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Robocar and Urban Space Evolution

City changes in the age of autonomous cars

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Evolution

Robocar and Urban Space

Symposium 13.09.18

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Evolution

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Robocar and Urban Space Evolution
City changes in the age of autonomous cars

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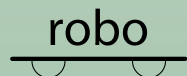**Copy Editors**

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Anca Ioana Ionescu and Víctor Muñoz Sanz

The Urban Design Section of the Faculty of Architecture and the Built Environment (TU Delft) has a tradition of research in the design of the physical form of existing urban areas and is concerned with the complex relationship between urban form, land-use, social processes, health objectives and climate challenges. Through research and education, the Urban Design group develops innovative concepts for urban analysis and design, acknowledging contextual changes that call for a rethink of theory and methods in urban design. Recent developments in technology and the requirements of environmental acts are driving forces for our research topics in the coming years: Technology, Growth and Health in relation to the urban fabric.
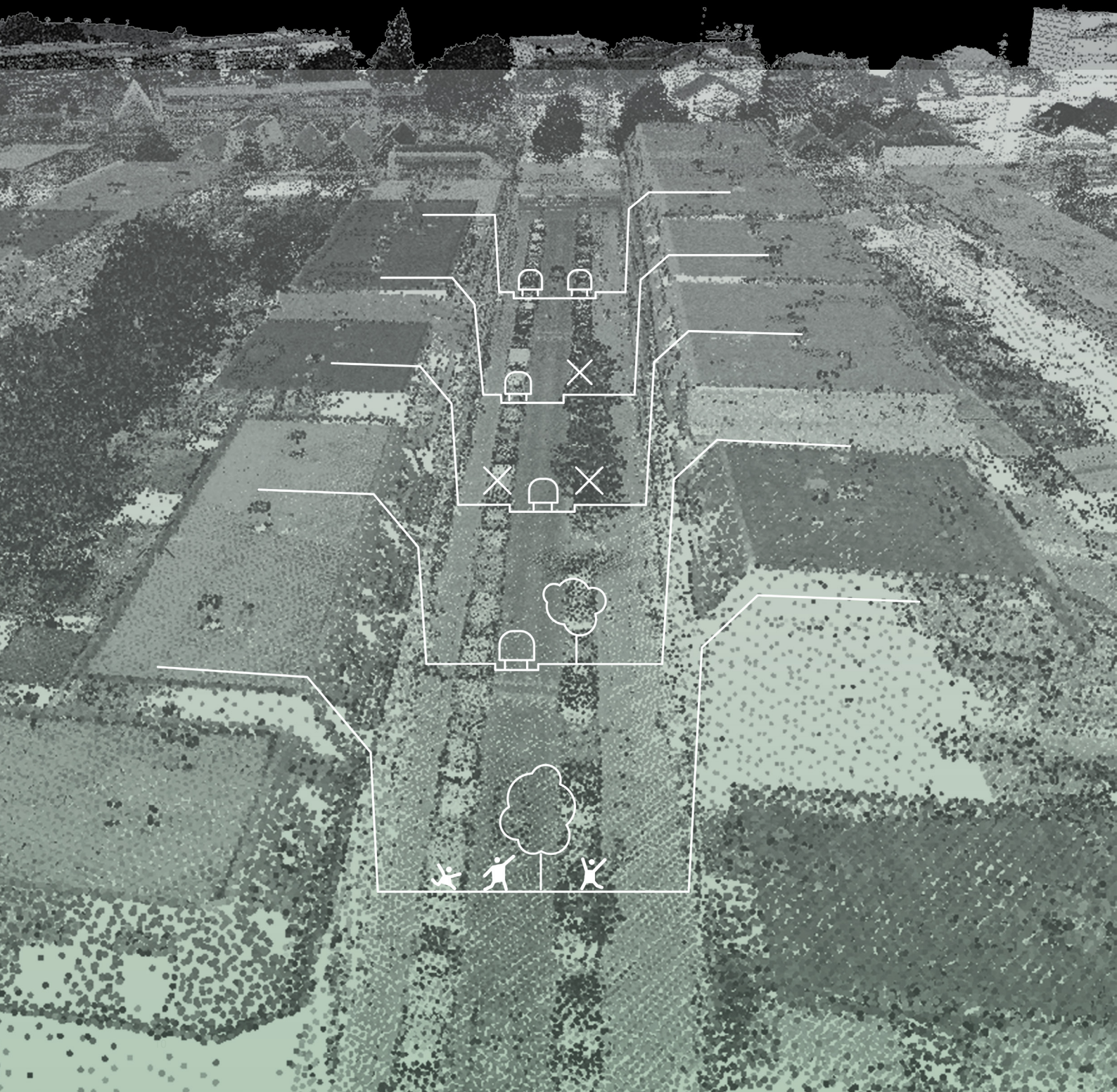
Evolution

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Introduction

Autonomous cars—Robocars—will dramatically change urban environments and the practice of urbanism, potentially making cities less dependent on and less dominated by cars. Driverless and mainly guided by digital infrastructure, Robocars can open up new opportunities for urban development. If guided by sustainable development goals, mobility automation can lead to urban evolution—a shared paradigm shift in mobility and urban design.

However, if introduced as profit-driven product rather than a tool to improve cities, Robocars can cause sprawl, undermine public transport and reduce active mobility, ultimately affecting people's health and wellbeing. Consequently, further research and design work is needed to explore how the Robocars' technological capabilities may provide solutions to deal with pressing urban issues, such as growth, climate change, environmental quality, social inequality and the energy transition.

On September 13, 2018, the Section of Urban Design at the Faculty of Architecture and the Built Environment, TU Delft, organised a public debate with international and Dutch experts to discuss the spatial changes that Robocars may bring about in cities, and what they mean for current urban issues. The three thematic sessions of the symposium were video recorded and are available online at robocarevolution.com. This publication gathers illustrated contributions from key speakers at the symposium as a further reflection on Robocars' relation to the urban environment. The focus is on the city and how Robocars may improve or harm it.

The goal of the symposium and of this subsequent publication is to raise awareness about the importance of the topic for the field of urban design and other disciplines dealing with various aspects of urban sustainability. To date, the topic of autonomous cars has mainly been addressed by car industries, technology companies and transportation planning groups. The current discourse is predominantly driven by business and marketing goals, potentially leading to cities shaped around technology. In this context, the symposium was a step forward to engage various experts in a debate around Robocars and urban design.

This publication proposes a complementary approach to the current tech discourse on automated mobility by emphasising the importance of an urban design and spatial planning perspective, thus exploring Robocars as a spatial project. Automated vehicles can bring a mobility revolution: the traffic system and infrastructure can be reinvented, public and private transport modes may blend, and the logic of mobility in cities can be reformed, as time spent in the car will no longer be lost. Such changes create spatial opportunities and could help cities to better respond to sustainable development goals. For instance, the space made available if Robocars could park themselves can be redesigned and, instead of parked cars, streets can accommodate more green space and larger sidewalks, revaluing streets as public spaces.

How can we create more human-centered, resilient, and sustainable cities in the tech age? Can we make use of technology and the opportunities presented rather than resisting its fast-paced evolution? What are the biggest and most likely spatial changes that autonomous vehicles will bring in cities? How can this change in mobility contribute to a better urban environment? To what extent do the spatial opportunities created by automated mobility respond to current urban issues and what is the role of urban design and spatial planning in this debate?

The symposium generated a multidisciplinary debate around these questions, involving projects that explore the possibilities opened up by autonomous cars in relation to urban development goals, in three thematic sessions:

(1) Mobility transition and its spatial implications
(2) Revaluing public space
(3) Urban design in the context of automated mobility

(1) Mobility transition and its spatial implications
The first session provided an overview of autonomous cars and their implications from a spatial planning perspective. The session was opened by David Hamers, senior researcher at the Netherlands Environmental Assessment Agency (PBL) and lecturer at the Design Academy Eindhoven, who presented urban scenarios for the Netherlands towards 2050. The scenarios explore how cities may evolve in relation to sustainability and climate change, and how politics and spatial configurations can change in the context of automated mobility.

Dominic Stead, associate professor in spatial planning at TU Delft, discussed the matter of accessibility and active travel in relation to automated mobility. He illustrated the potential impact of automated mobility by using examples and highlighting the fine line between the advantages and perils that Robocars can bring to cities. His conclusion focused on fundamental planning principles, which should form the base conditions for sustainable cities with regard to mobility. This pertains to walkability and active mobility, and how they need to be protected from the potential negative impacts of Robocars.

The session was closed by professor Rients Dijkstra and researcher Anca Ioana Ionescu, both from TU Delft, who presented their exploration on design solutions and spatial scenarios of street transformations in the context of Robocars. According to them, if autonomous vehicles will be guided, clean, slow and silent, and on-street parking space will be freed up, then driverless mobility can improve the quality of streets as public spaces, leading to significant spatial and cultural transformations.

(2) Revaluing public space
The second session extended the discussion beyond autonomous vehicles, and proposed a parallel between Robocars and ongoing urban projects concerned with urgent urban issues and sustainability. In response to growth, climate change, and social inequality, the goal of such strategies is to enhance human wellbeing, improve environmental quality, and to create climate responsive environments. The speakers of this session stressed how autonomous vehicles can be supportive of such challenging urban goals (e.g. eradication of parking and accessibility solutions).

Fig.1 *Three sessions provided a forum for multidisciplinary debate on the topic of autonomous cars and their impact on cities.*

Salvador Rueda, director of BCN Ecologia, presented the *Superblocks* concept that he developed and applied in Barcelona. The Superblocks project and concept has advanced the approach to creating sustainable urban environments by reducing the domination of cars through an innovative model of shared space implementation. This project and concept has become a reference for other cities around the world that are trying to reduce the negative impact of cars on the urban environment.

Frans van de Ven, associate professor at TU Delft and author of the Adaptation Support Tool (AST), talked about climate resilient and attractive cities, addressing potential connections to automated mobility. His research at TU Delft and Deltares Institute focuses on climate responsive solutions and participatory design. He explained the urgency to deliver integrated climate responsive and socially responsible solutions.

Florian Boer, co-founder of De Urbanisten and designer of the *water square* concept, explained the importance of green-blue spaces for cities through urbanism projects. He emphasised how integrated public space design solutions can improve both the response to climate change and human wellbeing.

(3) Urban design in the context of automated mobility
The third session gathered planning and urban design groups engaged in research and consultancy projects on autonomous vehicles, involving partnerships with industry and public institutions. It addressed the spatial impact of Robocars and their implementation. These initiatives are connected to industry, tech companies, and municipalities and their central focus is the integration of Robocars in certain urban contexts and communities.

Nico Larco, professor at the University of Oregon, talked about the impacts of autonomous vehicles and e-commerce on land-use, as well as the urgency to address the topic – preferably across more disciplines concerned with sustainable urban development – given that in the United States AV fleets are already on the ground.

Representing the Avenue21 project developed at TU Wien and the Daimler Foundation, Mathias Mitteregger, project manager, and Emilia Bruck, PhD candidate, presented normative-narrative scenarios created to explore how alternative urban futures will be shaped by connected automated vehicles (CAV) in European cities.

The final talk was given by Arthur Scheltes, transportation planning expert from Goudappel Coffeng, who was involved in several key projects dealing with the implementation of autonomous vehicles in Dutch cities and regions. He gave insights into the state-of-the-art, on-going and upcoming mobility projects.

Each session concluded with a panel discussion that reinforced the general goal of the symposium: to start a more inclusive debate about the relationship between Robocars and the urban environment, and to explore the potential of this new technology beyond market-oriented goals. The experts involved came from multiple disciplines, including spatial planning, urban design, architecture, ecology, psychology, environmental engineering and transportation planning. The sessions stressed why and how we need to engage with the topic, who should lead and who should be involved in the debate, given that the automation of mobility will dramatically shape the urban environment in different contexts and societies in the coming decades.

