fewer trips. Do AVs support MaaS and shared mobility?	Appendix 1: References in planning documents
Amsterdam	Yes	No	No	Brief description	1–3
Berlin	No	No	No	No	4–8
Copenhagen	Yes	No	No	Brief description	9–15
Helsinki	Yes	No	No	Minor description	16–18
London	Yes	No	No	Extensive description	19–23
Rome	No	No	No	No	24
Stockholm	Yes	No	No	Little description	25–29
Tallinn	No	No	No	No	30–34
Vilnius	No	No	No	No	35–36
Warsaw	No	No	No	No	37–39

Amsterdam) which link but do not strictly require AVs to integrate with MaaS and public transport. Thus González-González et al.'s (2020) and Liu et al.'s (2020) shared and autonomous mobility scenarios (parameter 3) seem out of range, apart from London and Helsinki that mention AVs with possible shared futures. Considering the lofty visions, the limited considerations of more concrete design and the role of AV-aligned interventions can be characterised as empty hype, much in line with Davis's (2018) point about 'lingo planning'. While the above cities, Berlin, Stockholm and Copenhagen included, promote visions and goals that strengthen mobility on foot, by bicycle and by public transport, the uncertain nature of AVs makes planning dilemmas more likely.

5.2. Planning dilemmas

In several planning documents (e.g. Copenhagen, London and Stockholm), the relation between AVs and public transport represents a planning dilemma. Model predictions of future AV transport, for instance, represent a paradox in that projections foresee a mobility shift away from public transport towards AVs (recrafting scenario), which runs counter to the policy framings set in the planning documents (sequencing and interlocking scenarios). London (Appendix 1: City of London, 2018d, p. 279) and Copenhagen (Appendix 1: City of Copenhagen, 2017a, p. 9) represent cities that raise concerns over such planning dilemmas in terms of health, climate and public transport. By way of illustration, the city of Copenhagen has a transport mix with bicycles approximating 1/3, public transport and walking 1/3 and cars 1/3 of all transport. Much in line with the images of the liveable and shared city (see also González-González et al., 2019), these numbers are part of a long-term planning strategy, and mobility planning aims to raise soft mobility further to reduce emissions, congestion and noise pollution and to increase liveability. Similarly, the Stockholm Action Plan advocates for soft mobility planning as public transport accounts for 66% of all passenger transport, but 5.3% of the total greenhouse gas emissions (Stockholm, Action Plan for Climate and Energy, p. 17). In a similar vein, Brovarone et al. (2021) raise concern over policy framings to steer the transition of AV towards liveability. By contrast, the Danish Road Directorate transport model foresees AVs increasing CO_2 emissions by up to 20% compared with ordinary cars (Appendix 1: City of Copenhagen, 2017a, p. 4). The dilemma is that AVs are expected to increase the length and number of trips per day, as passengers enjoy the comfort of being able to use the time for other purposes. When ordinary cars are replaced with AVs, the City of Copenhagen (Appendix 1: City of Copenhagen, 2017a, p. 4) estimates that traffic will increase by 14% in the city and by 20% on highways. Furthermore, congestion and overall travel time will increase by up to 15% (Appendix 1: City of Copenhagen, 2017b, p. 4). To further complicate matters, the model projection suggests more people will shift from walking, cycling and public transport to an AV mobility service with negative health effects as a result (City of Copenhagen, 2017a, p. 9). The planning document reflects AV recrafting framings. Positive and negative externalities translate into planning dilemmas, much in line with Mladenović's (2019) and Brovarone et al.'s (2021) finding that modelling projections cannot cope with dilemmas.

In the same vein, the London Transport Plan sets out planning dilemmas that are paradoxical to the aims of reducing car traffic. 'In the worst cases, the adoption of new technologies [autonomous vehicles] could increase car dependency and traffic dominance, undermining efforts to increase walking, cycling and public transport levels. If car-sharing services are promoted in the wrong areas, people could switch from cycling or getting the bus. If autonomous vehicles make car use more appealing and easier to do, people may walk around their neighbourhoods less. This would present serious problems for the health of Londoners and the functioning of the city' (Appendix 1: City of London, 2018d, p. 279).

