Making Automation Work for Cities: Impacts and Policy Responses

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Abstract There seems to be great concern and perhaps even greater uncertainty about how autonomous vehicles (AV) in cities may possibly affect not only mobility and transport but also infrastructure, land use, and the natural environment. Along with the debate on the impacts of AV the question arises what urban and transport planning strategies will be needed to ensure that the transition towards a fully automated transport in urban areas will contribute in the best possible way to urban sustainability goals and make it compatible with existing key urban policies. This paper addresses the question: What do city planners and policy makers have to know about the technology, its impacts and how can they prepare? It reviews the status of planning and implementing automation in cities and metropolitan areas in the US and in Europe. The paper draws on the presentations, discussions and conclusions from a breakout session 'Making automation work for cities' at the Automated Vehicle Symposium in July 2017.

Keywords Autonomous vehicles · Urban planning · Cities · Transport
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1 Introduction

Autonomous driving has started to receive attention not only by the research community but also by planning practitioners and policy makers concerned with transport and urban planning. There seems to be great concern and perhaps even greater uncertainty about how autonomous vehicles (AV) in cities may possibly affect not only mobility and transport but also infrastructure, land use, and the natural environment. This debate on the impacts of AV has raised concerns about what urban and transport planning strategies will be needed to ensure that the transition towards a fully automated transport in urban areas will contribute in the best possible way to urban sustainability goals and make it compatible with existing key urban policies.

This paper responds to these needs. It addresses the question: What do city planners and policy makers have to know about the technology, its impacts and how can they prepare? To find answers it draws on the presentations, discussions and the synthesis of a special breakout session at the Automated Vehicle Symposium (AVS) 2017, which brought together about 30 experts from practice and research.

Following the contents of the session, this paper reviews the status of planning and implementing automation in cities and metropolitan areas in the US and in Europe. The paper firstly provides a structured overview of different forms and options of AV technology application in cities and summarizes the current state of prediction about their deployment. In addition to the most commonly discussed options of private automated vehicles and flexible fleets of so-called ‘robotaxis’, the overview includes applications for urban services, freight and novel options for integrating flexible services into public transport. Secondly, the paper discusses expected impacts of AV in cities. Aside from direct impacts on mobility decisions and behavior, we also review indirect effects. Thirdly, the paper explores concrete case experience in cities where AV technology is currently being implemented in the form of pilot and demonstration projects. These cases provide valuable insights for creating an enabling policy framework for transport automation that also contributes to meeting key urban policy goals. A concluding section pulls together the findings from the previous sections and suggests key action fields to urban planners and policy makers for making automation work for their cities.

2 AV Technology Application in Cities: Options and Deployment Scenarios

While high levels of automation technologies in transport can already be found in aviation, maritime transport and rail-based public transport systems, road transport has yet to reach a high degree of automation. This is equally true for private vehicles and public transport vehicles. One reason is that navigating on roads requires much more complex interaction with other users.

However, this is starting to change. Despite the technological challenges that need to be overcome before AVs become a reality on public roads, the degree of automation in road vehicles is continuously rising. Advanced driver-assistance systems, such as lane-keeping assistants and adaptive cruise control, are already available in currently produced vehicles, and this is moving the technology development forward. Most major car manufacturers already market and sell high-end vehicles with features like automated braking, self-parking, lane-departure warning, and variable-speed cruise control. Most are also racing to develop fully autonomous vehicles. In addition, there are other applications under way. Cities like Boston or Singapore are currently testing fleets of driverless taxi vehicles. And European Union–funded projects (e.g. CityMobil1 and 2, CoExist) have already begun testing driverless transit on public streets or explore applications for freight and public services like garbage removal.

