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# Through the eyes of Autonomous Vehicles – using laser scanning technology to engage the public via the analysis of journeys seen from a different perspective.

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**Abstract**

It is likely that Autonomous Vehicles (AVs) will have significant social, cultural, spatial and environmental implications and the interaction between humans, automated vehicles and physical environment will provide an array of challenges. This paper aims to explore use of innovative visualisation approaches, to communicate and foster discussion to anticipate possible scenarios involving AVs. It is argued that such an approach might be used to help conceptualise human experiences with the potential to enhance public engagement and understanding of the complex human-machine associations and open a dialogue with potential end users.

Presenting the journeys from different perspectives and reconceptualising the context through the eyes of AVs emphasised the nuances of experience between the machines, urban space and human bodies. Unexpected user-technology interactions and experiences will emerge as humans are not always sensible and passive followers and can be apprehensive when it comes to accepting such a novel technology as self-driving vehicles on the roads.

The focus applied in the methodology and data capture was on inclusivity of data, and an aspiration to capture not only movement but also noise and human experience of a space. The integration of AVs on public roads will rely on technical innovation to ensure that vehicles can safely operate in a practical sense yet, the study of the perceptual and ethical effects of new technology and potential influences on society via engaging the general public in the process will help to manage expectations and create platforms for mutual learning.



*Keywords:* Autonomous vehicles; engagement; human-machine coexistence; automation; urban space

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## 1. Introduction

*'Humans are sentient beings, capable of interacting with and negotiating AVs in and through their own ways'*
(Yeo and Lin 2020, p.2).

It is anticipated that by the 2030s Autonomous Vehicles (AVs) will be widespread on European public roads. AVs as low cost, clean, widely available door-to-door transport hold the potential to significantly change peoples' travel behaviour and this will have an immediate effect on spatial planning as well as having numerous societal, cultural and environmental implications. Many cities in Europe have already started testing AVs, where the integration of new mobility solutions on public roads, often with complex mixed mobility scenarios, will be crucial (PAV, 2020). The notion of fully automation of vehicles is often regarded as a possibility for the distant future (Wolf 2016), where users will have the ability to use mobile phones, work, socialise or even sleep during a drive (Habib and Lynn, 2020 ; Kun, Boll, and Schmidt 2016). However, there remains a limited knowledge about autonomous vehicles among the general public (Wolf 2016), and the implications for our living environments. The interplay between humans, automated vehicles and physical environment will provide an array of challenges, as well as presenting significant technical and social research challenges.

The acceptance and interaction with new technology, and its adaptation into the everyday life of communities, can often be met with initial scepticism (Brooks 2017). Recognising new issues of safety – real and perceived - in an urban environment in the era of existing and novel transport modes and technology will be crucial. Visual representation of the effects of technology used by autonomous vehicles would potentially lead to an enhanced understanding of the travel experience and interrelationships between the AV users, other vehicles, pedestrians and the physical context of the built environment. This paper aims to explore use of innovative visualisation approaches, to communicate and foster understanding and discussion the scenarios involving AVs. It is argued that such an approach holds the potential to enhance public engagement and understanding of the complex human-machine associations. In so doing, the research helps to conceptualise human experiences and interactions when encountering autonomous vehicles travelling through space.

## 2. Through the eyes of autonomous vehicles

Human brains are visually biased, as 10 of the 11 million bits of information per second come from our eye (Koch et al. 2006). How is the world navigated and how does it look through 'the eyes' of AVs? The algorithmic and all-encompassing volumetric images produced continuously by the sensor/LIDAR technologies in AVs yield an astonishingly detailed 360° 3D record of the surroundings. Recreating that record through the use of a mobile laser scanner - during a potential journey - enabled the research to help in understanding the experience and illustrate how physical elements might interact with human aspects of the journey – for both passengers and pedestrians. Providing this insight from the perspective of AVs played a significant role in addressing issues of safety from the perspectives of vehicle passengers and other road users, as the technology enabled a reliable deconstruction of the experience, measuring the objective physical characteristics of the context, while moving through the surroundings. The resulting visualisations provide an abstracted view of the world, which prompts and welcomes fresh perspectives and observations.