The London plan raises concerns over AVs supportive dynamics to fulfil interlocking scenarios. Insofar as AVs absorb passengers from public transport, they run counter to the aims of the city's traffic plans for reducing car traffic. This sets out a concern around parameter 3 regarding transport mix and aligns with Venturini et al.'s (2019), González-González et al.'s (2019) and Reardon's (2020) scenario framings of AVs and MaaS solutions.

Planning documents also suggest positive net benefits to planning the city scape, e.g. improved mobility, especially for the elderly and those who have no access to cars, reduced land use (km^2/citizen) and increased road safety (Appendix 1: City of Copenhagen, 2017a, p. 4; City of London, 2018d, p. 277). Policy framings also concern parameter 3 in terms of standards of access, as a dilemma for other policy framings and governance aims. Thus, policy framings within these documents are in line with existing AV literature as to the pros and cons of AVs (Acheampong et al., 2018; Fishman et al., 2018).

Whereas positive and negative AV externalities are context-specific and depend on factors such as taxation, urban planning requirements and geography (Brovarone et al., 2021; Fraedrich et al., 2019), AV policy framings suggest they might improve car sharing and MaaS solutions (Stockholm, Helsinki, London and Copenhagen). The Stockholm City Plan, for instance, suggests that 'technological advances are likely to increase the availability of digital and autonomous services for mobility in the form of individually tailored information, greater car sharing and self-driving vehicles' (Appendix 1: City of Stockholm, n.d., p. 82). Potentially high-occupancy services (such as demand-responsive services) may contribute to a shift away from car use, if regulated as MaaS or car-pooling solutions, the London Transport Plan suggests. Nevertheless, the document also stresses planning dilemmas regarding parameter 3 in terms of MaaS integration with public transport: 'Increasing access to car sharing could bring benefits, but these would be outweighed by the impacts on congestion, emissions and health if cheap, convenient car travel is extended to Londoners who do not own a car or do not have a driving licence. Even if technology is able to improve how efficiently cars use road space, connected and autonomous cars will not be as space-efficient as walking, cycling or public transport' (Appendix 1: City of London, 2018d, 285).

The relation between AVs and public transport produces planning dilemmas as AVs are expected to have a number of positive and negative benefits (Acheampong et al., 2018; Agriesti et al., 2020), but AVs and public transport are juxtaposed as no clear recrafting, substitution or interlocking planning advocacies exist and all scenarios appear to be applicable at the same time. This supports Davis's (2018) and González-González et al.'s (2019) concern over dysfunctional planning as unclear governance and regulation opening up the terrain of uncoordinated planning in which each AV actor pushes for their own priorities.

5.3. Practice

The document analysis found that four of the surveyed cities' plans included policy interventions aiming to reduce car ownership (both concrete planning and testing solutions). Four cities – Helsinki, London, Stockholm and Amsterdam – explain their AV visions, and intend to integrate sharing mobility services with public means of transport. The Municipality of Helsinki mentions AVs in one sentence, in relation to public transport and the current MaaS testing with autonomous electric buses (Appendix 1: City of Helsinki; n.d., p. 9). The City of Stockholm mentions AVs as 'Technological advances [that] are likely to increase the availability of digital and automated services for mobility in the form of individually tailored information, greater car sharing and self-driving vehicles' (Appendix 1: City of Stockholm, n.d., p. 82). In the planning principles for new mobility services and technology, the City of London notes:

Car dependency and traffic dominance have many significant impacts on cities and their residents. These range from health impacts – increasing inactivity and road danger; worsening air pollution and noise; and creating severance between people and communities – to congestion. Many new technologies aim to resolve some of these problems – electric vehicles will reduce some types of pollution and autonomous vehicles may reduce road danger – but no car-based approach to transport can solve them all. (Appendix 1: City of London, 2018d, p. 277).

Similarly, the City of Amsterdam relates AVs to MaaS and envisions 'shared and emission-free cars that drive themselves' (Appendix 1: City of Amsterdam, 2016, p. 2) toying with recrafting (parameter 1) in terms of climate solutions and parameter 3 in terms of intermodalities. Also, the City of Copenhagen notes that AVs should meet the urban goals with regard to urban planning, mobility and climate plans. Hence, the municipality takes part in experiments that test AVs 'to ensure they improve mobility conditions; are based on alternative energy sources; and promote public transport and car sharing' (Appendix 1: City of Copenhagen, 2017a, p. 3). This aligns with Reardon's (2018) and Brovarone et al.'s (2021) call to look not to AVs in themselves but to the cities we want and to interlock planning debates into policy visions of future cities. However, no backcasting scenarios or specific goals are set (González-González et al., 2019) and little debate or participatory planning efforts have been achieved apart from public conferences and the reports analysed.