These examples illustrate that the diffusion of AV technology in urban transport systems is unfolding for many different applications and along different deployment scenarios. Three main scenarios have been identified [1]. A first scenario is the steady increase in the use of advanced driver assistance systems followed by successive steps towards vehicle automation and a corresponding reduction in the driver's responsibilities. This is labelled as "evolutionary scenario". The car industry is currently launching a range of systems that automates both longitudinal (acceleration, braking) and lateral control (steering), with driver monitoring still to be introduced—in other words, a partially automated system. A second pathway, the "revolutionary scenario" does not pursue such a continuous improvement of driver assistance towards automated driving, but rather a disruptive leap straight from today's traffic pattern, with human-driven vehicles, into a scenario in which the driver hands over control to the system completely. One credible possibility could be the introduction of vehicles and services like those being tested in Boston and Singapore with higher-order automation as competitors of conventional taxis. A third deployment scenario for automated driving involves implementing transportation paradigms that provide slow-moving passenger vehicles, for example in urban areas like those tested in the city of Helmond in the Netherlands, Milton Keynes and elsewhere. Users would call such vehicles using a smartphone app and ride them over relatively short distances. These transportation solutions would compete with conventional taxis but be more affordable, comfortable, and innovative from the standpoints of both users and operators. Such automated mobility on demand (AMOD) systems represent an individualization of public transportation as a "transformative scenario" for traffic in urban areas.

While current announcements by the industry claim to bring autonomous vehicles to the market within the next few years (while being vague on the intended levels of automation), it is hardly possible to make predictions beyond the target date of 2020 in particular with respect to the revolutionary and transformative deployment scenarios. A few roadmaps exist (e.g. [2–5]) showing the expectations when fully automated vehicles will be available in urban environments. With respect to the evolutionary scenario, they expect that higher order automation in the form of an urban and suburban pilot will be ready by 2026 [2] and fully automated vehicle should be able to handle all driving from point A to B without any input from the passenger driverless cars with no driver backup in 2030 [2, 5] provided that legal frameworks are in place [3]. Similar expectations exist for the revolutionary and transformative scenarios. Automated taxis are expected to operate from 2030 onwards [2, 4]. The same projection exists for AMOD services that would operate on their own exclusive infrastructure [2].

City managers and planners will play a strong role in shaping the advancement of automated driving in urban areas. Already now, they are crucial as benchmark setting "local champions". And they'll create regulatory and liability structures that advance or impede new technologies, may it be by enacted laws that favor autonomous cars or building out communication networks in part to accelerate the development of connected cars.

3 Impacts of AVs in Urban Areas

Several authors [6–8] have developed frameworks of AV impacts. Following [8, 9] we divide impacts into two major groups: direct and indirect. Figure 1 depicts the impact areas and their respective linkages. Direct impacts are those which have a relatively clear cause-effect relationship with the primary activity or action. They are generally easier to capture, measure and assess, and are often (though not always) immediate to short-term in nature. In Fig. 1 they are in the upper left,

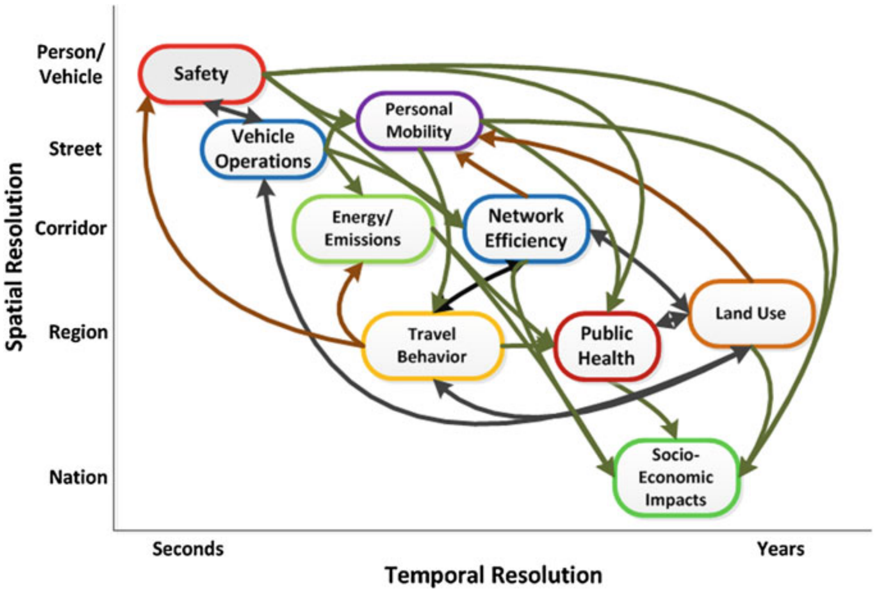

Fig. 1 AV impact areas and their respective linkages

and include safety, vehicle operations, energy/emissions, and personal mobility. Indirect impacts summarize the broader effects of the individual direct impacts and are produced as the result of a path/chain of impacts, often with complex interactions and external factors. They are typically more difficult to measure and are longer than the time horizon of a field test.