### *2.1 Laser scanning as an engagement tool – study in Aberdeen*

Consideration of the resilience of cities, technology and transportation systems may be enhanced by efforts to think spatially. In so doing, viewers are enabled to more clearly perceive and better understand the factors that generate movements and reactions of people (Kirzek et al. 2021). As part of the public and stakeholder engagement process, a portable laser scanner was used to depict and visualise the journey of an AV through 'real' environments (Fig. 1&2). The captured data was then analysed and presented as a tool in engagement workshops enabling a deeper insight into the mapping technology and a way of learning the conditions of the physical context as well as subtle familiarisation exercise to possible futures. It is argued that this use of technology and visual resources can act as a springboard to conversation and positive engagement in order to apprehend the interlinked phenomena of urban realm, people, imminent technological advances and future mobility options. The contribution of such technology in participatory

approaches to planning seems to offer an accessible and inclusive method through which one can envision and reconcile the complexities of mobility, personal needs, interactions and design of the built environment with the levels of familiarity with AV technology among participants (PORTIS 2020).

Three-dimensional mobile laser scanning technology has been extensively applied in AVs to perceive their surroundings and collect information on geometrical qualities of physical environment in real time, detect and track obstacles, boundaries, other cars, and pedestrians (Brummelen et al. 2018, Martines Diaz et al. 2018, Zhu et al. 2017). Laser scanning technology as rapid, precise spatial data acquisition, documentation and mapping is also an established technology in architecture, 3D printing, engineering, construction, surveying, archaeology and built heritage with a wide range of applications (Tait et al. 2016, Zlot et al. 2014). This study aimed to reach beyond the primary purpose of scanning and explore whether data obtained from the scanning device, corresponding directly to potential routes of AVs within the city, that supported the visualisation of a detailed record, would prompt thinking about the micro-interactions between individuals and technology. Presenting the journeys from different perspectives and reconceptualising the codified surroundings through the eyes of AVs emphasised the importance of noticing the nuances of experience between the machines, urban space and human bodies – 'inhabiting and feeling machines' (Yeo and Lin 2020, p.1).