None of the planning documents contain strategic attempts to set policy framings that combine AVs with public means of transport, or organise AVs as public transport, to challenge the existing automobility regime. Yet particularly London and Stockholm explicate policy framings of future mobility mixes and planning for soft mobilities, that in the case of London set guidance that sequences the circumstances under which AV might be allowed. Nevertheless, while there are links to the concept of MaaS (London, Helsinki and Stockholm), no attempts to limit private AV ownership are put forward. This is despite cities like Berlin setting visions for ownership of combustion cars. London, Amsterdam, Copenhagen and Stockholm, for instance, forecast continued growth in car dependency under recrafting policy framings[4]; the documents consider sequencing or even interlocking policy framings if common goals are to be achieved. Nevertheless, while planning documents mix up framings of sequencing discourses, AV ownership prevails and none of the cities explicitly reject AV recrafting framings.

5.4. Recrafting, substituting and changing the interlocking of existing mobility practices

Increasingly, scholars stress that decarbonisation of today's transport sector requires ambitious policy and practice intervention (Freudendal-Pedersen & Kesselring, 2017; Spurling & McMeekin, 2014) as opposed to a continuing focus on solely technical innovation. In parallel with questioning the demand for mobility, the sustainable mobility regime (Banister, 2008) also focuses on the potentials of digitalisation of the transport sector, AVs included. In contrast to solely focusing on low-carbon mobility, for instance, this approach requires a completely new set of planning goals and principles (e.g. Banister, 2008; Spurling & McMeekin, 2014). It is a move away from the conventional approach to transport planning focusing on economic evaluations and forecasting through predict-and-provide. Sustainable mobility planning demands multi-criteria analysis in order to fully assess the impact of new technologies (Kent, 2018; Legacy et al., 2019). The comparative document analysis suggests such efforts are under consideration, particularly regarding climate and MaaS scenario framings (Reardon, 2020; Venturini et al., 2019). According to Banister (2008), such multi-criteria analysis centres around four major areas: new technologies (alternative fuels, intelligent transport systems – ITS), demand management (fuel prices, road pricing), land-use development (integrated planning) and communication measures (campaigns and acceptability) (Banister, 2008). Thus, the planning documents following the new mobility paradigm (Sheller & Urry, 2006) juxtapose planning dilemmas in that AVs can potentially decarbonise the automobility regime (recrafting) but do not reduce the need for mobilities, unless either sequencing or sharing and interlocking framing scenarios are implemented (González-González et al., 2019; Nogués et al., 2020). Stockholm, London, Helsinki, Copenhagen and Amsterdam all display concern over such framings, though only two cases are explicitly linked to AVs and may envision different backcasting scenarios. This is in line with Kester's (2018) findings on AV ownership, though AVs are likely to change norms (Acheampong & Cugurullo, 2019).

If based on the dominant conventional techno-centric predict-and-provide approach in transport planning, AVs (much like in the case of EVs) will most certainly reproduce and accelerate the existing automobility regime (Fraedrich et al., 2019; Freudendal-Pedersen et al., 2019; Kester, 2018; Sheller, 2020). Factors associated with traditional transport such as commuting practices, geographical networks, distances and time spent in the car remain. AV planning principles need to intensify geographical networks, rather than expand them, and more strategically challenge the increasing demand for mobilities. As long as privately owned cars dominate cities, transport will continue to grow and urbanisation to develop in parallel with the ubiquity of cars (Freudendal-Pedersen & Kesselring, 2017; Kent, 2018).

None of the policy documents from the 10 cities discusses the AV contingency in relation to the 'need' for mobility or how this is constructed through the institutional and infrastructural context of cities; for instance, in relation to 'how households are provisioned, where children go to school, and how work and leisure are organised' (Spurling & McMeekin, 2014, p. 81). The complexity of everyday life organisation is not present, but the construction and adoption of new mobility needs and practices is identified as visionary frames. In the following we will discuss which new perspectives would appear when implementing Banister's (2008) sustainable mobility planning and Spurling and McMeekin's (2014) practice-based mobility framings.