Examples of **direct** impacts include the response of vehicle occupants and other road users, safety, vehicle operations (e.g., acceleration, car following, gap acceptance), energy/emissions, personal mobility (e.g., the ability of persons, including non-motorists and persons with disabilities, to travel). Finally, the capital and operating costs of the system are important, for understanding likely future deployment.

Specific areas of **indirect** impact include the following:

Network Efficiency, which refers to lane, link, and intersection capacity and throughput in a regional transport network. It also refers to travel time and travel time reliability.

Travel Behavior: A traveler may respond to AV options, including new service offerings, by changing travel behavior. There may be more or fewer trips. Modes, routes, and destinations may change.

Public Health: Automation may impact the health (physical and mental) of individuals and entire communities via safety, air pollution, amount of walking and bicycling, as well as access to medical care, food, employment, education, and recreation.

Land Use: Automation may affect the use of land for transport functions (e.g., parking, road geometry). Longer term land use changes may include community planning, i.e., location and density of housing, road network design, employment, and recreation.

Socio-Economic Impacts: Improved safety, use of time, freight movement, travel options (for motorists and non-motorists), public health, land use, and effects of changed will have longer-term economic impacts. Automation may also have substantial impacts on labor markets and industries.

In assessing indirect impacts, note that fleet composition and service offerings might change, for example:

- Vehicle ownership might change. For example, there may be greater use of shared vehicles, which will affect the amount of land required for parking.
- Better crash avoidance may enable the use of lighter-weight vehicles (affects material and energy use or emissions) and prevent crash-related congestion (affects network efficiency).
- The advanced control systems used for automation may also contribute to electrification (affects energy use and emissions).
- If there is no human driver, the layout of the vehicle might change (affects energy use).

- Without the labor cost of a human driver, it may become economical to use smaller vehicles for both trucking and transit (affects energy use and network efficiency).

Finally, several uncertainty factors will affect the impacts of AVs [10]:

- Policy factors include law/legislation, risk, cost structure and infrastructure (right-of-way).
- Technology factors include those that affect cost and the operational design domain, including sensor/control system performance, security, communications needs and ability to handle the unexpected.
- User factors include willingness to share vehicles, trips and data, willingness to cede control, value-of-time (multi-tasking) and the response of other road users to the presence of automation.

All of these impacts are important in urban areas. Particularly important are the safety of interaction between AVs and non-motorized users (pedestrians and bicyclists), impacts on road congestion, and impacts on land use, as urban land is usually valuable.

4 How Cities Prepare: A Review of Ongoing Initiatives

As outlined above, city initiatives and demonstration and research projects are under way in various locations. More recently, they have been complemented by initiatives of Networks of Cities with the attempt to derive broader insights and orientation for policy and action.

Among cities, an increasingly consistent set of common themes is emerging from first (limited) pilots and local stakeholder dialogues:

- City goals first: While most of the first pilots focused on proving technical feasibility and many decision-makers used the publicity around those tests to promote their cities as forward-looking and innovative places of investment, there is now widespread agreement that automation must contribute to meeting key urban development goals in order to justify public support and investment. Although this is accepted in general, very few cities have actually included automation in the development strategies.
- AV-Sharing is the preferred model: There is growing awareness that automation may lead to an increase in vehicle miles travelled and may cannibalize mainstream transit services. To prevent this, many transit agencies follow a strategy of “transit first” also in the automation context by focusing on models that promote shared use of automated vehicles.
- Public engagement is important: public acceptance of automation is difficult to measure theoretically, but there is clear indication (e.g. from Boston, San Francisco and Milton Keynes in the session) that citizens may be supportive if

they get better access, increased safety, higher reliability. Involving the public, therefore, appears to be an important precondition for successful implementation.
- Working in cooperation: Automation-based services can be very disruptive (in a positive or in a negative sense). There was agreement in the session that cities should lead a collaborative, multi-stakeholder process where public and private stakeholders coordinate technology and service deployment and policy development/planning.
- Upscaling is the next challenge: Moving from technical showcases to pilots that involve real users on public roads is a wide step. As the example from Helmond and other cities shows, financing, service and infrastructure integration post new challenges.