Fig.2 *The first session of the Robocar and Urban Space Evolution Symposium.*
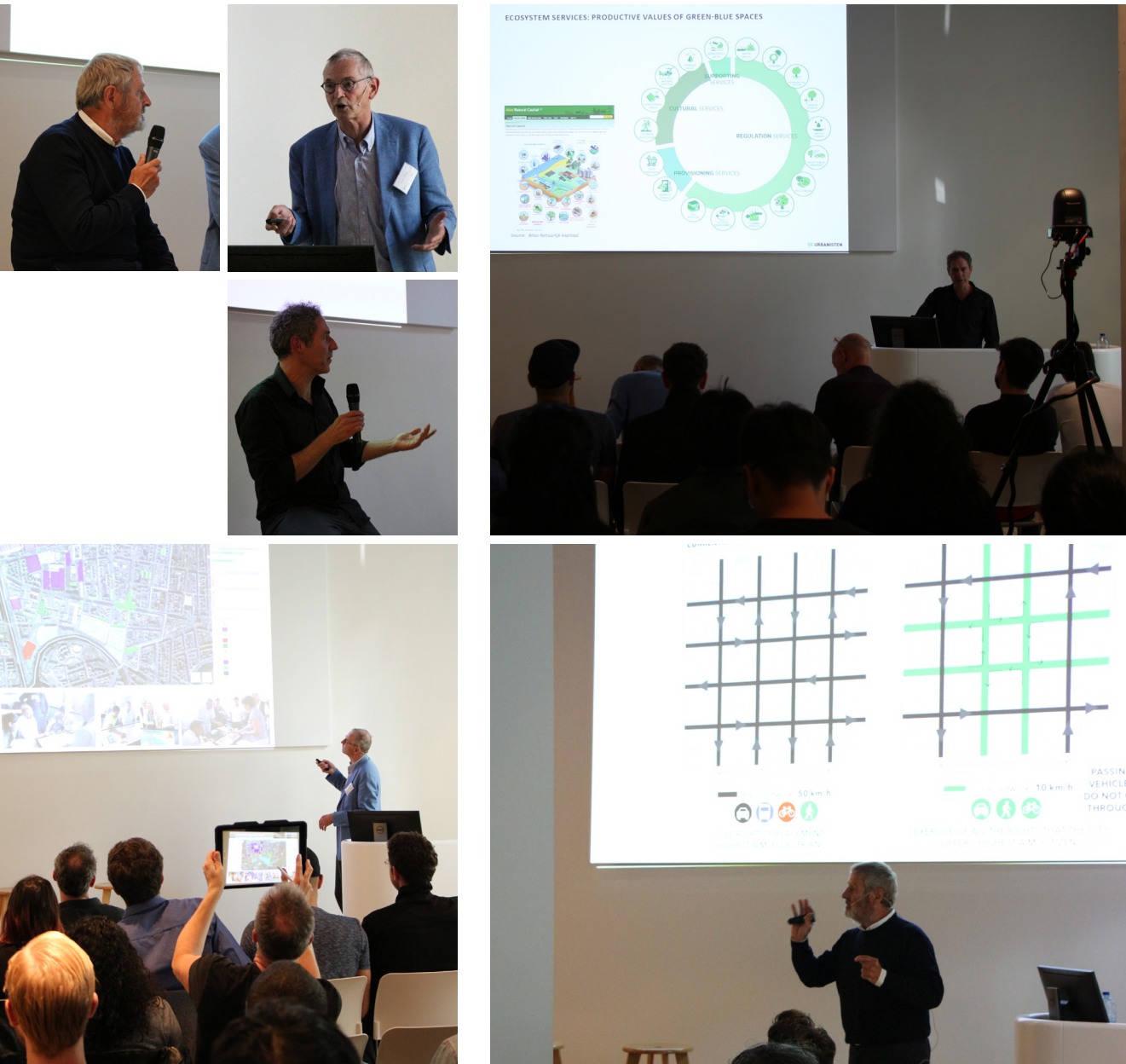
Fig.3 *The second session of the Robocar and Urban Space Evolution Symposium.*

Fig.4 *The third session of the Robocar and Urban Space Evolution Symposium.*

Multi-dimensional Scenario Making
Four futures to help policy makers embrace uncertainty in the fields of urbanisation and transport in the Netherlands

by David Hamers, Daniëlle Snellen, Anton van Hoorn, Kersten Nabielek, Joost Tennekes & Lia van den Broek, PBL Netherlands Environmental Assessment Agency

In the fields of urban development, infrastructure and transport, strategic policy makers and long-term planners face many uncertainties with regard to the future. How to deal with climate change? Which new technologies to expect? How will social and cultural changes influence what citizens and companies value? How will government bodies anticipate or react? Many of these uncertainties cannot be reduced by more advanced statistics or better models.

To help strategic policy makers deal with so-called deep uncertainty (Lyons & Davidson, 2016; Marchau et al., 2010) we have developed scenarios about the future of Dutch urban regions and their transport infrastructure (PBL 2019, forthcoming on April 12). Here we give a sneak preview, based on the preliminary findings of the research presented at the Robocar and Urban Space Evolution symposium, held on September 13th 2018 at TU Delft.

Year 2049
Future scenarios in the fields of land use and transport, where many developments interact, should take a large variety of elements into consideration. It is not just about the development of places (existing and innovative types of environments), connections (physical and virtual) and transport modes (low-tech and high-tech), but also about what people will think of these, and how institutions can act. Some examples based on the topic of the symposium can demonstrate what kind of issues should be dealt with. Is an automated vehicle (AV) an improved car or a new vehicle category? When will AVs be ready, from a technical perspective, for the complex task of driving efficiently in cities? Will they be accepted in society? Will they improve traffic flow or make it worse? How will people's experience of travel time be affected? Should the city's public spaces adapt to AVs or vice versa? Could AVs speed up suburbanisation?

More data is not going to answer all these questions, but scenarios can help. There are different types of scenarios, each offering specific opportunities as well as limitations. Our scenarios (2019-2049) have the following characteristics: they are qualitative in nature (no model computations); they are explorative (focusing on new trends and so-called weak signals of possible discontinuities); they are descriptive and normative (combining descriptions of potential development paths with possible changes in societal values and related policy goals); they are plausible and imaginative (both logically consistent and surprising); and, finally, our scenarios tell stories—they are narratives, rich in detail, that we use in our research to affect policy makers in a way that is quite different from presenting tables and graphs (cf. Dammers et al., 2013).
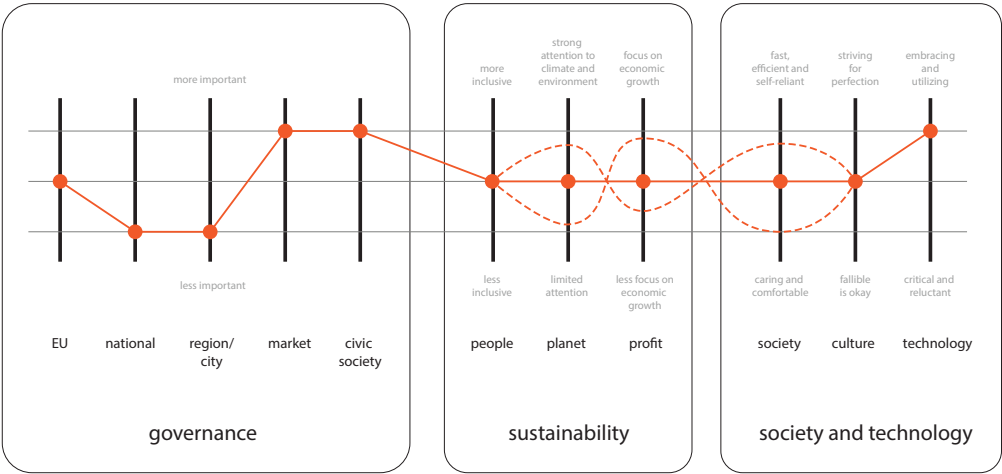
Bubble City
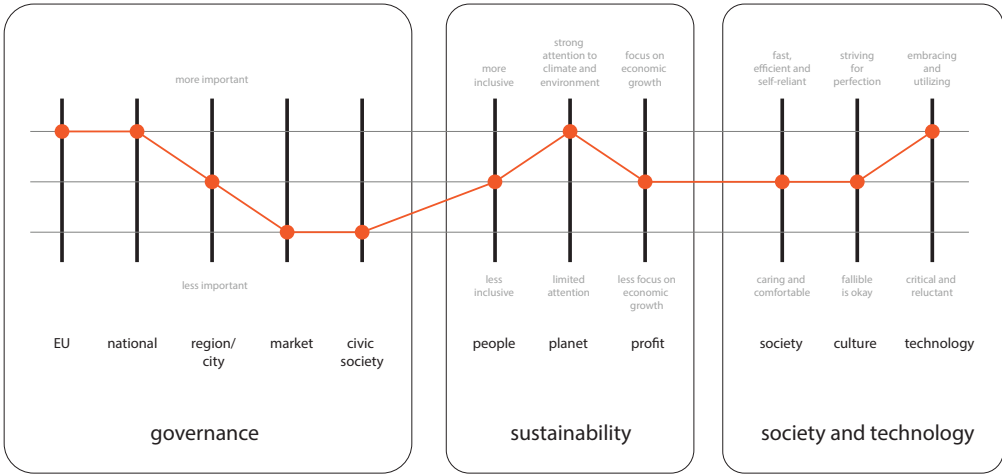
State of Green

Fig.1 *Equaliser with eleven key uncertainties.*

Eleven key uncertainties, four future world views

In order to construct the scenario narratives, first a number of different future world views were developed. To ensure that these world views would address relevant uncertainties, would each be consistent (plausible) and would differ enough from each other (so that a variety of possible futures can be discussed), we developed a 'mixing console' containing an 'equaliser' corresponding to eleven key uncertainties regarding who is in control (governance), the attitude towards people, planet and profit (sustainability) and social and cultural characteristics of our society (including the attitude towards technology). By choosing (and discussing and testing) different settings, four future world views were constructed, each with a fitting name to summarise its character: Bubble City, State of Green, Market Place and Our Neighbourhood *(Fig.1)*.
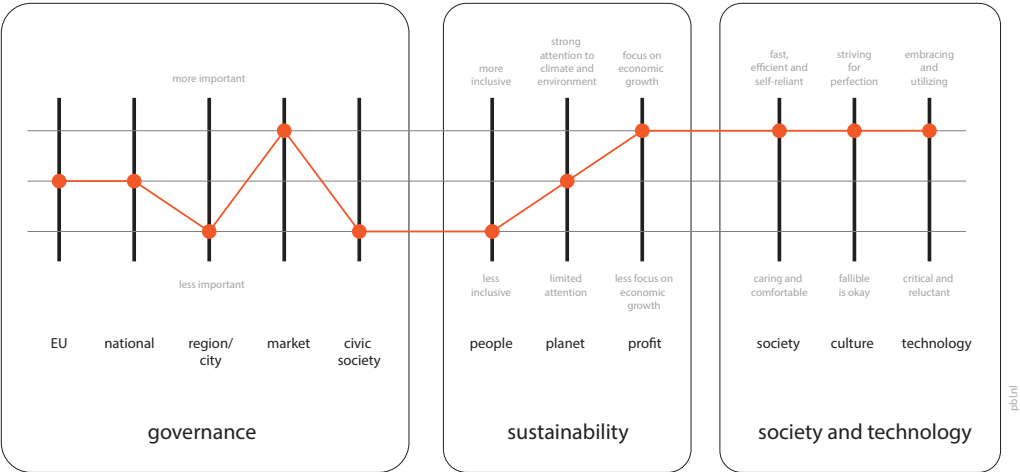
Market Place
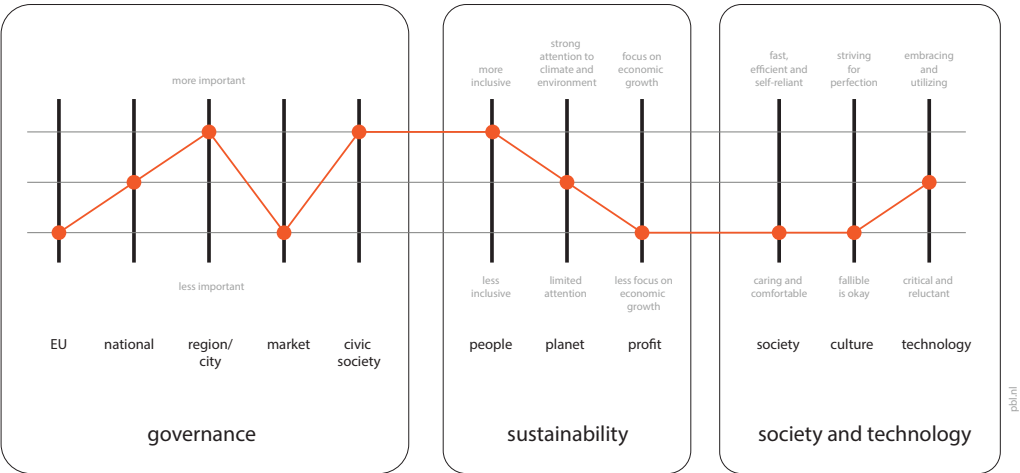
Our Neighbourhood

Bubble City

- Society is made up of lifestyle 'tribes'
- Geographic location has little meaning; network logic
- Digital is more important than physical; less need to travel
- Make-shift society; little higher-level coordination
- Complex, especially if you lack digital skills
- Collectives of citizens and market parties are in the lead

State of Green

- Top-down green transition
- System of so-called 'planet points' introduced [1]
- Less freedom of choice; cleaner, healthier living environment
- Proximity; transit-oriented development; active modes of transport
- Technology serves green ambitions
- Offers clarity

Fig.2 *Four future world views: Bubble City, State of Green, Market Place and Our Neighbourhood.*

Each future world view presents an image that differs substantially from the present but that does not seem far-fetched. Thus, these world views enable policy makers and other actors in the fields of urban development and transport planning to compare possible futures with the current situation in the Netherlands and discuss some of the defaults in present-day thinking, challenge them, and consider possible alternatives.

The brief summaries of the four future world views in this sneak preview do not do justice to their multi-layered character. However, by presenting six key characteristics of each world view, we offer a first impression of these potential futures *(Fig.2)*.

Market Place

• Performance; success; self-reliance
• Technology serves efficiency
• Economy; freedom of choice; hedonism
• Large socio-economic contrasts
• Lots of travel; all possible modes of transport
• Government facilitates businesses

Our Neighbourhood

• One's neighbourhood is the centre of daily life
• Small-scale; recognisable; social control
• Active travel
• Decentralised decision-making
• Large differences between neighbourhoods, districts, cities
• Difficult to develop supra-local projects

AV in each world view

These four world views can help policy makers think through potential development paths as well as a range of (novel) conceptions and values. Applied to the case of AVs, for instance, Bubble City shows a future in which self-driving cars enter the city, but cause congestion and gridlocks, because clear communication protocols are lacking. In State of Green, privately-owned AV technology does not fully develop because it proves to be too resource-consuming; slow-moving collective pods and automated public transport, however, are introduced. In Market Place, AV flourishes, both between city regions and within cities, leading to increased levels of car traffic. In Our Neighbourhood, AV has low priority and human contact, e.g. with a bus driver, is preferred.