6. Interlocking AV policy framings and practice-based mobility framings

The lack of practice-intervention initiatives targeting the interlocking of practices and the absence of policies problematising the mobility 'need' make it implausible that planning strategies for the cities studied would be able to promote a thorough sustainable transition of urban mobility and effectively prevent anticipated unsustainable systemic effects of a future diffusion of AVs (Brovarone et al., 2021). In light of these urban political ecologies, we will conclude the analysis by pointing to key design criteria identified as important for ensuring a sustainable transition of urban AV mobilities and which are in line with the practice-intervention strategies of substitution of practices and changing how they interlock (Nogués et al., 2020; Porter et al., 2018).

According to the new mobilities paradigm, a hierarchy between different modes of transport systems exists in achieving sustainable cities. The Stockholm, Copenhagen and London transport plans represent interlocking policy framings that juxtapose AVs with ordinary cars (Appendix 1: City of London, 2018d, p. 277; Stockholm Mobility Plan, 2012, p. 17). The new mobilities paradigm proposes that city planning should favour walking and cycling over other means of transport, then public transport and, lastly, cars (regardless of fuel type or technical system). If private ownership continues, urban mobility dysfunctions will remain (Canzler & Knie, 2016, p. 59; Kent, 2018) regardless of the effectiveness of AV technical systems. The mobility planning hierarchy implies that mobility modes like walking and cycling should always be preferred over cars, whether these are privately owned or shared, fuelled by electricity or by fossil fuels, or driven by humans or autonomous,

[4] Like in this example from Amsterdam: 'Cars in the Netherlands will rise by between 23% and 58% by 2050. This is apart from the development of self-driving cars which, in the early stages especially, will result in more car traffic' (City of Amsterdam, 2016, p.11).

because cars require roughly 10 times the land use of bicycles (Banister, 2008, 2011a).[5] Hence, in line with the EU guidelines for sustainable mobility planning, it suggests that cars – including AVs – remain at the bottom of the transport hierarchy (Banister, 2011b; Rupprecht et al., 2019).[6] On an urban scale, interlocking practices (e.g. Appendix 1: City of London 2018d, Policy 23, p. 281) suggest planning that does not lead to a growth in car use, whether autonomous or not, and not at the expense of walking, cycling and public transport. Hence AV framings are identified as visioning mobility regimes and not as normalisation, rationalisation and predicting and providing space-time mobility efficiency (Kesselring, 2015). Rather, planning documents that oppose cars and AVs via sequencing planning scenarios as in London and Stockholm, for example, interlock them as niche policy framings through which the mobility hierarchy (Appendix 1: City of London, 2018d, p. 277; Stockholm Mobility Plan, n.d., p. 17) transforms rationalisation and optimisation into what we term techno-mobile AV framings. Such framings align Venturini et al.'s (2019) scenarios for MaaS as climate advocacy and González-González et al.'s (2020) shared and autonomous mobility scenarios.

Rather than developing MaaS practices, current AV governance largely reproduces existing mobility planning through recrafting policy framings. Apart from Stockholm and London, the cities surveyed do not yet adapt sustainable urban planning schemes (Rupprecht et al., 2019). Instead, urban governance of AVs must encompass concrete initiatives that do not replace cars with AVs but make it less attractive to use the AV and thereby change how practices interlock. To pick up on the example of the autonomous bus test in Helsinki and Copenhagen planning documents, it was never the intention to test it as part of a future MaaS system. The bus is connected to the Metro, but no further connections are envisioned at present and the autonomous bus will mostly absorb walking and cycling practices. Rather, the Helsinki plan explains the test as part of a growth-oriented strategy and underscores dilemmas for other planning objectives: 'Automatic electric minibuses have been tested in Hernesaari, Helsinki, since summer 2016. The aim is to make Finland into a pioneer in technological solutions in autonomous transport and to generate new export activities. In addition to Helsinki, testing is also being continued in Espoo and Tampere' (Appendix 1: City of Helsinki, n.d., p. 9). The Copenhagen test followed a similar trajectory critical of Reardon's (2018) claims, meaning that planning paradoxes as a recrafting test do not align with a sequencing strategy set in the mobility plan. No policies have been established to change the prevalent system of automobility and to rethink practices of work, shopping, recreation and institutional practices as a starting point for the test. The test would have been far more interesting had it moved beyond recrafting practices, focused less on being interesting for tech tourism and on AVs as a frontrunner, and instead championed new ways of integrating AVs with public transport and testing MaaS solutions.