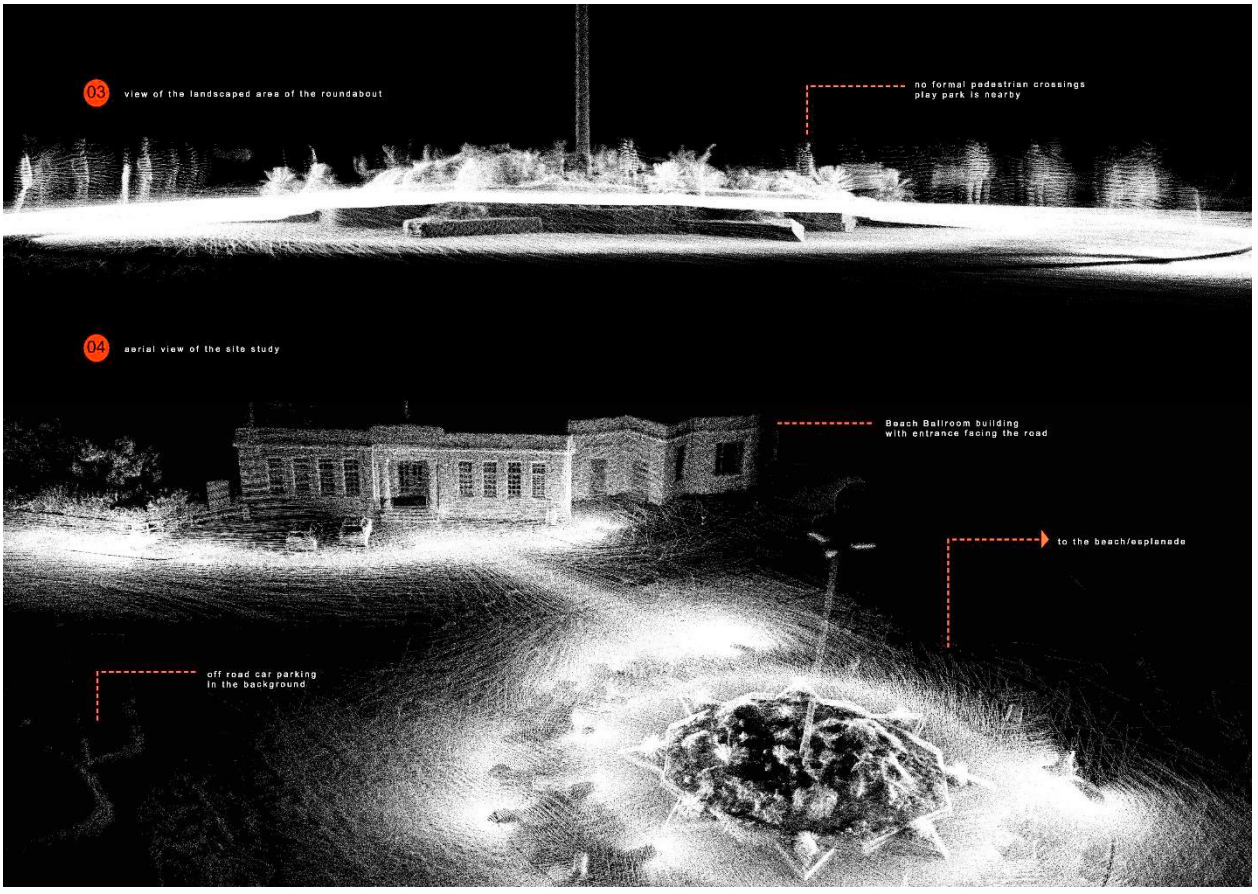


Fig. 1. 3d render of busy roundabout retrieved from laser scanner [author owned]

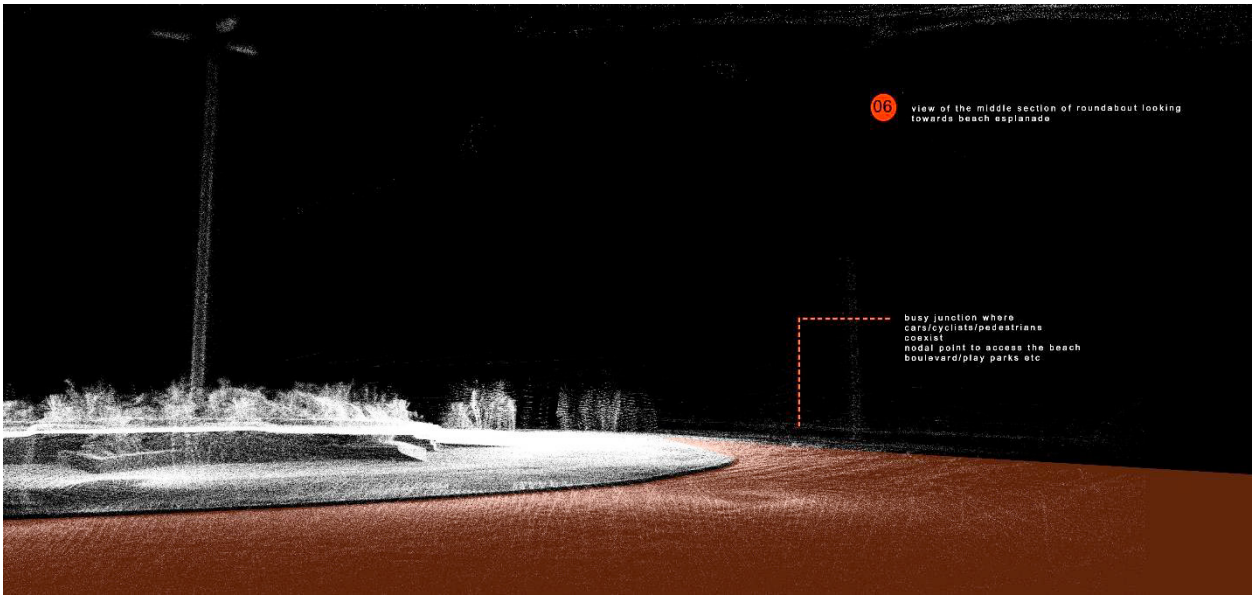


Fig. 2. 3d render of roundabout showing pedestrians crossing the street; retrieved from laser scanner [author owned]

## *2.2 Exaggerating glitches and scanning errors*

In 'The Dreamlife of Driverless Cars' project, Scan LAB studio weaved a 3D laser scanner through the streets of London to simulate how driverless vehicles 'might perceive - and misperceive - the world' by unveiling captivating perspectives of the city as seen from the vehicles perceptive instruments (Fig.3) exaggerating glitches and scanning errors (Manaugh 2015). The city as is appears eerie yet also encompasses all the vast surroundings and endless scenarios – intermingling of busses, cars, cyclists and people with urban realm – static elements of environment.