Four scenarios

Finally, the *pièces de résistance* of our research are not the four world views, but the matching scenarios: the narratives that present the gradual development of each of the four futures. None of them present cut-and-dried answers to the kind of questions raised in the previous sections. Each scenario is organised around a distinct set of tensions, dilemmas and conflicts that help policy makers, planners and other actors in the fields of urban development, infrastructure and transport to anticipate a variety of relevant long-term developments and explore a range of different policy and planning options.

The storytelling involved in the scenarios cannot be summarised in this short text. Readers who want to know more about what is at stake in the four futures, and, perhaps, find out if the scenarios can be used to reflect on existing policy paths and explore new roads ahead in their field, are invited to look up our publication (to be published on www.pbl.nl in April 2019).

Notes

[1] Everybody gets a yearly budget of 'planet points': a limited number of environmental credits that are neither tradable nor transferable, and that can be spent on consumption of polluting or energy-intensive products and services.

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Automated Vehicles and Active Transport: Making the Connections

by Dominic Stead

Automated vehicles (AVs) can best support and promote active travel when their access to cities is restricted and their use is pooled. In the absence of these basic conditions, the introduction of AVs in cities could lead to a decline in active travel and an increase in economic, social and environmental costs, many of which remain unmentioned in the mainly positive rhetoric about how AVs might transform cities in the future.

Universal or widespread access for AVs in cities (along the same kind of lines of access that cars currently enjoy in most cities) could lead to a range of detrimental outcomes, not least for active travel and public health. Promoting active travel is crucial for tackling growing health problems of obesity, diabetes and heart disease. This requires changes to the city which engineer physical activity into daily life.

Depending on the specific future conditions under which AVs are allowed to operate in the city, impacts can be expected in terms of: (i) a reduction in the use of non-motorised modes (feet, cycles, scooters, skateboards, etc.) to cover the 'last mile' of travel; (ii) an increase in the amount of space needed in cities for picking up and dropping off car passengers; (iii) segregation of AVs and active transport with restricted points where pedestrians or cyclists can cross AV lanes; and (iv) a growth in travel distances covered by motorised transport as AVs offer opportunities for recreation or work during journeys and increase the travel times that people consider acceptable. All of these impacts have direct or indirect implications for the use of active travel in the city and the health of society.

First, widespread use of AVs in the city might lead to a reduction in the use of active travel in situations where AVs are employed to cover the 'last mile' of travel between, for example, home and the bus stop or between the railway station and school. Currently, access to or from public transport services often involves a short walk or cycle ride for most people. In future, some people may choose to get to the bus stop or rail station by AV instead of walking or cycling. Or people may choose to move away from public transport and switch to AV completely. Clearly, both situations imply a decline in active travel.

Second, with the introduction of AVs, the amount of space needed in cities for picking up and dropping off passengers could increase. At the moment, people get into or out of their cars in car parks (apart from chauffeured passengers) but this is set to change. In future, AVs may not park in close proximity to the destination of their passengers: car parking is decoupled from other land uses. Instead, AVs may take themselves away to another part of the city where parking is cheap (or free). One possible consequence is that existing road infrastructure (carriageway or parking space) will be reallocated for passenger drop-off and collection, leaving little or no space that can be reallocated to pedestrians and cyclists.
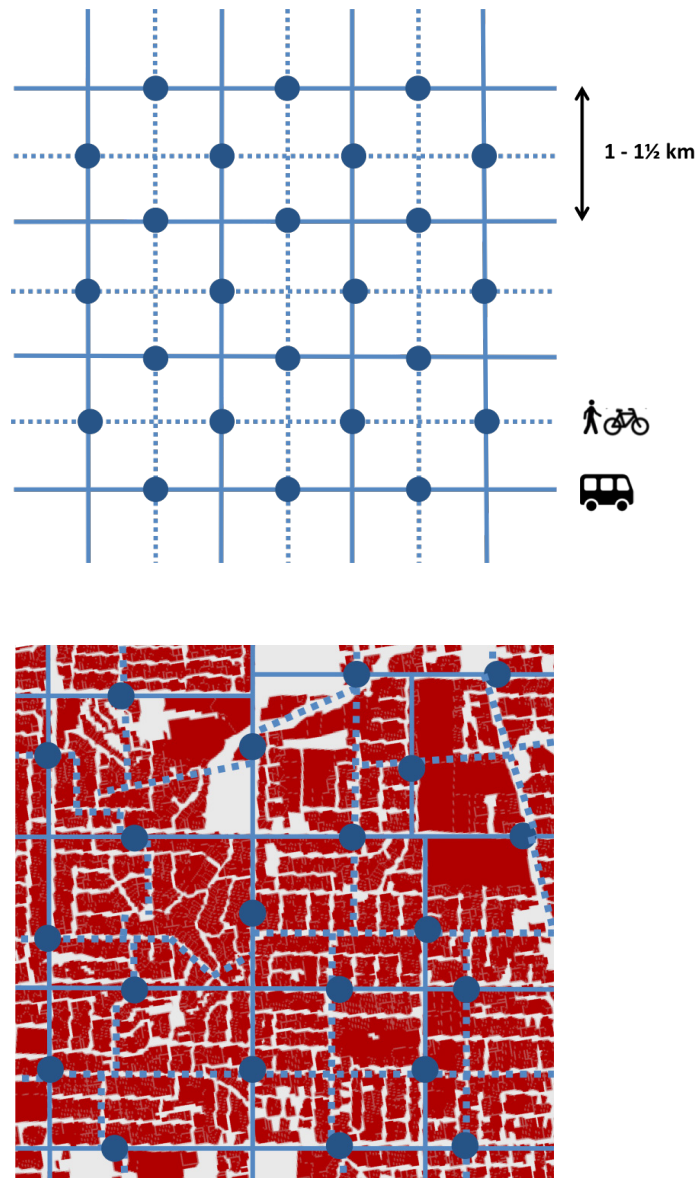
Fig.1 *Basic principles of the network and node design (top), and their application to an existing urban structure (bottom).*

Third, urban environments in which different road users (cars, trucks, pedestrians, cyclists) share the same space are unlikely to be proposed or developed. Although AVs offer the potential to increase road safety, it is likely that they will be kept separate from other road users to reduce the disruption of traffic flow by other road users (deliberate or otherwise) and increase the predictability of AV flow. Segregation of transport modes means that pedestrians or cyclists are only allowed to physically cross AV lanes at specific points, either via signalled crossings or grade-separated routes (such as bridges or tunnels). A problem with the segregation of motorised vehicles from other road users is that it reduces accessibility for pedestrians or cyclists and creates an urban structure that is less 'permeable' or penetrable for active transport with less direct routes.

Fourth, AVs may ultimately lead to an increase in car travel, both in terms of frequency and distance. By offering opportunities for recreation or work during car journeys (instead of driving), AVs may increase the amount of travel time that people consider acceptable. This may not only increase road infrastructure capacity requirements (since vehicles spend longer on the road), it may also lead to the relocation of homes and jobs in the longer term, thereby fuelling urban sprawl and reducing the viability of public transport services. Weakening public transport use is also likely to be detrimental for active travel and public health.

Addressing the negative consequences of AVs outlined above requires first and foremost strong restriction on the level of access afforded to AVs (and other motorised vehicles) in the city. This access should be substantially more restrictive than the access afforded to conventional vehicles at present. Access to the city by motorised vehicle, whether AV or otherwise, should be limited to specific nodes and axes in the city. Here we do not solely refer to restricting access in the city centre but to the whole city. Exceptions for certain users and situations will of course be necessary (e.g. passengers with disabilities; emergency services; construction and maintenance; deliveries of heavy goods).

The underlying logic of vehicular access control in the city should be to channel vehicle movements along a limited number of corridors and locate pick-up and drop-off points at key urban nodes along these corridors. These nodes should be well served by high-frequency public transport services and well connected to a dense network of attractive pedestrian and cycle infrastructure. The aim is to promote fast and efficient node-to-node journeys, rather than door-to-door journeys. Locating nodes say one kilometre apart would mean that the maximum distance to reach the nearest node is half a kilometre *(Fig.1)*, a typical distance used in transit-oriented development (TOD) designs and generally considered to be an acceptable walking distance. Moreover, restricting traffic from accessing other streets in the urban area provides space which can be used almost exclusively for active transport (except for vehicles granted exceptions – see above).

Compared to a situation where AVs are individually owned, a future situation in which AVs are pooled will clearly reduce the number of vehicles required to serve the city and the amount of infrastructure to accommodate them. The pooled situation will have more economic, social and environmental benefits for cities. However, even in the situation where AVs are individually owned, the control of access to selected nodes and axes in the city can still have benefits for the liveability and sustainability of the city and the health of its citizens. Developing the policies and strategies described above requires time and need to be ready soon – well in advance of widespread AV use.

Robocars don't need a driver.
They drive people and then can drive away.

How will Robocars change the 'link' between home and work?

Fitness in the Robocar age?

Parking space can be detached from destintions. Robocars can park away from home...

...and away from work.

Where and when should Robocars park?

Robocars will free streets from car problems: parking, pollution and lack of public space.

Less parking

Less (air, noise) pollution and unsafe speeds

More (quality) public space

Robocars will be guided. Accesibility, routes and speeds will be flexible.

Safer and more shared streets due to Robocars?

Freed-up street parking can create more space for activities and slow mobility.

Slimmer roads and less parking create space to improve major city streets.

Fig.1 *Diagramatic representation of street changes in the Robocar age.*

Streets and Robocars

by Rients Dijkstra and Anca Ioana Ionescu

Robocars: the entire fleet of fully autonomous (self-driving) and connected future 'cars' for people and goods that can be classified as half-robot / half-car, small or large, personal and/or shared. In general literature, they are also referred to as Level 5 (L5) cars (SAE International, 2018).

Streets will change with the widespread implementation of fully autonomous vehicles in the city, just as they changed when the motorcar replaced the horse-drawn carriage. It would be a mistake to let this change be dictated by mobility considerations alone. Robocars might be the next revolution in transport efficiency, but they should also initiate an evolution in spatial quality. They should become a driver for a new age of streets, in which public space is revalued and made safer, accommodating social activities for all ages, with ample capacity for slow modes (e.g. walking, cycling) and improved water management and micro-climate conditions at street level.

Under what conditions can this happen? It has been widely discussed whether Robocars designed to drive long distances at high speeds can be beneficial. Ideally, longer trips could be used to work, rest or play and presumably save time. But fast Robocars do not improve cities; the slow ones do. Robocars could drive at speeds of 30 km per hour or less - depending on where and when they drive. They could also be planned to park themselves in compact mobility hubs spread around cities in locations that are less suitable for homes and workspaces. It is such features of the L5 cars that can open up the possibility for a new balance between the fundamental values that streets must support in our cities: mobility and quality of life.

What will Robocars be like? How will streets change in a Robocar future? And how can Robocars become an opportunity to improve the quality of streets? In response to these questions, this article provides a list of conjectures addressing the future development of Robocars and streets, and recommendations on how their joint development can be guided through urban design.

What will Robocars be like?
With Robocars, the time spent in transit will no longer be considered lost. This way, people might accept spending more time in their cars, living and working further apart, and in consequence stimulating sprawl. However, as Robocars accommodate activities and revalue the time spent in cars, 'rush hour' could become 'slow hour'. Trips could become longer and slower. In such a mobility system, the traffic capacity would be met through adaptive routing, and slow/shared streets (with speeds of 10-30 km/h) can become ubiquitous in cities.

Fig.2 *With less clutter, cars can turn into flexible 'spaces on wheels' to work, meet, eat or relax. When moving between destinations time will no longer be lost. Interior car collages made by the authors on the base image created by IDEO (2014) to illustrate an autonomous car concept as a working space on wheels.*

Robocars will be moving spaces. There will be more freedom in the design of Robocars with the disappearance of the steering wheel and engines becoming smaller. Over time, computers, energy units and safety systems will take up less space and much smaller and lighter cars will become possible. With less clutter, cars can turn into flexible 'spaces on wheels'[1] , which can be customised and used to work, meet, eat or relax while moving between destinations *(Fig.2)*

Robocars are expected to be highly affordable and comfortable as a service. In the coming decades, Robocars delivered as a service are predicted to be from half the price to ten times cheaper than taxis, shared vehicle services or personal cars today (Litman, 2018). Furthermore, personal Robocars are not expected to be significantly more expensive than cars today (Litman, 2018). Yet, with cheap Robocars and too little sharing, vehicle numbers and kilometres driven may increase. On the other hand, the increased attractiveness of sophisticated Robocar services (cheaper, more comfortable, diverse vehicle options) is likely to create a cultural change, cause Robocar sharing to go mainstream and drastically reduce car ownership (Ratti and Claudel, 2016). In addition, due to security issues and the mentioned threats posed by personally owned Robocars, the Robocar fleet will most probably be delivered as a mobility service.