7. Conclusion

Worldwide, autonomous vehicles (AVs) are expected to have great potential to fix the existing unsustainable mobility regime. None of the policy approaches of the 10 capitals surveyed require AVs to link with public means of transport, though London and Stockholm produce policy framings in advocacy of non-motorised mobility. Yet AVs are likely to individualise and intensify the existing automobility regime and emissions are likely to increase if subjected to recrafting AV governance.

Considering that the global widespread acknowledgement of AV mobility services anticipated promises (Bissell et al., 2018), concrete specific initiatives and implementation plans seem difficult to extract/track down. What is clear is that the urban planning of AVs comes with a wide range of planning paradoxes, benefits and hazards. Although AVs combined with concepts of Mobility-as-a-Service could presumably offer valuable solutions, the absence of specific initiatives and interventions testifies to 'lingo planning' (Davis, 2018) with somewhat limited/empty ambitions to accommodate the required radical changes in current mobility infrastructures. In the policy plans for, respectively, London and Stockholm, AVs are directly envisioned in connection with MaaS as a means to change the dominance of existing car driving practices. Hence, two of the five cities that mention AVs in planning documents demonstrate an awareness of not simply recrafting the existing automobility regime with AVs, by the ways in which purely techno-oriented planning solutions are substituted with broader socio-technical mobility transition framings. Spurling and McMeekin's third practice intervention, i.e. changing how practices are interlocked, is only acknowledged to a limited extent, and again only on a visionary level. While not in the context of AVs, the City of London suggests "new 'mobility' models could also be explored, for example demand-responsive services, where these can make public transport a more attractive alternative to the car" (Appendix 1: City of London, 2018d, p. 71).

In Tallinn, attempts at substituting practice have been made by making the public transport system free of charge since 2013, and further improvements to public transport such as hybrid buses, trams, etc. have been implemented (Appendix 1: City of Tallinn, 2013, p. 7).[7] Similarly, the Stockholm Urban Mobility Strategy envisions a mobility planning hierarchy in which walking and cycling are favoured in physical planning (Appendix 1: City of Stockholm, 2012, p. 17). This exemplifies strategies to change the demand for different modes of mobility through spatial patterns, resembling the practice-intervention strategy of sequencing practices through discouraging unsustainable mobility in favour of more sustainable alternatives. These examples, though, are not related to AVs, so even if the 10 cities are somewhat moving towards practice-intervention policies, none of these are related to the implementation of AVs. The love of autonomous vehicles comes with the critical risk of neglecting mobility planning dilemmas, recrafting AVs with increased mobility and individualised emissions as a result.

Declaration of competing interest

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[5] Average speeds in congested cities can be less than 15 km per hour, causing productivity losses and travel stress (Burns, 2013). This brings up what we call the 'urban transport paradox': from London to Paris and from Berlin to Warsaw, the average speed drops with a growing numbers of cars (Canzler & Knie, 2016, p. 59). The higher the share of vehicles in an urban area, the lower the speed of overall transport. In California, for instance, transport infrastructure, roads and parking lots often eclipse the land use of the buildings they serve (Chester et al., 2011). The planning of cities, the urban structure and governance have tremendous effects on daily mobility practices.

[6] While the City of London's policy intervention (Appendix 1: City of London, 2018d, p. 281) suggests that planning does not lead to a growth in car use at the expense of walking, cycling and public transport, these efforts are not specifically articulated around AVs. In consequence, AVs might replace traditional cars with the status quo as a result.

[7] By way of illustration, Berlin has 342 cars per 1000 inhabitants. While this is low in Germany, Berlin plans to reduce car ownership to 17% by 2025 (170 cars per 1000 inhabitants). Berlin forecasts that public means of transport, car sharing included, will absorb passengers. The plan does not mention AVs, either as part of the car ownership pool or as a MaaS, car sharing or semi-public service. New mobility parameters such as phasing out fossil fuels completely by 2050 (Appendix 1: City of Berlin, 2015, p. 17), recrafting modal splits towards low carbon and EV mobility (33% by 2030), carpooling and sharing feature in the plans.

Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2021.103504.

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