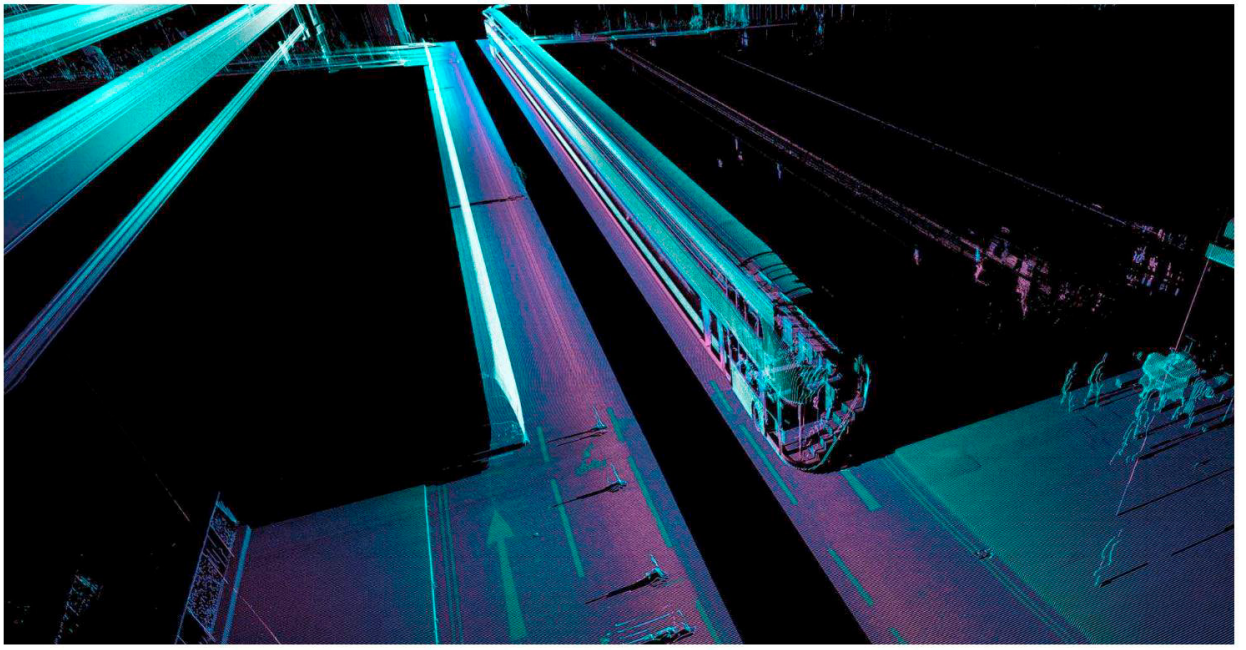

Fig. 3. Images of London retrieved from laser scanner depicting double-decker bus as a continuous mega-structure.
Credit.: ScanLAB Projects for The New York Times 2015
[Available from: https://www.nytimes.com/2015/11/15/magazine/the-dream-life-of-driverless-cars.html]

Cities are in constant flux affording unpredictable scenarios, which will have to somehow be fully anticipated and programmed for in the robotic future. How will seeing the city through the eyes of the vehicles be any different to the experience of a person on board, possibly sitting passively at the 'drivers' seat? Urban resilience in this case can be regarded as a way to best adapt to inevitable future situations by exhausting options of machine-human learning and understanding to fully and amicably function in real near future contexts. In the face of the expected gradual automation in cities, the uncertainties and unpredictableness of rather organic machine-human interactions will have to be carefully considered. Human behaviour is difficult to foresee and far away from being automated, the autonomous vehicles somewhat need to acquire 'additional social intelligence' (Camara et al. 2020, p. 1) to function in the complex socio-spatial environments.

Laser scanning has been treated in this instance not only as the technology associated with vehicles computation but a springboard for discussion on car-human-environment vulnerabilities and engagement tool to induce smooth transition to safer, automated urban future. This is arguably an extension of previous studies (Tait et al. 2016) which explored the use digital data capture to enable user engagement, where the strengths (adoption, discussion, participation) greatly outweighed any weaknesses or barriers to adoption (due to widespread availability of potential technologies). By showing moments of devices' misinterpretation through the eyes of 'unblinking machines' - ghostly, somewhat unsettling depictions of everyday street life, it emphasises the need for discourse on nuances of 'fundamentally inhuman, perspective on the built environment' (Manaugh 2015).