There will be many types of Robocars: public/shared, private or a mix of those, in a wide variety of sizes, qualities, uses and designs *(Fig.3)*. The impact on traditional public transport systems (rail, metro, tram, bus) is yet to be fully understood, but it is very likely that personal mobility and public transport will blend. All surviving modes and types of transport will become part of the mobility service system. During the weekend one might choose from a variety of vehicle models, while going to work one might have the option to ride a small and cheap Robocar, requiring less energy and space. Small Robobuses might become ubiquitous and start to play an important role in the mobility fleet.

PERSONAL TAXI Robocar SHUTTLE Serviced SMALL Serviced ROBOX

(m)any use(s)
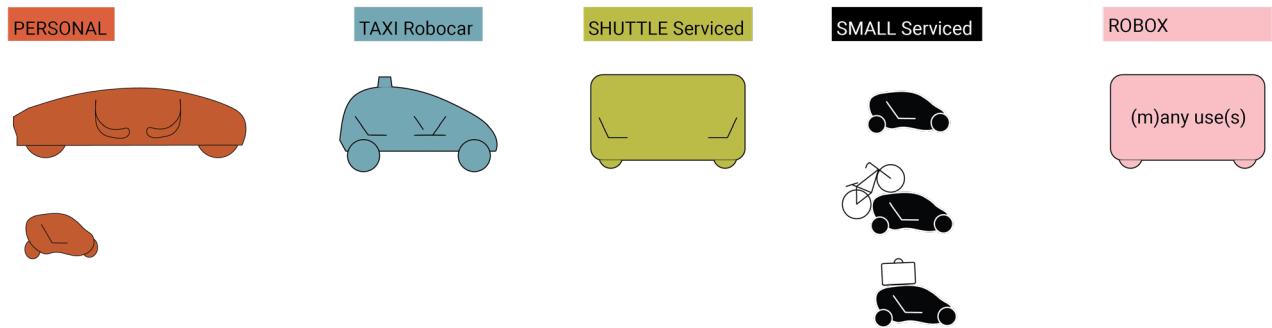
Fig.3 *There will be many types of robocars: public/shared, private or a mix of those, in a wide variety of sizes, qualities, uses and designs. All types of transport (personal, public, autonomous, active) will blend into mobility services, designed to be affordable, confortable and customized to ones needs and urban rules.*

How will streets change in a Robocar future?
Robocars allow for systemic changes in street hierarchies. If Robocars are guided by external operators (human, machine), then they can be assisted in route planning, and speed bandwidths can be dynamically set depending on location and time of day. With such automated, guided and adaptable vehicle behaviour, speed limits on streets can be significantly reduced. On weekends, for example, Robocar speeds can be lowered to the point where the fleet can mix with slower modes (e.g. pedestrians and cyclists) in a shared space. A reduction in the number of car lanes may be possible—for instance by promoting one-way streets—making room for slow mobility, local activity and other land uses.

On-street parking can be reduced as Robocars park themselves unobtrusively, disconnected from people's destinations. In neighbourhoods, personal cars can auto-drive to efficient and compact nearby parking facilities. Robocabs and shared Robocars can retreat to remote locations at night, keeping shared services affordable and competitive. The 'remote parking' capability of Robocars results in large amounts of street space that can be freed up for other uses *(Fig.4)*.

Freed-up street space can support slow and active mobility. Better, safer, more generous slow mobility infrastructure provides incentives for walking, cycling and sports, which are beneficial for people's health. A significant shift in modal split towards the slow modes is encouraged, establishing a positive relationship between mobility automation and active mobility.
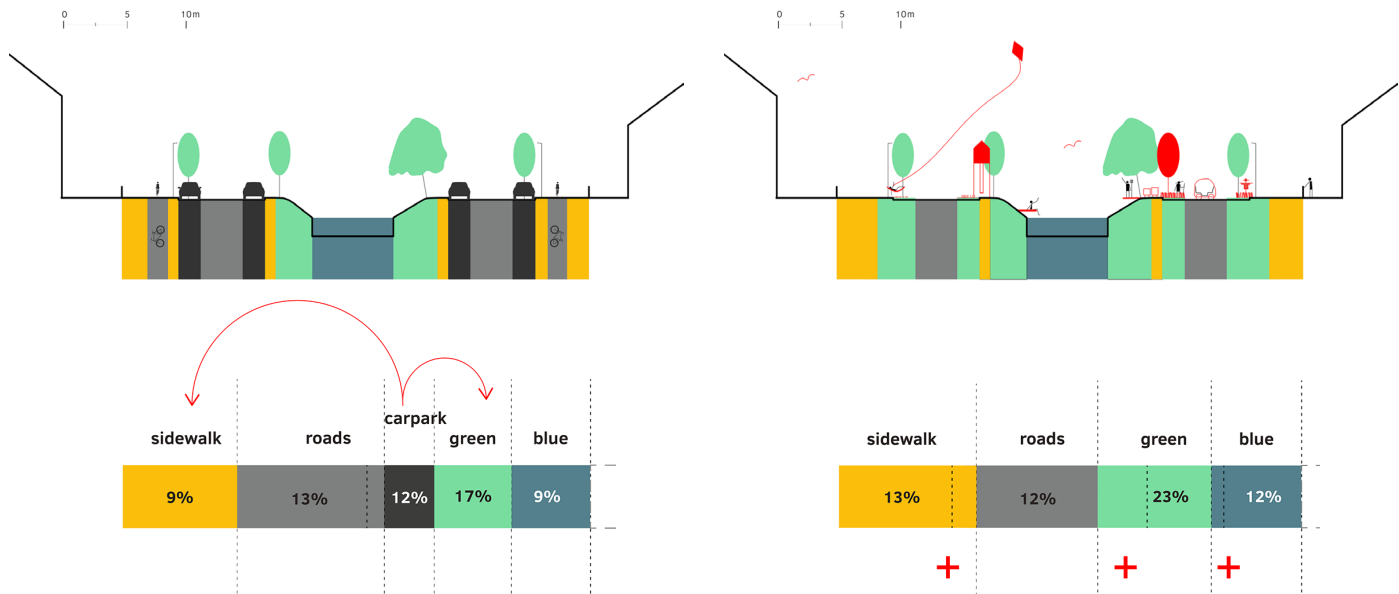
Fig.4 *As Robocars park unobtrusively, on-street parking space can be freed-up and redesigned, as shown in this simulated transformation of a canal street in Rijswijk (left, collage; right, street section).*

Fig.5 *By removing parking and lowering speeds, streets can become quality environments supporting social and economic activities. Amsterdam street 2017 vs. its possible transformation in a Robocar future.*

Freed-up street space can also be turned into green space or space to meet and play.
Depending on its size, location and the character of the surrounding urban fabric, freed-up space can be used to improve a neighbourhood's ecological qualities and microclimatic conditions, to improve public space or even offer space for densification *(Fig.5,6)*. Trees can be added, urban farming encouraged, air quality improved, rain water absorbed. A well-balanced street helps cope with climate issues and supports people's health and well-being (Carmona, 2018) .

By removing parking and lowering speeds, streets can become better-quality environments and can support higher urban densities. Served by (shared or personal) autonomous mobility services, urban design can be less constrained by cars and more considerate towards spatial quality. Densification has economic benefits (agglomeration power and patronage) and can be seen as an opportunity to reduce social segregation. Additionally, the introduction of cultural destinations and small businesses in monofunctional areas, combined with a better-quality streetscape, can improve the socio-economic environment at the street scale.

Fig.6 *Parking space can be detached from destinations and mobility services can provide accesibility to study/recreation/work locations where parking space can be redesigned. For example, the parking at TU Delft Faculty of Architecture can become a park and a place for outdoor exhibitions.*

Recommendations

- **City officials, experts from multiple disciplines and urban designers should engage in the Robocar topic and explore the opportunities for cities beyond the technological discourse.** Tech companies are eager to become the designers and developers of cities, as seen in the case of Toronto's Waterfront[2]. Cities should be human-centred, without the pressure to accommodate tech, whose primary goal is to serve a business model. Tech should serve the city, not the other way around.

- **Urban sustainability must be put on the agenda of Robocar development.** Urban design should guide Robocar technology in support of a number of spatial improvements. For instance, Robocars can be used to reduce the number of cars and parking spaces, promote shared or car-free streets, and enable denser and more mixed-use developments. This way, Robocars would support sustainable land use and streets would be revalued as essential public spaces in cities.

- **A parking approach for Robocars should factor in ownership and sharing.** Robocars for personal use should park closer to destinations in a network of compact mobility hubs spread around the city, in locations less suitable for homes and workspaces. Parking further away from destinations can lead to more driving and empty cars on the move. The less shared and more expensive Robocars are, the closer to destinations they should park. On the other hand, shared Robocars could park further away and be cheaper, making sharing attractive.

- **Explore solutions for the elimination of street parking and relocation in the context of autonomous mobility and highly efficient parking facilities.** On-street parking space can be grouped at efficient parking stations. Parking spaces for personal cars can be accommodated unobtrusively in the urban fabric or can be relocated remotely in the case of shared Robocars. Cities should explore where such parking locations could be and how they should be planned and integrated into the inner city or at its edge.

- **Parking requirements for buildings and urban development projects can be reduced as Robocars and buildings can be detached from each other.** Lower parking requirements open opportunities for cheaper and denser housing or more mixed-use developments (Speck, 2018). In addition, such a development model can be supported by planning, regulating and programming Robocars' speed, accessibility, parking rules and prices as part of a more sophisticated mobility service.

- **Explore the effect of massive temporary or permanent mobility infrastructure downgrade.** Robocars create the opportunity for more streets that are slow, shared and car-free, which would lower pollution and improve well-being. In such a street network, speed, accessibility and parking rules are based on an autonomous mobility system. To that end, Robocars should be slowed in cities to speeds as low as 10-15 km (time in Robocars is not lost!) and street parking spaces should be reorganised and gradually freed up.

The Robocar as an urban project should be undertaken in collaboration between car industries, software developers, traffic planners, urban planners and designers of public space. In order to improve the urban environment, Robocars must be: shared, accessible and affordable to all, delivered as a service, unobtrusively parked, slower, smaller and guided in speed and accessibility. All these characteristics influence how cities will be designed and how they will evolve. Robocars should be regarded as an urban project which combines the consolidation of sustainable mobility systems with making streets healthier and more attractive, in support of higher quality and inherently sustainable cities.

Notes

[1] IDEO (2014) created the concept of automated pods as moving (office) spaces, which was followed by other similar concept vehicles, such as that created by Toyota. In 2017, Space10, IKEA and foam Studio elaborated on this concept and coined the term spaces on wheels (SPACE10, 2017).

[2] Sidewalk Labs (a Google affiliated company) proposed a plan for Toronto's waterfront, in which the vision is a city founded on technology, including autonomous mobility (Scola, 2018).

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CURRENT SITUATION

SUPERBLOCK MODEL

400 meters

400 meters
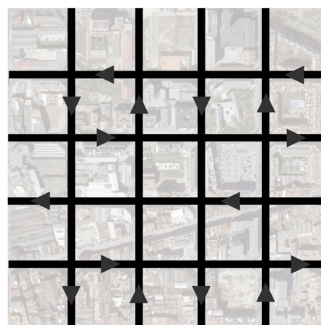
■ Basic network: **50 km/h**
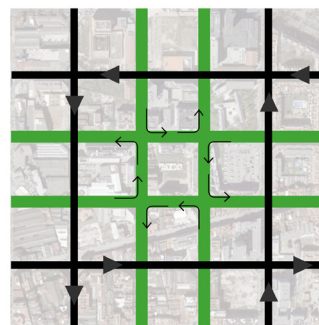
■ Local network: **10 km/h**

CIRCULATING VEHICLES DO NOT PASS THROUGH

SOLE RIGHT IN STREET SPACE: **MOBILITY**
HIGHEST AIM: PEDESTRIAN.

EXERCISE ALL THE RIGHTS THAT THE CITY OFFERS.
HIGHEST AIM: ACTIVE CITIZEN.

Fig.1 *Road hierarchy and accesibility in the Superblock model (bottom); photograph of an intersection in a Superblock (top).*

Superblocks and the Implementation of Autonomous Cars

by Salvador Rueda

The superblock as a concept is an urban cell defined by specialised routes which connect different parts of the city, whether by public transport, bicycle or car *(Fig.1, bottom)*. A superblock covers between 16 and 20 hectares of an urban area. The time it takes for a car to go around a superblock is almost equivalent to the time it takes for a person to go around a regular block. Thus, the implementation of a network of superblocks in a city means that the car is slowed down to adapt to a walkable city.

The specialised pathways defined inside the superblocks are aimed at developing socio-cultural urban usages, such as entertainment, exchange, culture and knowledge, expression and manifestation—a contemporary agora. Inside superblocks, streets become squares, and the liberated area becomes a space that accommodates the rights of all citizens in this 'small city'. To achieve this, it is forbidden to cross the superblock by car. A system of loops allows drivers to access all façade fronts inside a superblock and enables them to return to the same street from where access was made *(Fig.1)*.

