The transition to autonomous cars, the redesign of cities and the future of urban sustainability

DOI:
10.1080/02723638.2020.1746096

Document Version
Accepted author manuscript

The transition to autonomous cars, the redesign of cities and the future of urban sustainability

Abstract

Autonomous cars controlled by an artificial intelligence are increasingly being integrated in the transport portfolio of cities, with strong repercussions for the design and sustainability of the built environment. This paper sheds light on the urban transition to autonomous transport, in a threefold manner. First, we advance a theoretical framework to understand the diffusion of autonomous cars in cities, on the basis of three interconnected factors: social attitudes, technological innovation and urban politics. Second, we draw upon an in-depth survey conducted in Dublin (1,233 respondents), to provide empirical evidence of (a) the public interest in autonomous cars and the intention to use them once available, (b) the fears and concerns that individuals have regarding autonomous vehicles and (c) how people intend to employ this new form of transport. Third, we use the empirics generated via the survey as a stepping stone to discuss possible urban futures, focusing on the changes in urban design and sustainability that the transition to autonomous transport is likely to trigger. Interpreting the data through the lens of smart and neoliberal urbanism, we picture a complex urban geography characterized by shared and private autonomous vehicles, human drivers and artificial intelligences overlapping and competing for urban spaces.

Keywords: autonomous cars; autonomous urban transport; urban sustainability; urban design; smart cities; urban politics

1. Introduction

Cars driven by an artificial intelligence (AI) are gradually entering the every day. Autonomous cars can be seen in cities like London, Singapore, Dublin, Beijing and Auckland, where this new transport technology is being tested in real-life urban environments (Bansal and Kockelman, 2017; Talebian and Mishra, 2018). However, the extent to which vehicles controlled by an AI will become part of the transport portfolio of cities is still unknown. Above all, there are many question marks regarding how the built environment might evolve, to accommodate this disruptive technology. Urban history shows that cities have repeatedly changed their shape according to the evolution of urban transport (Hall, 2002; Sheller and Urry, 2000). Notable examples can be found in the Baroque city where the diffusion of stagecoaches led to the removal of the crooked alleys of the Medieval city in favour of straight roads, and in the Modernist city whose design was revolutionized by the entry of the automobile, through highways and arterial roads (Mumford, 1961). At the dawn of the advent of the autonomous car, the future of the design of the built environment is opaque.

This paper sheds light on the urban transition to autonomous transport, in a threefold manner. First, from a theoretical perspective, we advance a framework to understand the diffusion of autonomous cars in cities. Our framework approaches the autonomous car from three interconnected social, technological and political perspectives. We acknowledge the influence of social attitudes on the public acceptance of a transport technology controlled by an artificial intelligence, as well as how the technology itself is developing, thereby becoming safer and more reliable. In so doing, we also stress the role of urban politics, arguing that the emergence of AI in urban transport should be understood not simply as a process of technological innovation and sociological change but, above all, as a political phenomenon. The second contribution of the paper is

empirical and quantitative in nature. We present what is, to date, one of the largest and most detailed quantitative study of the upcoming diffusion of autonomous cars in a specific city. We use Dublin as a case study and draw upon an in-depth survey counting 1,233 respondents, to provide strong empirical evidence of (a) the public interest in autonomous cars and the intention to use them once fully available, (b) the fears and concerns that individuals have regarding autonomous vehicles and (c) how people intend to employ this new form of transport. Third, we use the empirics generated via the survey as a stepping stone, to examine possible urban futures. More specifically, we discuss the changes in urban design and sustainability that the transition to the autonomous car is likely to trigger, depending on how the technology is employed. We consider an urban future in which autonomous cars are shared and public and natural spaces abound, and an opposite scenario dominated by private AI-driven vehicles running in sprawling cities. Our study indicates that such extremes are simplistic and unlikely, picturing instead a complex urban geography characterized by shared and private autonomous vehicles, human drivers and artificial intelligences overlapping and competing for urban spaces.

The remainder of the paper is divided into seven sections. In the second section, we review the multidisciplinary literature on the diffusion of autonomous cars in cities, and frame the transition to autonomous urban transport as an uneven phenomenon shaped by interconnected social, technological and political factors. In the third section, we explain the methodology of the quantitative study. In the fourth section, we empirically discuss how, in Dublin, many people intend to employ autonomous cars despite having strong concerns about this new technology. In the fifth section, we draw upon urban history to show how the introduction of new forms of urban transport has repeatedly changed the design of cities, and then explore this link in relation to autonomous cars and the redesign of the built environment. In the sixth section, our quantitative study provides evidence of

the attitudes of Dublin's population towards different modes of adoption of autonomous cars, which include sharing, public transport, private ownership, as well as combinations of transport modes. We explain how these emerging attitudes will influence the shape of the city of the future, while stressing that they must be read in relation to contextual technological barriers and political questions. In the final section, we argue that, in an era of autonomous cars, urban sustainability will not be only a matter of social attitudes and technological innovation, but of political context too, emphasizing the urgency of critical urban political research. We unpack this point through the lens of smart and neoliberal urbanism, concluding that no matter how sustainable the technology and the employment of autonomous vehicles can be, urban politics will have the last word on the sustainability of the city.