## 3. What is the future of mobility?

Over the past 100 years the dominance and realm of private car ownership has become the most prominent mobility system. Urry (2007, p.120) described a somewhat bleak state of the contemporary situation as '*people inhabit congestion, jams, temporal uncertainties and health-threatening city environments through being encapsulated in a domestic, cocooned, moving capsule, an iron bubble.*' This statement further indicated a sort of alienation experienced by being in - inhabiting - the car as '[the] world of anonymized machines, ghostly presences moving too fast to know directly or especially to see through the eye' (Urry 2007, p.124) and not experiencing surroundings, local contexts in a meaningful way. Perceiving and sensing the world through the (car) screen became a dominant way of living in the contemporary world.

Modern societies have become reliant on cars as daily transportation. It can also be implied that people have exhausted the use of cars on the streets – making roads 'killing fields' of late modern societies' (Urry 2007, p. 272). The number of fatal accidents on the roads has been steadily increasing, together with general world population and vehicles (WHO 2018). Adorno wrote as early as 1942: 'And which driver is not temped, merely by the power of the engine, to wipe out the vermin of the street, the pedestrians, children and cyclists?' (1974: 40 quoted in Urry 2007, p.123). What is more 'cars have increasingly overwhelmed almost all environments, so everyone experiences such environments through the protective screen and increasingly abandons streets and squares to omnipotent metallic iron cages' (Urry 2007, p. 130). Therefore, any discussion on the future smart, autonomous mobility system must be grounded on the notion of existing infrastructure and transport modes with all positive and undesirable consequences that have been associated with it.

The gradual introduction of autonomous vehicles could potentially be seen as an opportunity for a major rethinking of transportation systems in cities that challenges prevailing car-centric visions to the point of facilitating more sustainable mobility and making space for walking and cycling. In that respect, AVs could be seen as potentially most innovative and promising (Fagnant and Kockelman 2015), yet at the same time potentially most disruptive that would profoundly remodel our cities and socio-spatial organisation (Legacy 2019, Yigitcanlar et al. 2019).

### *3.1 Possible scenarios*

It has been suggested that the idea of introducing self-driving transport vehicles to the context of contemporary cities is often perceived as the 'technological fix to the challenges of 21st urban development' (Yeo and Lin 2020). However, the normal practices of urban design and management draw as much on the humanities and an appreciation of human life, as they do on technology. "*What actually complicates this process is the limited social science*

*scholarship on the impact of AVs on our cities and societies. The engineering literature is well developed, but the corresponding social science insights are only now emerging.*" (Yigitcanlar et al., 2019, p.12).

It is crucial to anticipate and understand possible scenarios, as the change in mobility patterns is imminent and inevitable as AVs are functioning on the roads already (Yeo and Lin 2020). The apprehension associated with new technology and the moral dilemmas of security, 'dystopic digital Orwell-ization of self and society' (Urry 2007, p.276) need to be considered together with wider issues of ethics and safety. A spectrum of emotions can be associated with introducing such a novel technology as self-driving vehicles on the roads, oscillating between excitement and enthusiasm to the uncomfortable feeling of the helplessness that can be experienced (Martines Diaz et al. 2018, Wolf 2016) when we devote ourselves to the hands of technology – overriding algorithms of robotic device. Is the system acceptable – what about fluctuating conditions, physical, weather concerned or rhythmical - the ever-changing city choreographies - often extremely unpredictable scenarios? Are initial mistakes made by the machines necessary for us to learn from? Can the algorithm ever evolve beyond the human perception and conceivable understanding? Are AVs likely to provide a nuisance on the road or salvation to the society?

Some of the recent demonstrations of AVs highlighted the issue of pedestrians stepping in front of cars, taking advantage of the safety features creating an issue of the '*freezing robot problem*' (Brooks 2017). The environment perception in AVs stems from an integration of built-in sensor systems positioning the laser technology at its centre in active object detection (Brummelen et al. 2018, Khatab et al. 2021). One of the key features for safe and efficient driving systems in AVs is the development of algorithms that anticipate actions as well as communication of all agents to gain an understanding of the patterns and diverse types of road behaviour (Madigan et al. 2019).