At the same time, services and urban logistics are ensured. The trips made on foot and by bicycle can be made in both directions and the maximum speed inside the superblock is 10 km/h. At this speed, the compatibility of uses in the public space is guaranteed. In this way, a blind man who is crossing the street or a child who is playing with a ball are not going to be in danger of traffic accidents. However, they are at risk when the street speed is 30 km/h: statistics indicate that 5 out of 100 fatalities from accidents involving a car and a pedestrian happen at this speed. The intermediate speed of 20 Km/h is suitable for creating a shared space between pedestrians and cars, but not with bicycles. In consequence, the maximum speed allowed in the internal routes of superblocks was fixed at 10 km/h.

The superblocks are the basis of the functional model and system of public spaces for a city. With their implementation, functionality and urban organisation is assured and at the same time, 70% of the public space, which is now dedicated to car mobility can be shared with and released for other uses *(Fig.2, bottom)*.

In order to ensure that the implementation of the superblocks delivers a level of traffic service similar to the current mobility scenario, it would be necessary to reduce, in the case of Barcelona, 13% of vehicles on the road. However, the Urban Mobility Plan of Barcelona proposes a reduction of 21% so that the levels of air pollution are below the limits set by the European Community. With the implementation of the superblocks, and using current automotive technology, pollution has been reduced. Results show that after implementation

Length

912 km

Surface area

1483,6 ha

Barcelona road network (streets and sidewalks)
CURRENT SITUATION

Length

355 km (-61%)

Surface area

815 ha (-45%)

Barcelona road network (streets and sidewalks)
FUTURE SCENARIO WITH NEW SUPERBLOCKS
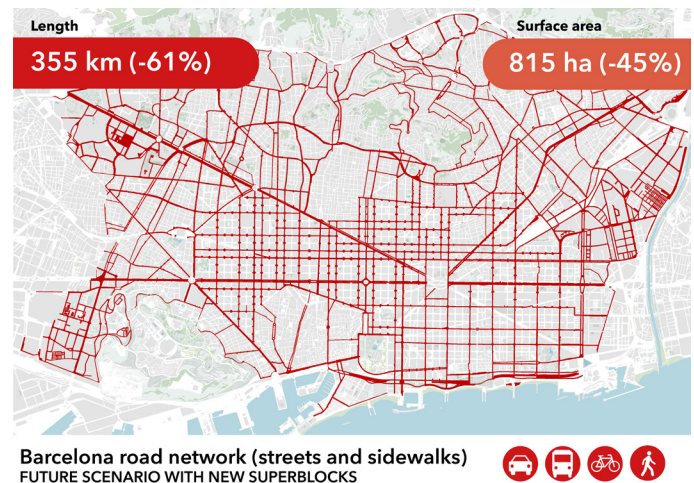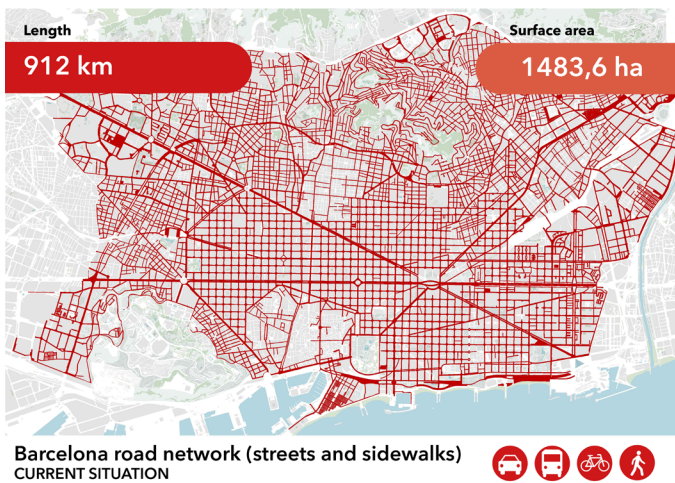
Fig.2 *The Superblock model vs. the current situation at the city scale (bottom): the streets dedicated now to car mobility can be shared with and released for other uses; photograph of a transformed intersection inside the superblock, where road space was turned into a playground (top).*

the urban environment has dramatically changed, as unacceptable levels of pollution have been reduced from 44% to 6% (mainly along the main access roads). In a similar way, noise pollution has also plummeted.

With the arrival of autonomous electric cars, these pollution levels will continue to decrease, yet their occupation of public space will remain. Recreational uses of this space and the rights of citizens to active mobility can only be exercised if we free up the space dedicated to autonomous motorised mobility.

The superblocks allow integration of all transport networks. They also allow for the creation of a true green network, taking advantage of the freed-up space, which is currently occupied by cars. Mobility plans based on superblocks define a new mobility model, with a different modal split and where the hierarchy of transportation in the city prioritises, in the following order: journeys made by foot, public transport, bicycle and lastly, by car. The aim is to limit the percentage of journeys made by car in the city to 10% of daily trips. In a future of autonomous mobility, the goal would be to keep the same low percentage of journeys by car. This way, trips by public transport would be encouraged, as well as other alternative means of slow mobility.

Autonomous cars would enter the superblocks in the same way that cars with a driver do, including the speed limit of 10 km/h. Moreover, the implementation of autonomous vehicles will allow the release of public space dedicated to parking, which is currently an important challenge for many superblocks, as they do not accommodate sufficient indoor parking infrastructure.

Fig.3 *A walk in a Superblock in Barcelona.*

Fig.1 *Parking is the largest single land use in most urban areas in the United States. Image: Parking in Cleveland (top) and Gresham (buttom).*

Urbanism Next:
Autonomous Vehicles and the City

by Nico Larco

We are currently at the start of a potentially massive change that will affect cities around the globe. Advances in autonomous vehicle (AV) technology are progressing rapidly with a growing number of cities testing and deploying these vehicles on their streets. While the rate and geographic extent of widespread deployment are still subject to speculation, the impacts AVs will have on city development, urban form and design when they arrive will potentially be as dramatic as the introduction of the automobile was to cities during the last century.

Projected changes to the ease and cost of transportation, the role of transit, parking use, and right-of-way needs, will have dramatic secondary effects on urban areas. While there has been significant research on the technological aspects of AVs, there has been a dearth of systematic exploration of their secondary effects on city development, form and design, or the potential opportunities and unintended consequences on quality of life. This paper discusses some of these potential impacts including impacts on land use, street design, metropolitan footprints, and urban activity and vitality.

Land Use
AV adoption is likely to significantly reduce or eliminate the need for parking (International Transport Forum, 2015; Zhang, 2015), as fleets of vehicles will pick up and drop off riders without the need for vehicles to be stored at destinations. Services such as Uber and Lyft have already demonstrated potential impacts, using the same model of passenger transport. The growth of these services is correlated with the drop-in parking use in major cities and airports (Morris, 2018; National Academies of Sciences, Engineering, and Medicine, 2017). A continued reduction will cause significant changes to land use as parking is the largest single land use in most urban areas in the United States (Shoup, 2005) *(Fig.1)*. Parking also occupies a significant amount of land in cities throughout Europe.

For instance, the reduction of parking could lead to an increase in density in core areas, as space for parking is no longer required and parking lots can be infilled with development. This is projected to drastically increase property values in core areas where increased density is desirable as more income generating development can be put into smaller parcels (Skinner, 2016). This shift might mostly affect suburban areas which are dominated by parking. These areas may see an increase in mixed use as former parking areas are redeveloped. Suburban office parks that no longer need large expanses of parking might be inclined to shift to locations that offer more amenities and services such as restaurants and shopping opportunities. Additionally, land uses which have previously been unfeasible at specific locations due to the cost of providing parking, could now become economically viable, shifting where certain uses – notably housing – occur within the city.

Street Design
The adoption of AVs could lead to dramatic changes in street design *(Fig.2)* including: narrower lanes, potential reduction of number of lanes due to more efficient vehicle throughput, and, as stated above, the reduction or elimination of on-street parking (Chapin, 2016; Bell, 2016). As the available right-of-way width is one of the largest limitations for creating multimodal street design (McCann and Rynne, 2010; National Association of City Transportation Officials, 2013), the opportunity for reclaimed right-of-way space could be a tremendous boon for creating robust multimodal infrastructure and increasing walkable and bikable communities. Conversely, AVs are projected to dramatically increase trip generation rates due to increased ease, affordability, and more positive use of time during travel (Bierstedt, 2014; Childress, 2014; Fagnant, 2015, 2016; International Transport Forum, 2015; Schoettle, 2015). This might lead to increased congestion, creating pressure to replace the regained street space with additional vehicle travel lanes.

With the reduction of parking, buildings will be able to move closer to the street and will no longer be separated by a sea of cars. This will open up the possibility for buildings to frame the street space, narrowing the perceived street section and increasing the number of entrances and 'eyes on the street.'
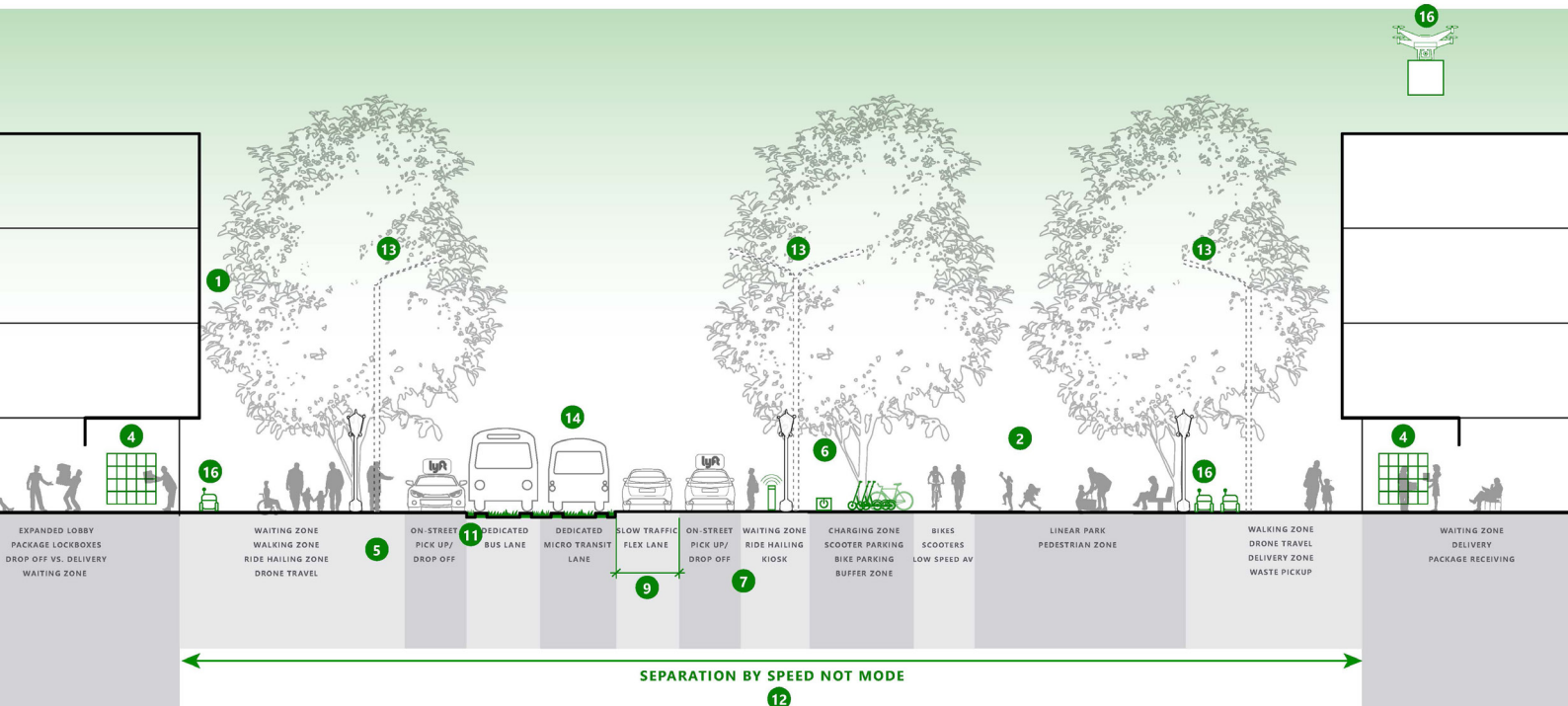
Fig.2 *Changes that autonomous cars may create in street design, according to an urban design study by Urbanism Next.*

1. STREET FACING BUILDINGS

Because we will no longer need off-street parking in front of buildings, buildings can engage the street directly
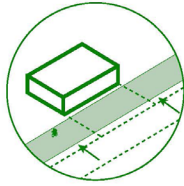
2. OFF-STREET PARKING

Reduction of required off-street parking would allow for buildings to get closer to the street therefore improving building-street interactions
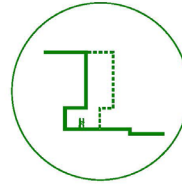
3. LOBBY EXTENSION

The role of the lobby may shift to accomodate increased demand for waiting areas and package receiving, therefore expanding closer into the street.

4. PACKAGE LOCKBOXES

Package lockboxes for online shopping may become a common feature near the entrance of buildings for ease of deliveries. They could be on the exterior or interior of the building

5. PICK-UP/DROP-OFF

Increased ridesharing demand will require increased pick-up and drop-off locations. On-street vs. off-street pick-up and drop-off will have profound impacts on streetscapes and urban form.