The process of formulating common positions on automation and urban development is facilitated by associations like National Association of City Transportation Officials (NACTO) in the US and POLIS in Europe. The NACTO represents a City network in the U.S. NACTO has recently launched its Blueprint for Autonomous Urbanism. This Blueprint outlines a vision for cities in a future where automated transportation is both accepted and widespread as part of the built environment. It is a human-oriented vision for the potential of city streets, intersections, and networks-one in which automation can serve the goals of safety, equity, public health, and sustainability [11].

The blueprint endeavors first and foremost to illustrate policy goals using renderings and diagrams, and to present an alternative vision of the future oriented around city streets as public spaces. Cities need strong policies to guide the future of automation and to help communities shape powerful technologies around their goals, rather than the other way around. Clearly articulated policy goals represent a good first step for cities. Achieving these goals will require creative public private partnerships, adaptive decision making, and critical data sharing agreements.

In concrete terms, for NACTO making automated vehicles work for cities rests on a set of main pillars:

- Redesign of streets and intersections for people, not vehicles.
- Design for safety: new rules on the road including setting safe speed limits, safe and frequent crossings, attention to cycling through intersections.
- Embracing new mobility systems: expanding transit, with high ridership transit as a backbone, flexible services to connect point-to-point, creating a new mobility network.
- Curbside management: utilize the gradual disappearance of street parking and manage the immense public asset represented by the curb for multiple and flexible purposes.

POLIS is an association of 70 (mostly) European cities and regions is developing its view on automated vehicles. In a situation where unrealistic expectations about the likely impact and availability of automated vehicles are created, many cities want to be the first to have automated vehicles on the roads, while many city managers fear the unknown effects. POLIS, therefore, intends to raise awareness and promote reflection about AVs among local and regional authorities, communicate views of cities and regions to policy makers and other AV players, and challenge the AV sector to develop products and services suited to urban context. Possible implications of automation include travel behavior, spatial, social, road safety, traffic efficiency, and investment impacts. Local/regional authorities need to determine the point on a spectrum where AVs can deliver most benefit to their city/region and develop policies accordingly. Cities need to explore urban planning and development, specific automated services, safety of vulnerable road users, travel behavior changes and traffic management implications.

POLIS is currently preparing a position paper on automation. Some preliminary recommendations include:

- City and regional authorities should build and implement AV policies to guide their introduction in the most effective manner.
- A structured dialogue between the public sector and AV industry needs to be established.
- Research on the potential impacts of AV on urban and regional transport is needed (travel behavior, vulnerable road user interaction and safety, infrastructure implications, new transportation services, etc.).
- EU and national policy on AV should give greater consideration to sustainable urban mobility policy.

In the U.S. regional planning organizations have engaged in exploratory analysis of the potential effects to automation on a metropolitan area's transportation system (for example [10]). The National Cooperative Highway Research Program (NCHRP) Project 20-102 has funded several research tasks to support planners and policy-makers. A U.S. C/AV analysis modeling and simulation (AMS) project is providing a framework and models for the effects of C/AV applications. This project is twinned with the European Horizon 2020 CoEXist project, which is developing simulation tools for a mix of automated and non-automated vehicles in several European cities and developing a "automation readiness" concept for transport authorities and infrastructure owners. Both projects are cooperating to develop a common representation of automated vehicles in major transport simulation models.

5 Making Automation Work for Cities: Towards an Action Agenda

In conclusion, what do city planners and policy makers have to know about the technology, its impacts and how can they prepare? The previous discussions highlight that cities and their networks are becoming active players in seeking ways to shape AV technologies around their goals, despite (as highlighted in Sect. 3) the various uncertainties that exist. It also becomes obvious that the current round of experimentation attends to all of the alternative (or complementary) deployment scenarios: evolutionary, revolutionary and transformative. A few key learnings can be derived from these insights.

Firstly, penetration of AV technology in cities is happening but at slow pace and the applications and use cases are diverse. As automation is a new topic for most cities, it needs joint efforts. Networking of approaches and experiences is indispensable to speed up knowledge exchange. Secondly, cities are motivated by very similar goals. These emphasize improving safety, inclusion/access and mobility for all citizens. There are equity concerns whereby AVs are not intended solely for the wealthy population. Across cases, there is a strong interest in supporting walking, cycling and transit. This reflects a thinking that goes beyond a single mode of transport but one that considers the potential of AV technology to innovate the entire transport network and that considers the integration of modes. Thirdly, there is the need to involve a wide range of stakeholders including citizens. They should understand that tests are innovation pilots, not yet regular services. A major challenge is how to organize the involvement process. Approaches to stakeholder participation are more a "social experiment" than technical approaches. Both approaches should coexist and need to learn from each other. Finally, cities need to work closely with OEMs and technology providers who are looking for new markets and are interested in testing and demonstrations in cities.