**4. Ethics/algorithmic morality -** 'human agency vis-a-vis automation' (Yeo and Lin 2020, p. 5)

Alongside discourses on technological innovation and technical issues still to be overcome in AVs come consideration of its social, cultural impacts on individuals and society (Atkins 2016; McKinsey & Company 2016). The pace of change regarding ethical considerations (JafariNaimi 2017) and the potential environmental benefits in the reduction of CO2 emissions (Winkle 2016; Davila and Nombela 2012) are arguably of greatest concern. Indeed, one of the main reasons to introduce the technology is an improvement to safety and reduction in fatal accidents due to human error and distractions. However, the technology itself cannot eradicate all (fatal) accidents as they will occur due to software or machine mistakes and failures (JafariNaimi 2017).

What can be learned and implemented possible AV futures, and how human-machine interactions can realise the promised potential, remains a key consideration. The social experience of traffic for passengers in the automated vehicle. and that of people walking or driving alongside, will undoubtedly evolve when AVs are introduced at scale on public roads. As Thrift (1996, p. 1468 quoted in Yeo et al. 2020) explains: 'no technology is ever found working in splendid isolation as though it is the central node in the social universe. It is linked—by the social purposes to which it is put—to humans and other technologies of different kinds'.

As humans are not always rational and passive beings when it comes to seamlessly accepting novel technology (Yeo and Lin 2020), discussion about 'creative forms of robot abuse' (Nourbakhsh 2013, p. 59) is valid in describing possible futures scenarios. The human –autonomous robot social context is a complex one, as 'there will be plethora of willing people interested in testing legally indistinct boundaries to entertain themselves at a robot's expense' (Nourbakhsh 2013, p.60). In terms of AVs most people will probably use it in 'ordinary ways', others however, might 'creatively' manipulate and misuse it beyond the designed purposes by hacking the technology to commit acts of crimes (Yeo and Lin 2020, Carter 2019, Tarantola 2017, Rasouli and Tsotsos 2019). This paper argues that the use of digital data capture technology can be used to effectively represent aspects of the human experience when using autonomous vehicles, and also of the surrounding physical environment. The costs associated with such technology have decreased significantly in recent years, partly through the development of robust photogrammetry techniques (3D modelling from photographs), and through wider availability and complementary use of laser scanning and LIDAR technologies (see, for example, Fassi et al. 2011). Therefore, it is argued that the approach described herein could be readily applied in much wider contexts, and across other sites and scenarios.

Urban dwellers' use of AVs, including unexpected technology interactions and experiences, will certainly emerge and must be accounted for in the discourse of the way the technology is currently framed - as an all-encompassing fix to the urban development and mobility challenges (Yeo and Lin 2020). The understanding of unpredictable future

society and technology coexistence will be crucial in urban hard to predict realms - accommodating people, architecture, temporary structures, and all the good, bad, accidental, and most unlikely occurrences.

## 5. Summary

The reason for the discussion about AVs and its integration into actual context is to envision, critically appraise, better prepare for the changes and potentially influence how it unfolds. The current dominant narratives of AVs are oscillating around technocentric ways of approaching the subject. As there are still many unknown unknowns surrounding the subject - it felt essential to include discussion on possible scenarios unfolding in near future and fathom potential influences on society of integrating AVs via engaging the general public in the process to manage expectations and create platforms for mutual learning.

The paper specifically considers the AV as it moves through an environment, and the capture and visualisation of the complex effects which AVs may have on perception, experience and behaviour. In this regard, the research concerns not only the users of a vehicle, but also the manner in which the vehicle might interact with and sense or detect its surroundings. It is suggested that further study could usefully concern the behaviour of occupants of the AVs during a journey, and that digital data capture might provide a method to facilitate such work.

This paper sought to explore how innovative methods of data capture and visualisation might be used to help stimulate debate, facilitate understanding, and help to open a dialogue with potential end users. That the emphasis taken in that data capture was on inclusivity of data, and a desire to capture the movement, noise and human experience of a space, is critical. As discussed, the introduction of AVs on public roads will rely on technical innovation to ensure that vehicles can operate in a practical sense. However, study of the social, perceptual and ethical effects of AVs is at least equally important. The notion ‘autonomous’, as independent of human control, itself indicates the need to look at the issues of spatial, social, ethical and cultural human-nonhuman coexistence from the widened, relational and potentially more sensitive perspectives to fully realise the transformative possibilities of automative city and impacts of technology on people, their lives and spaces in urban realm.

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