6. TECHNOLOGY ZONE

The sidewalk will need to accomodate emerging street hardware such as ride-hailing kiosks, drone charging stations, electrical scooter parking, etc
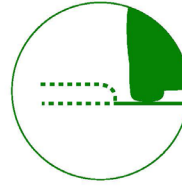
7. CURB DESIGN

Safe autonomous vehicles might lead to rethinking the design of the curb and how necessary it will be for the future

8. PED-CAR BARRIERS

Barriers protecting vehicle lanes from disruptive pedestrian interactions in the case of social unrest
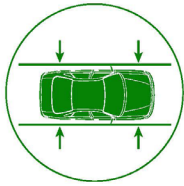
9. LANE WIDTH

AVs could reduce lane width to 8'

10. ROAD SIGNAGE

Smart, interconnected AVs could lead to a reduction of car-oriented road signs

11. ROAD PERMEABILITY

With smart AVs, we could reduce the amount of impervious surfaces on the road to reduce stormwater runoff
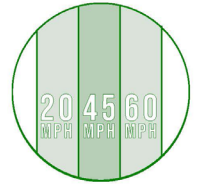
12. SEPARATION BY SPEED

In order to manage lane conflicts as well as optimize the roadway, lane separation may be based on speed instead of mode

13. STREET LIGHTING

AVs will reduce the need for car-oriented lighting, therefore reducing light pollution from conventional street lamps. Street lighting may be focused on pedestrian paths instead

14. MICRO TRANSIT

Publicly or privately operated, nimble transit systems offering fixed schedules or on-demand services could serve low-density region and connect them to the urban core
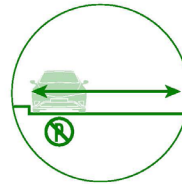
15. ON-STREET PARKING

Reduction of on-street parking would allow for more right-of-way to be used for other necessary services

16. DRONE DELIVERY

Roofs may have to have infrastructure to accomodate aerial and terrestrial drone deliveries

An additional area of impact for streets will be the curb, as AVs potentially shift the place where people enter and exit vehicles, away from the parking lot and onto the street. Dense urban streets are already impacted by an increase in pick-up and drop-off activity, placing a substantial burden on curbside capacity and with further impacts on congestion (Fehr & Peers, 2018, 2019). This could lead to a restructuring of curbside areas and the re-design and re-allocation of space.

Metropolitan Extent - Density and/or Sprawl
AVs will potentially increase the distance that individuals are willing to live from central cities in two ways. First, as AVs are predicted to increase travel speeds on arterials and freeways, commuters will be able to travel further while keeping the same travel time. Second, as travellers no longer need to pay attention to the road, individuals might be inclined to increase their commute time, as their use of time in an AV shifts from a low value activity of driving to higher value activities such as working, eating, or sleeping. This will allow individuals to live even further from city centres.

If housing location preferences are motivated by the desire for cheaper land, virgin land, or proximity to natural areas, then the increase in the ease of commuting due to AVs will increase the pressures to develop on currently undeveloped land and will stimulate sprawl (Anderson et al., 2014; Le Vine and Polak, 2014). This expansion to the metropolitan footprint could mimic the degree of urban growth seen following the introduction of the automobile in the last century and exacerbate existing environmental, social and economic impacts created by cars.

Activity/Vitality
The advent of AVs will create both opportunities and challenges for urban vitality - the measure of daily activity, events, celebrations, and use of an area (Montgomery, 1998). Street vitality and economic activity created by people walking between destinations and parked cars in urban areas might be dramatically reduced, as AVs deposit people directly in front of their destination and potentially reduce walking trips to and from parking spots. Additionally, as mobility becomes easier with AVs, individuals may become more selective about where they spend their time, less focused on ease due to proximity and more focused on quality of place. This trend is already affecting the vitality of retail areas (Synchrony Financial, 2016) and might now shift activity towards areas that offer engaging experiences and environments as opposed to merely proximity. This will pose a true opportunity for designers to highlight the importance of design quality in urban areas.

Conclusion
The impacts of AVs will go well beyond impacts on transportation *(Fig.3)*. This emerging technology has the potential to dramatically shift urban form and development, including changes to land use, street design, metropolitan footprint and urban activity and vitality. The outcome of this change is not a forgone conclusion and instead can largely be shaped by the policy and design approaches communities can bring to this new challenge. Cities must be proactive and must think ahead to understand potential impacts and the levers available to help shape them. This will allow cities to best take advantage of the potential of AVs while avoiding the pitfalls they might bring.

URBANISM NEXT | FRAMEWORK

LAND USE

SECONDARY IMPACTS

RETAIL/COMMERCIAL/OFFICE/INDUSTRIAL (EMPLOYMENT USES)
How will the changing nature of travel, employment and shopping impact retail, commercial, and industrial districts?

HOUSING
What are the opportunities to increase housing through infill? Will people choose to locate in cities? Or move farther out in the suburbs?

PARKS & OPEN SPACE
How do we protect open space under the pressure to expand cities? What opportunities are there to reclaim parking lots for parks?

URBAN DESIGN

METROPOLITAN FOOTPRINT
When proximity to workplaces and goods/services is no longer holding people in cities, what will happen to their already sprawling footprints?

STREET DESIGN
As cities make plans for future expansions, changes to their street network, the inclusion of various modes/complete streets, and overall street design – what should they be considering?

CENTERS AND CORRIDORS
Will AVs support transit to strengthen current nodes and corridors or will they lead to more dispersal with continuous low-density development?

DENSIFICATION
How and where will AVs and new mobility increase or decrease development density?

PLACE/IDENTITY
When shopping and transportation can be acquired anywhere, what happens to business districts, shopping districts and neighborhoods?

PARKING (URBAN FORM)
How will reduced need for parking impact urban form?

TRANSPORTATION

WALKING
How will we regulate the interactions between pedestrians and vehicles? What happens when pedestrians can stop AVs by simply stepping into the street?

BIKING
Will the mixing of modes be frowned upon because it is such a limitation to AV efficiency? Will some areas ban bikes? How will bikes work around curb-side deliveries and dropoff.

PARKING (TRANSPORTATION)
What happens if parking utilization needs drop dramatically over a short period of time. How quickly will parking requirements shift with that?

VEHICLES
One of the biggest questions is: Preliminary models of individual ownership of AVs show VMT increasing dramatically. Will AVs be fleets or individually owned?

TRANSIT
Transit faces many challenges including economic displacement, demographics, and ridesharing. What happens to transit when AVs are deployed?

REAL ESTATE

LAND VALUE
A reduction in demand for parking will open up between 10% and 20% of land for redevelopment. How will this impact land value and project feasibility?

PROJECT FEASIBILITY
Development will likely get more risky as market conditions related to parking demand and commercial and retail viability change. How do we reduce risk?

BUZZ/VITALITY
What will draw people to places in the future? How important will entertainment factor in to where people want to congregate? How do we create "buzz"?

QUALITY
If location in relation to other areas of the city is no longer a strong factor in housing/commercial building location, will quality of design become more relevant in attracting and keeping people in cities/neighborhoods?

IMPLICATIONS FOR ...

EQUITY
How will the impacts of emerging technologies impact vulnerable and low income populations? What opportunities are there to improve services and reduce inequities?

HEALTH
Preliminary research finds that people are replacing walking, biking, and transit trips with rideshare services. If this trend continues and is exacerbated by AVs, what will the impact be on our health? What are the impacts of E-commerce on health?

ENVIRONMENT
How can we take advantage of emerging technologies to improve sustainability and environmental outcomes? Can we reduce GHG emissions? Can we improve stormwater treatment?

ECONOMY
Up to 4 million people drive for a living. What happens to their jobs with the deployment of AVs? Brick-and-mortar stores are closing as shoppers go online. How will emerging technologies disrupt the economy?

GOVERNANCE
Emerging technologies will disrupt revenues for cities, counties, and states. How do we provide a great level of service and support thriving communities?

RESPONSE

WHAT SHOULD WE DO?
Given the possible range of secondary impacts of emerging technologies on land use, urban design, transportation, and real estate, and the implications on equity, the economy, and the environment, how should governments, companies, and institutions respond to maximize the benefits and minimize the risks? How do policies, programs, and infrastructure investments need to adapt and change?
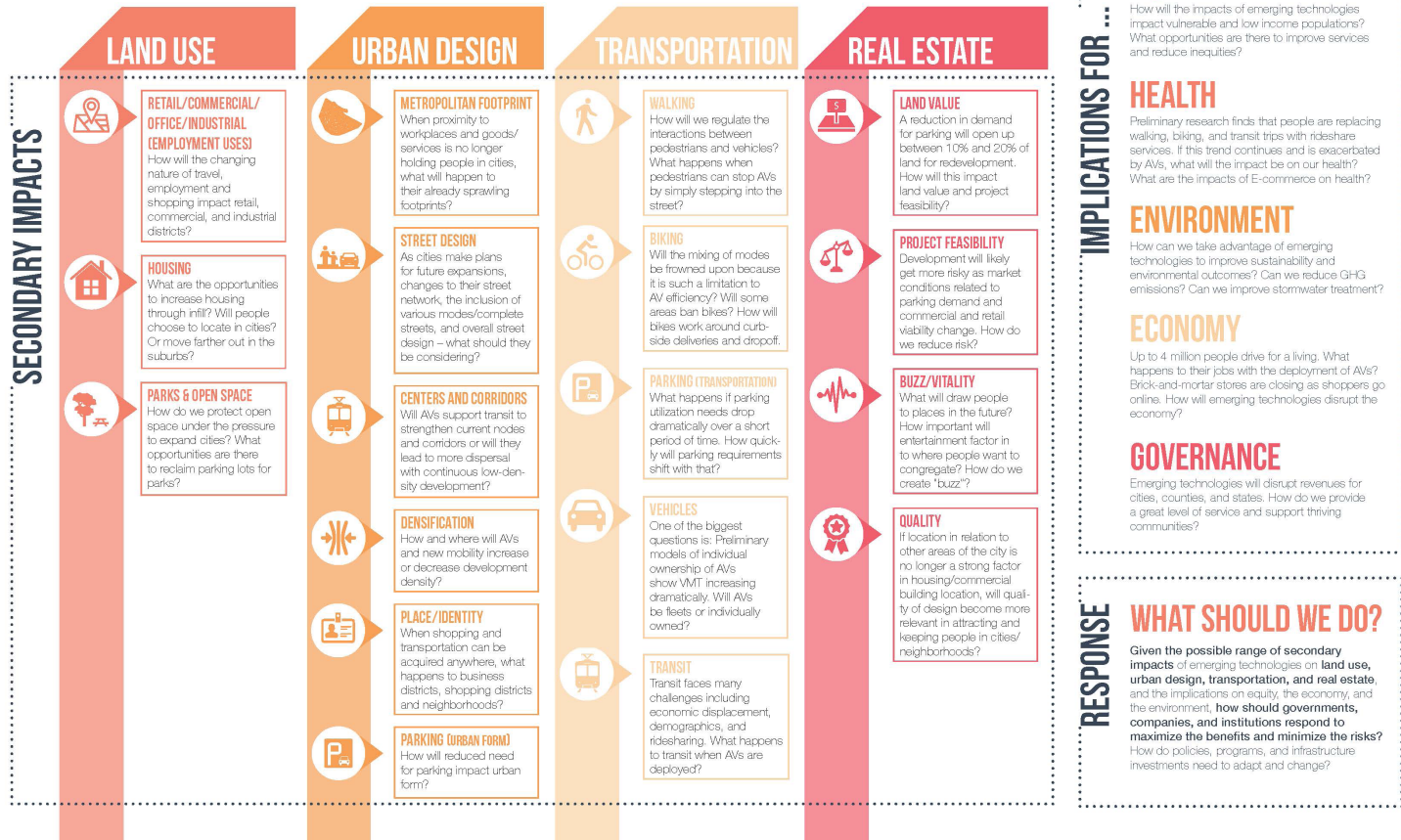
Fig. 3 *The impacts of AVs will go beyond transportation. Framework to understand these impacts by Urbanism Next.*

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The Driverless City and Its Discontents

by Mathias Mitteregger and Emilia Bruck

It took time, but automated vehicles (AVs), promoted by the automotive and IT industry, are finally taking urban planning and architecture by storm. Coinciding with this new technology, once infrequently used planning methods now proliferate; scenario planning, in particular, is the method of choice to explore not only the driverless city, but urban futures in general.[1] Within Avenue21, a multidisciplinary research project at the Faculty of Architecture and Spatial Planning of TU Wien, we developed narrative scenarios that build upon the following methodological reflections. We raised the question, how can planning practitioners, who are struggling to understand this technology in its infancy, take a proactive stance while keeping in mind the urban challenges cities face at the beginning of the 21st century. The scenarios were thus developed to deliberate on the question, where could AVs contribute to achieving urban development goals and where would they undermine them.

Linear versus structural scenarios
Considering the proliferation of scenario planning in urban design and related disciplines, it is helpful to briefly look at some of the criticisms of this method. As a strategic planning tool, both for military and monetary uses (Swart et al., 2004), scenarios were originally used to systematically frame uncertainties and conceive alternative pathways based on previously defined key factors and trends. This is useful when anticipating potential draws of martial or business competitors. However, "serial history" (Le Goff & Nora, 1985, p. 14), or a linear reading of historical developments, has been challenged due to causality being constructed *ex post* and the negation of historical contingency (Foucault, 1972). Furthermore, due to a prevailing fetish with "great men" and their biographies (Spencer, 1873, pp. 26-33).[2] Nonetheless, scenarios that construct successions of events *ex ante* are the predominant methodology to explore the future of the urban condition transformed by AVs (Beiker, 2015; Stanford, 2015; Tillema et al., 2017; EBP, 2018).[3]

To add a different perspective to the insights of existing studies, the scenario method used in Avenue21 focuses on structural relations, qualitative effects and ambivalences. In doing so, we build upon a line of thought in architectural and urban theory which dates back to the early Modern days and focuses on the elements thvat constitute a city and its resulting urban dynamic. As Loos (2000) already observed in 1908, the modern city is structured by the coexistence of different temporalities and lifestyles. Another important decision was to challenge the assumption that AVs would be available in cities without any functional limitations. What if, maybe for decades, AVs will operate in some areas, while others remain unfeasible for this technology?