What should policy makers in cities do to create an enabling policy framework for transport automation that also contributes to meeting key urban policy goals?

A first set of actions concerns the task to put in place basic "automation readiness" criteria. This involves setting widely supported policy goals, expected CAV contributions and creating a strong multi-stakeholder partnership (private-public, public-public, between departments, state/national support).

A second set of actions concerning moving ahead with implementation. The case experience suggests a lightweight, incremental approach that systematically builds critical mass and manages (complex/contradictory) citizen expectations. A communication that frames implementation as innovation can be a key for success. Implementing automation also means thinking about the business case. Again, the experience shows that application can be manifold and can involve public transport as well as other municipal services (e.g., waste collection, street cleaning, snow plowing). As there is yet little knowledge on effects, thinking about impact assessment from "from day 1" and identifying clear performance measures for automated services/providers (local KPIs) are important, as is clarifying expectations on users' cross-brand experiences (or a uniform local brand?). Given the possible implications of AV deployment on urban space, space management is a key future challenge (on-street/off-street).

A third set of actions concerns the wider context of automation and innovation. This includes ensuring that automation is part of an innovation cycle (including learning) and synchronizing technology and policy transition. In other words, cities planners and policy makers need to "upgrade" their strategies in line with the new mobility paradigm that the technology involves. This also includes considering the wider transition landscape of influencing factors (Mobility as a Service, digital infrastructure, energy, etc.) and how supporting ecosystems can contribute (e.g. planning, labor relations, procurement). Finally engaging in learning and exchange activities, including international dialogue, scales up the learning process.

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References

1. Beiker S (2016) Deployment scenarios for vehicles with higher-order automation. In: Maurer M, Gerdes JC, Lenz B, Winner H (eds) Technical, legal and social aspects. Springer Vieweg, Wiesbaden, pp 193–211
2. ERTRAC—European Road Transport Research Advisory Council (2015) Automated driving roadmap. ERTRAC, Brussels. http://www.ertrac.org/uploads/documentsearch/id38/ERTRAC_Automated-Driving-2015.pdf. Accessed 4 Dec 2017
3. VDA, Automatisierung (2015) Von Fahrassistenzsystemen zum autonomen Fahren. Verband der Automobilindustrie e. V. (VDA)
4. European Technology Platform on Smart Systems Integration (2015) European roadmap smart systems for automated driving. Berlin, Germany. http://www.smart-systems-integration.org/public/documents/publications/EPoSS%20Roadmap_Smart%20Systems%20for%20Automated%20Driving_V2_April%202015.pdf. Accessed 11 Dec 2017
5. Strategy & PwC (2015) Connected car study
6. Smith S, Bellone J, Bransfield S, Ingles A, Noel G, Reed E, Yanagisawa M (2015) Benefits estimation framework for automated vehicle operations (No. FHWA-JPO-16-229)
7. Milakis D, van Arem B, van Wee B (2017) Policy and society related implications of automated driving: a review of literature and directions for future research. J Intell Transp Syst 1–25
8. Innamaa S, Smith S, Wilmink I, Reed N (2017) Impact assessment. In: Meyer G, Beiker S (eds) Road vehicle automation, 4th edn. Springer International Publishing, Cham
9. Smith S, Innamaa S, Barnard Y, Gellerman H, Horiguchi R, Rakoff H (2017) Where will automated vehicles take us? A framework for impact assessment. Poster presented at the automated vehicles symposium, San Francisco. https://higherlogicdownload.s3.amazonaws.com/AUVSI/14c12c18-fde1-4c1d-8548-035ad166c766/UploadedImages/2017/PDFs/Proceedings/Posters/Wednesday_Poster%202.pdf
10. Childress S, Nichols B, Charlton B, Coe S (2015) Using an activity-based model to explore the potential impacts of automated vehicles. Transp Res Rec J Transp Res Board 2493: 99–106
11. National Association of City Transportation Officials—NACTO (2017) Blueprint for autonomous urbanism. Module 1