	MARKET-DRIVEN APPROACH	POLICY-DRIVEN APPROACH	COMMUNITY-DRIVEN APPROACH
AGENDA	Development challenges are considered opportunities that can be solved with the right technology.	Development challenges are met with specific policy measures by the responsible level of government.	Development challenges are met on a local level by self-empowered groups and communities.
GOALS — **INHERENT LOGIC**	Efficiency, Competition	Legitimised by the general public	Diversity
ASSUMPTION	Mobility as a Business Model	Multi-Modal Mobility System	Sufficiency-based, Peer-to-Peer Sharing
NECESSARY PRE-CONDITION	Policy liberalisation for private sector investments	Public acceptance	Change in power dynamics, value-based social change

MARKET-DRIVEN

POLICY-DRIVEN

COMMUNITY-DRIVEN

CITY-REGION

Operationally optimised locations along central transit routes

Polycentric development of multi-modal transport nodes

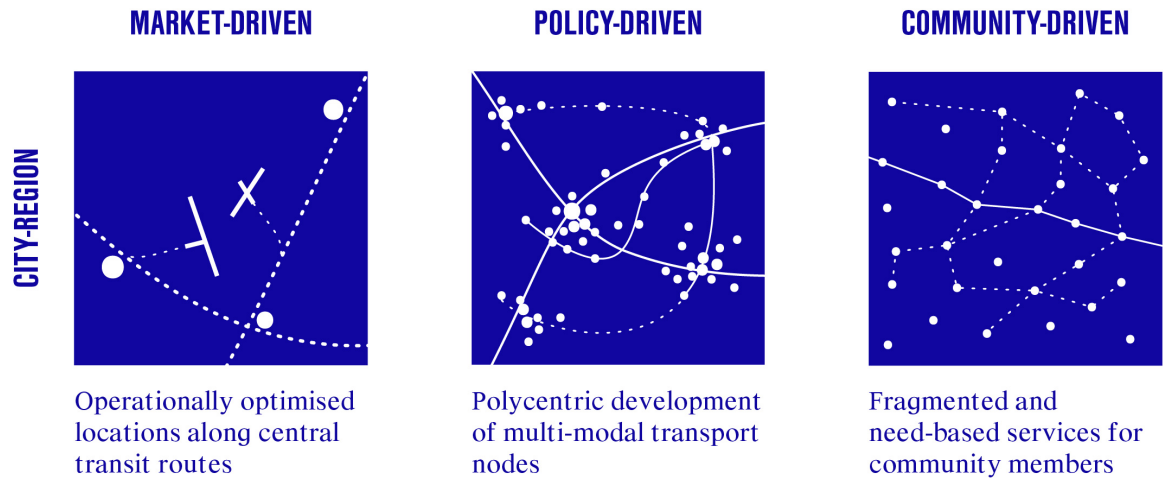Fragmented and need-based services for community members

Fig.1 *Scenarios overview (top) and typologies of spatial transformation (bottom).*

Worldviews and logics of operation as key factors

We developed the narrative scenarios in a transdisciplinary process. In many iterations, scientific and non-scientific stakeholders collaborated in order to elucidate the possible roles of planning and governance in shaping the driverless city. The research team then framed possible developments within three distinct worldviews *(Fig.1, top)*: The Market-Driven Approach, The Policy-Driven Approach and The Community-Driven Approach.

They differ with regards to *(Fig.2)*:
• the dominant rationale in planning and governance;
• the main drivers of change;
• their assessment of main urban development goals and the means applied to achieve them;
• the spaces of transformation;
• and the deployed use cases of AVs (as well as the effects on the existing transport system).

Alternative future narratives & urban implications

In a **Market-Driven Approach**, private mobility providers establish self-driving ecosystems, which people navigate using customised service packages. The deployment of AVs, and resulting technological efficiency gains, are limited to priority routes along highways and within individual housing developments or office and retail clusters. These smart 'edge cities' benefit from the proximity to the transnational highway network. Their spatial development, however, remains selective. The willingness of private actors to invest in infrastructural adaptations such as road lanes, digital infrastructure, hop-on/hop-off areas or automated car parks, determines the spatial distribution of and quality of access to automated mobility services. The early adoption of AVs within such edge cities *(Fig. 1, bottom)* enhances technological innovation and accelerates the development of AVs for people, goods and services. While individual ridership remains the preferred travel mode choice by high paying customers, many others rely on shared services at more affordable prices, which are often less convenient to reach. This scenario reveals several spatial challenges, such as the potential increase in suburban sprawl and the design of thresholds between automated and non-automated routes and environments. Moreover, infrastructural adaptations increase spatial barriers and undermine walkability beyond the perimeter of edge cities. The tension between technological progress and uneven spatial, technological and social access is in this case reactively met by governance and planning.

An integrated multi-modal transport network lies at the core of the **Policy-Driven Approach**. Despite financial constraints, the metropolitan government provides physical and digital infrastructure in order to secure technological standards and maintain governance over generated data. An overarching mobility platform and travel card eases inter-modal travelling by automated public automated transport (shuttle-buses, trams and subways) and micro-mobility-services such as e-bikes or scooters. In order to counteract excess traffic due to an increase in delivery and service vehicles, the urban distribution network is revised, regional distribution centres are built and municipal distribution is licensed. Newly developed transport nodes, located between areas of high and low AV feasibility, integrate the mobility of people and goods and become new urban centres which catalyse densification. As part of such transit-oriented developments (TOD), the existing highway network is integrated into the urban fabric in order to establish coherent urban environments and provide transfer zones between regional and local mobility. Everyday functions and public amenities are clustered in order to increase walkability and cycling. A disparity remains between the densification along central urban growth axes and the hinterland.
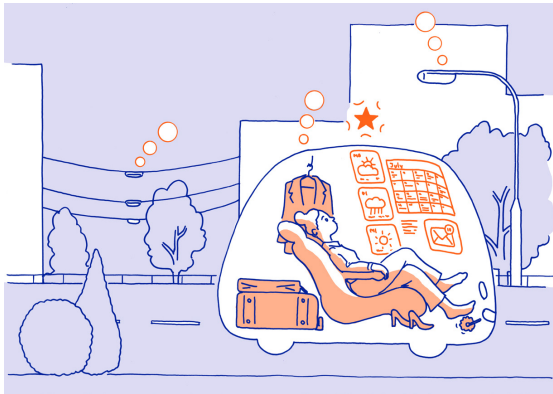
MARKET-DRIVEN APPROACH

POLICY-DRIVEN APPROACH
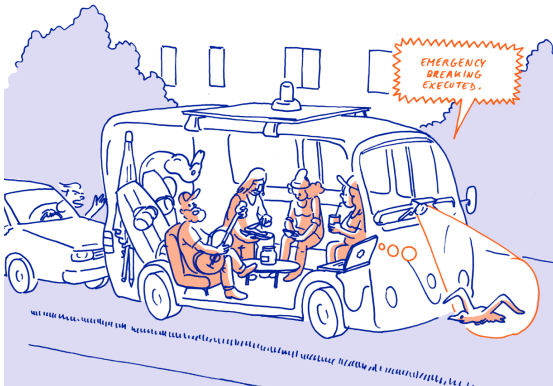
COMMUNITY-DRIVEN APPROACH

KEY FACTORS

Dominating rationale in planning and governance

Main drivers of change

Urban development goals

Spaces of transformation

Use cases of AVs

Fig.2 *Future mobility scenes within the three narrative scenarios.*

Empowered individuals and groups, who create AV services according to their local needs, characterise the **Community-Driven Approach**. They act as pioneers of a technological, but sustainable and sufficiency-based mobility transition. As such, they seek out strategies to avoid excess traffic and prioritise active mobility. Striving for social value creation, like-minded communities might be spatially fragmented, but draw their strength from a global network and knowledge. Uniting their resources, they collaboratively develop civic technology services and improve the quality of urban environments. AV services are developed for peer-to-peer sharing of rides or transport of goods across the city region, connecting destinations of interest to the community and establishing mobility options for social groups who were previously immobile. AVs travel at low speeds in order to navigate all road types. Hence, shared spaces are favoured on a neighbourhood scale, enabling liveability and appropriation of urban streetscapes. Mobility arrangements in the community-driven scenario face ideological frictions, public scepticism and the risk of short-lived success due to value-based beliefs and selection of participants. Community initiatives act as motors for change by seeking novel solutions to social, urban and mobility challenges. But, without respective adoptions and stabilisation efforts by the government, their scope remains spatially and socially constrained.

Conclusion

The three narrative scenarios emphasise that the impact of AVs on the urban fabric, mobility use and social relations depends on policy and planning approaches, as well as the diversity of involved stakeholders. While technological transitions happen globally, it is possible to shape alternative trajectories on a metropolitan or neighbourhood scale. However, looking back at the transition towards the automobile city, architecture and planning practitioners need to be aware of the fact that systematic change is impossible to foresee and even more difficult to control. Considering various urban futures and anticipating unintended consequences together with diverse stakeholders is an important starting point in developing contextual strategies. Short-term and location-specific urban interventions can serve as real-world explorations but require transdisciplinary collaboration and an overarching strategic trajectory. Thus, urban planning visions need to provide a navigational context, but should remain flexible and open enough in order to adapt to changing circumstances.

Notes
[1] For a historic overview on the use of scenarios in the Dutch planning context, see: Salewski, 2010.
[2] It is enough to consider today's obsession with media personalities such as Elon Musk to appreciate the revival of this contested, but always influential, concept.
[3] Other examples are the studies conducted by consultancies, restlessly searching for who, be it a great company or a public figure, might take the next step to advance technological developments. See: Roland Berger, 2014; KPMG, 2018; Welch & Behrmann, 2018.

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Fig.1 *LIDAR rendering in real-time a 3D image of the environment around a car. Photo in an automated car by Steve Jurvetson.*

Readiness
by Víctor Muñoz Sanz

Devised by KPMG International, one of the largest consultancies in the world, the Autonomous Vehicles Readiness Index (published for the first time in 2018, with a subsequent edition in 2019) assesses the "openness and preparedness" of twenty countries to future, autonomous mobility systems. To do so, the index weights data across four areas, namely: policy and legislation; technology and innovation; consumer acceptance; and infrastructure. Based on this per country analysis, the report concludes with recommendations for policy-makers on how to create the "conditions for success" in the AV revolution.

Holding pole position when it comes to readiness is seen as a guarantee for capturing the many advantages that the transition to AVs will entail. Benefits will be social and economic, KPMG argues: millions of lives lost by human error will be saved; the elderly, disabled people, or those without access to public transport will gain mobility; if AVs are electric, air quality will improve; and the many hours spent commuting will no longer be unproductive, as these could be used for sleeping, consumption, or working. All these are benefits embraced in many emerging spatial visions of an environmental, economic, and human friendly deployment of AV technology. However, it makes sense to ask whether global consultancies and corporations—powerful actors shaping policy agendas across the world—might be simultaneously imposing a set of expectations and conditions on the built environment that are less seductive.

In order to understand what it means to be ready for AVs from a spatial perspective, it is particularly interesting to look at what it means to be 'ready' in terms of infrastructure in the report. On the one hand, this will give a sense of what type of infrastructure will, potentially, be stimulated by autonomous mobility systems. On the other, it will expose which elements and characteristics of today's infrastructure are to remain unchallenged or even intensified to support the shift to autonomous mobility.

Concerning the first question, for the AV revolution to unfold, it will necessitate the construction of additional digital and energy infrastructure. This is clear from some of the factors used to assess preparedness: density of electric vehicle stations, 4G coverage, and the performance of mobile internet connectivity, as measured in affordability, content, services, and consumers. In fact, for the sake of safety and efficiency, AVs need to be connected in real-time, to get updated information on road conditions, and to communicate with other AVs. On top of that, for AVs to fulfil sustainability expectations, they will need to use, and charge their batteries. As such, on-road telematics and signage, charging stations, windmills, solar panels and the like, will bring about a new generation of smart roads.

However, as sophisticated as such a road system sounds, the report suggests that AVs will not mean, at a more fundamental level, a ground-breaking approach to mobility infrastructure. Of all the factors analysed, quality of roads is the parameter with the most powerful connection with the built environment. The data is extracted from the World Economic Forum's Global Competitiveness Report. There, quality of the road network is an index considering two elements: the average speed of a driving itinerary linking cities with a higher share of population and weight in a country's economy, and "a measure of road straightness," based on data from Open Street Maps and Google Directions. Further, quality is measured based on surveys of the road system's extensiveness and condition. On top of that, the 2019 report points at the need to segregate mobility systems. It states the difficulty of deploying AVs in an urban environment where the road is shared with other users on foot or using other modes of transport, namely bicycles. In sum, AVs would need a widespread, exclusive, efficient, and well-maintained and designed infrastructure to thrive.

In a way, legitimised by their expected benefits, designing infrastructures with AVs in mind holds the potential to not just perpetuate existing path dependencies—the modern paradigm of mono-functional infrastructure—but also trigger self-reinforcing mechanisms that lead towards mobility systems and an experience designed only with the car in mind. In fact, generating such self-reinforcing mechanisms is in some way embedded in the technology AVs use. As Jack Stilgoe has noted (2018), AVs are far from being an autonomous force, but are shaped by human assumptions, technical constraints, and economic interests. AI and machine learning, the brain of AVs, are learning by reading and assimilating the world and its infrastructure as it is now *(Fig.1)*. As such, AVs could lead to the perverse effect that infrastructures that were designed around humans—shared roads, pedestrian streets—will need to be "upgraded in order to become machine-readable" (Stilgoe, 2017).

In spite of the advantages AVs may bring, their outcome and how it may manifest in the built environment could be problematic. It appears that the pressure for efficiency and safety means that we will witness a conflict between the logic of social appropriateness—concerned with satisfying the expectations society has put on how AVs will transform space —and the logic of instrumentality—simply concerned with making the system work. Only after exploring and engaging with the rhetoric of the AV debate, the spatial potential of the technologies that make them possible, and the actors that shape their deployment, will we be able to get a more nuanced perspective on the spatial implications of AVs, and what the position of the spatial disciplines should be in steering the mobility transition.

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The Talks

Session 1: Mobility Transition and its Spatial Implications
chaired by Víctor Muñoz Sanz

Dominic Stead: The Transition towards Autonomous Mobility

David Hamers: Exploring futures of urban regions and their transport systems by multi-dimensional scenario building

Rients Dijkstra and Anca Ioana Ionescu: Robocar and the Re-Designed Street

Session 2: Revaluing Public Space
chaired by Rients Dijkstra

Salvador Rueda: Shared Streets and Livability, The case of Barcelona Superblocks

Frans van de Ven: Calculation and Co-creation of Climate Resilient and Attractive Urban Space

Florian Boer: The Value of Green-Blue Space in the City: Livability, Climate Change, Revenues.

Session 3: Urban Design in the Context of Automated Mobility
chaired by Dominic Stead

Nico Larco: The Urbanism Next Research Initiative: Understanding the Impacts of Emerging Technology on Cities

Mathias Mitteregger and PhD Emilia Bruck: The Driverless City and Its Discontents, Exploring alternative urban futures through normative-narrative scenarios

Arthur Scheltes: Driverless vehicles, a major game changer in urban mobility. Where are we now, and where to go?

Rients Dijkstra

Anca Ioana Ionescu

Dominic Stead

Víctor Muñoz Sanz

Salvador Rueda

David Hamers

Frans van den Ven

Florian Boer

Nico Larco

Mathias Mitteregger

Emilia Bruck

Arthur Scheltes

Biographies

Rients Dijkstra (1961) graduated in 1989 as an urban planner at TU Delft. After graduating, he worked for the ArchitectenCie and the Office for Metropolitan Architecture (OMA). With his own company Maxwan, he has worked over the past twenty years on master plans for, among others, Leidsche Rijn, Leiden Central Station, Rotterdam Central Station, Antwerp Ring and public space and districts in Moscow. Since 2012 he has been a Government Advisor for Infrastructure and City. In this capacity, Dijkstra advises the national government on spatial programs and themes such as cohesion in mobility and city. In 2018, Rients Dijkstra together with Han Dijk and Emile Revier co-founded PosadMaxwan.

Prof. Rients Dijkstra (Professor of Urban Design at the Faculty of Architecture and The Built Environment, TU Delft, and co-founder of PosadMaxwan)

Anca Ioana Ionescu is a researcher in Urbanism at TU Delft, working on the relation between autonomous cars and urban space. Ioana obtained two Master degrees, in architecture and urbanism. She studied at Ion Mincu University of Architecture and Urbanism in Bucharest (MArch), The Architecture University of Sheffield (Erasmus scholarship in architecture) and Faculty of Architecture and The Built Environment, TU Delft (Cum Laude, MSc). In her projects, she worked from the building scale to city scale and territorial design, exploring on different time scales through scenarios and future images. She was part of the winning team for Le:Notre International competition (2016) for the strategic reintegration of the Colentina chain of lakes in Bucharest. Her focus is on sustainable spatial transformation in relation to autonomous cars, green-blue infrastructures, rural-urban integration, and under-used space. The relation between users and spatial design always played a key role in her projects, leading to methods which involved locals and stakeholders. Amongst other collaborations with architecture and urbanism offices, Ioana worked at Palmbout Urban Landscapes.

Anca Ioana Ionescu (Junior Researcher at the Faculty of Architecture and The Built Environment, TU Delft)

Víctor Muñoz Sanz is a postdoctoral researcher at the Department of Urbanism of the TU Delft. His work examines the notion of workscapes, that is, the architectures and territories of human and nonhuman labor, and the spaces shaped by initiatives and innovations of industrial entrepreneurs. Related work includes Networked Utopia (his doctoral dissertation), the audio-documentary Off:Re: Onshore (Canadian Centre for Architecture, 2018), and his involvement in Cities of Making (TU Delft) and Automated Landscapes(Het Nieuwe Instituut). He holds the degree of Architect from the School of Architecture of Madrid (ETSAM, 2006), a Master of Architecture in Urban Design, with distinction, from Harvard University (2011), and a Ph.D. cum laude in architecture from ETSAM (2016).

Dr. Víctor Muñoz Sanz (Postdoctoral Researcher at the Faculty of Architecture and The Built Environment, TU Delft, Cities of Making)

Dominic Stead is associate professor of urban and regional planning in the Faculty of Architecture and the Built Environment at TU Delft. He began his academic career as researcher at the University of the West of England. From 1996 to 2001, he was research fellow at University College London in the Bartlett School of Planning and associate lecturer at the University of the West of England. In 2001 he moved to TU Delft, initially as a postdoctoral researcher supported by a Marie Curie Fellowship, a European postdoctoral research grant for young talented academics. Since moving to Delft, Dominic has been principal investigator for more than 10 large European research projects on issues related to urban development, governance and sustainability and has been involved in projects funded by ESPON, European Framework Programmes, JPI Urban Europe and the United Nations. Dominic has a strong interdisciplinary background: a doctorate in Planning Studies, a master's degree in Town and Country Planning and a master's degree in Environmental Science. His research and teaching focus on processes of policy-making and the impacts of policies, particularly in relation to urban transport and spatial planning. He has published widely in books, international journals, has co-edited five books and he is editor and member of editorial boards of highly esteemed international peer-reviewed journals.

Dr. Dominic Stead (Associate Professor at the Faculty of Architecture and The Built Environment, TU Delft)

David Hamers is an urban researcher, trained as a cultural theorist and economist. He is a senior researcher for Urban Areas at PBL Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving) in The Hague. His publications mainly deal with the development, design, and use of spaces and infrastructures within and around the city. In addition to his work at PBL, he is a professor (lector) of Places and Traces at Design Academy Eindhoven.

Dr. David Hamers (Lector in Places and Traces, Design Academy Eindhoven, and Senior Researcher for urban areas, Department of Spatial Planning and Quality of the Local Environment, Netherlands Environmental Assessment Agency (PBL))

Salvador Rueda is the founder and Director of the Urban Ecology Agency of Barcelona, established in 2000. He owns Degrees in Biological Sciences, Psychology and Energy Management from the University of Barcelona and a Diploma in Environmental Engineering from the Ministry of Industry, of Universities and Research. Previously, he has held managerial positions in the Planning Department, Government of Catalonia (la Generalitat de Cataluña) as well as with the Municipalities of Barcelona and Sant Adrià de Besòs, and was a member of the Expert Group on the Urban Environment in the European Union (1994-2000).

Rueda is the author and coordinator of several books and scientific and technical articles about urban planning. He has been a commissioner and scientific advisor for many national and international conferences, masters and postgraduate programs. He has developed projects such as strategic plans, urban planning, urban green and biodiversity, mobility, public space and urban metabolism (energy, water, pollution, noise and waste) such as the Mobility Plan of Barcelona (Spain), the Design Manual of Public Space in Buenos Aires (Argentina) or Participation in the Great Moscow Urban Planning enlargement (Russia) amongst others.

Salvador Rueda (Director of The Urban Ecology Agency of Barcelona, IAAC scientific committee)

Frans van de Ven is the team leader and expert advisor in the Urban Land & Water Management at Deltares and associate professor of Urban Water Management at the Faculty of Civil Engineering and Geosciences at Delft University of Technology. He holds a Ph.D. in Hydrology and is leading research worldwide on creating sustainable cities, making them climate resilient, flood and drought proof and subsidence-free. He previously worked for Rijkswaterstaat's Institute of Inland Water Management and Wastewater Treatment, being involved in several research programmes and projects, such as "Living with Water". Since May 2008 Van de Ven joined Deltares, where he and his team started research activities on climate resilience of cities, urban flooding and impact reduction, on creating adaptable cities and on the concept of the "closed city" – aimed at enhancing the functional use of all types of water in the urban area. Over the past couple of years, water resources management, as well as effectiveness and applicability of blue-green solutions for urban flood, drought and heat management, were added to the pallet of ongoing research projects.

Dr. Frans van de Ven (Associate Professor, Civil Engineering and Geosciences, TU Delft and expert adviser in Urban Land& Water Management at Deltares)

Florian Boer (1969) is an involved spatial designer and project leader with 25 years of experience. His expertise covers designing on 'urban systems' in which especially water plays an important role. With his office DE URBANISTEN he has built up a unique expertise concerning integral design for water sensitive places, neighborhoods, cities and regions; from overall visions to concrete designs. The city of Rotterdam plays an important role as a test location for innovative concepts and ideas. Florian has been intensively involved in the research by design of 'Rotterdam Watercity 2035' (2005), the (inter)nationally renowned 'Waterplan 2' (2007) and the Rotterdam Adaptation Strategy (RAS, 2012). He is the inventor of the concept of the 'water square' and has been responsible for the design and construction of the first water square: 'Benthemplein'. In 2014 he won the international design competition 'Rebuild by Design' for New York with the project 'New Meadowlands' (collaboration with MIT, ZUS and Deltares). At this moment Florian is working on climate resilient projects in Antwerp (BE), Copenhagen (DK), Mexico City (MX), Guayaquil (EQ), Amsterdam, Nijmegen, The Hague, and Rotterdam. Florian frequently speaks on international congresses and universities.

Florian Boer (Founder and Director of De Urbanisten)

Nico Larco is a professor of Architecture and Urban Design at the University of Oregon (AIA) where he leads the Urbanism Next Research Initiative. This initiative is focused on how technological advances such as autonomous vehicles, e-commerce and the sharing economy are changing city form and development. Prof. Larco assists cities and projects with future-proofing, has run workshops and charrettes nationally on this topic, and is currently coordinating work in this area with various municipal and state agencies around the country. He is also a Principal of Larco/Knudson, an urban design consulting firm.

Nico Larco (Professor of Architecture at the University of Oregon, co-founder, director of Sustainable Cities Initiative, Sci co-director of Urbanism Next)

Mathias Mitteregger has worked on a range of topics in architectural theory including political theory and architecture, architecture and technology, myth, superstition and architecture. He wrote his Ph.D. dissertation Reason might be a place. Critical regionalism and architectural autonomy as examples of architectural theory building on political philosophy under the direction of Kari Jormakka. Since 2016 he is head of AVENUE21 an interdisciplinary research project, investigating how connected and automated vehicles could contribute to major urban development goals and where they might undermine them.

Dr. Mathias Mitteregger (Senior researcher of AVENUE21, future.lab TU Wien and Daimler and Benz Foundation, Faculty of Architecture and Planning, TU Wien, Austria)

Emilia Bruck is a researcher and doctoral candidate at the Centre of Local and Urban Planning, Technical University Vienna. She holds a Master's degree in Urban Design from the Technical University Delft, and a Bachelor of Architecture from the Academy of Fine Arts Vienna. As part of the AVENUE21 research team, her particular research interest concerns the relational dynamic between emerging mobility technologies, spatial transformations and planning paradigms. She examines connected and automated vehicles in regards to their "Transformative Potential" for the built environment, as well as urban planning principles, goals and procedures. Two urban test sites for automated shuttlebuses in Toronto, Canada, and Vienna, Austria, are analyzed by means of a comparative case study research on the meaning of urban laboratories.

Emilia Bruck (Ph.D. at the Faculty of Architecture and Planning, TU Wien, Project Assistant in AVENUE21, future.lab TU Wien anwd Daimler and Benz Foundation)

Arthur Scheltes is a strategic public transport consultant, working in the field of mobility and trying to combine public transport with innovative forms of mobility such as driverless vehicles. During his career at Goudappel Coffeng, he has worked on a variety of projects regarding driverless vehicles. In these studies, driverless vehicles are not perceived as a solution to everything, but they are tackled in a more pragmatic way, as part of the mobility toolbox to tackle mobility-related challenges. An important aspect of the implementation of driverless vehicles is a systems approach in which the operational design domain of driverless vehicles acts as one of the boundary conditions of the system.

Arthur Scheltes (Advisor in Public Transport& Self-Driving Vehicles at Goudappel Coffeng)

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