2. Understanding the transition to autonomous cars

There is growing evidence showing that autonomous cars are becoming increasingly integrated in the transport portfolio of cities (Milakis et al., 2017). Advanced autonomous cars do not need a human driver and this is why, in common speech, they are often called *driverless cars* and *self-driving cars*. However, technically speaking, these cars have a driver: it is an artificial intelligence which is autonomously perceiving the surrounding environment, and controlling the movement of the vehicle. It has been estimated that the autonomous car will be the dominant form of urban transport by 2040, and the seeds of this phenomenon are already evident in cities like San Francisco, London, Pittsburgh, Gothenburg and Singapore, where this new technology is being tested in real-life environments (Bansal and Kockelman, 2017; Talebian and Mishra, 2018). Moreover, in several countries, the transition towards autonomous transport is being pushed forward

by overarching political agendas which are reshaping transport policy on a national scale. In the United States, for instance, the federal government, 'on the threshold of a period of dramatic change', has officially supported this new form of transport, by releasing policies designed to accelerate the deployment of fully autonomous vehicles through new *ad hoc* regulations and road development plans (US Department of Transportation, 2017: 1). A similar case is that of the Netherlands where 'the Ministry of Infrastructure and the Environment has opened the public roads to large-scale tests with self-driving passenger cars and trucks', aiming to make the whole country 'a fertile breeding ground for this kind of innovation' (Government of the Netherlands, 2018: no page)[1].

Despite such growing enthusiasm across cities and countries, the transition to autonomous urban transport is unlikely to be a smooth process. On the one hand, the first pedestrian fatality caused by an autonomous car in Tempe (Arizona) on the 18th of March 2018, by evidencing already feared deadly glitches, generated a scepticism which has since been voiced by many global media. Safety concerns have also been confirmed in sociological and psychological studies looking at the attitudes of people towards autonomous cars (Awad et al., 2018; Kyriakidis et al., 2015; Taeihagh and Lim, 2018, Wu et al., 2020). Scepticism is particularly strong amongst vulnerable road users like pedestrians and cyclists which are the categories that tend to be afraid of collisions the most (Penmetsa et al., 2019). Many are scared of employing as well as of simply being around vehicles controlled by an artificial intelligence, and these fears will arguably not disappear until manufactures are capable of convincingly demonstrating that an AI-driven car is as safe as an average human-controlled one (Hudson et al., 2019). Overall, considering the plethora of technological challenges that developers of autonomous cars are facing

[1] For other examples, see Government of the United Kingdom (2018) and Singapore Smart Nation (2018).

(cyclist detection, off-road driving, perception under severe weather conditions, for instance), society's acceptance of this new technology may still be a long way off (Van Brummelen et al., 2018).

However, on the other hand, the history of the city shows that accidents, fatalities and related concerns did not stop the diffusion of then dangerous forms of urban transport. In the seventeenth century, for example, as Mumford (1961: 370) notes, the introduction of the stagecoach in French cities 'killed more people annually than the railroad that followed it' and, nonetheless, this transport technology became a prominent element of the Baroque city. Similarly, as the 1930 Report of the US Committee on Traffic Accident Statistics shows, the advent of cars in American cities was accompanied by thousands of fatalities. In 1920 alone, the Committee reports 2,124 fatalities due to car accidents and yet the automobile quickly replaced the horse-drawn carriage as the primary means of transport in most American cities (Nakicenovic, 1986; US Committee on Traffic Accident Statistics, 1930). Moreover, it is important to note that car accidents continue to happen nowadays at an increasing rate but, somehow paradoxically, this trend does not prevent people from continuing to employ what is still a dangerous transport technology. Despite the fact that over 1.25 million people die each year because of road traffic crashes, and that road traffic injuries are the principal cause of death for children and young adults (aged 5 to 29 year) in the world, the car remains the dominant form of urban transport (World Health Organisation, 2015; 2018).

By the same token, the history of the city suggests, similar dynamics might appear today in the diffusion of autonomous cars. We argue that the transition to autonomous transport in cities, is a complex and uneven phenomenon whose evolution and materialisation can be understood in relation to three main interconnected factors. The first factor is how individuals feel about autonomous cars. From a social perspective, there is the question

of how people are reacting to what is a radically different transport technology: a means of urban transport controlled, for the first time in history, by a non-biological intelligence. People's attitudes towards autonomous vehicles will directly influence the extent to which this new transport technology will be adopted. As noted in the literature, this intricate factor is determined by a plethora of interrelated sociological, psychological, economic and cultural variables (Acheampong and Cugurullo, 2019). The age, the education and the income of the individual, the influence of significant others (family, friends and work colleagues), lifestyle, personal interest in sustainability, and view on technological innovation, exemplify some of these variables (Acheampong and Cugurullo, ibid; Daziano et al., 2017; Kyriakidis et al., 2015; Lee and Mirman, 2018, Potoglou et al., 2020). In essence, the first factor has a marked *social* connotation, capturing people's behaviours and attitudes within groups (sociology) as well as their inner reasons and emotions as individuals (psychology).

Second, the technology of autonomous driving is still evolving and until basic technological issues of safety are fixed, autonomous cars are unlikely to become the dominant form of transport in cities, despite what enthusiastic car manufactures like Volvo, Tesla and Toyota claim (Bagloee et al., 2016). The second factor behind the transition to autonomous transport is thus *technological* in nature. The literature indicates that the disciplines of computer science and engineering are facing a number of technological challenges whose resolution will affect the extent to which, where and how autonomous cars will be employed (Fridman, 2019). More advanced sensing technologies, for instance, are currently much needed in the context of severe weather conditions, such as snow, for autonomous vehicles to detect potential obstacles (Zang et al., 2019). Similarly, autonomous vehicles need detailed, accurate and up-to-date high-definition 3D maps of road networks: a critical issue given that the appearance and layout

of roads continuously undergo alterations, due to seasonal changes in the surrounding vegetation and occasional roadworks (Ros et al., 2015). Greater connectivity among autonomous vehicles can improve the efficiency and safety of urban transport by enabling autonomous intersection crossing, or allowing vehicles to share information about upcoming obstacles, speed changes and brakings (Tachet et al., 2016). However, the reliability, timeliness and security of vehicular communication is, to date, still underdeveloped (Parra et al., 2017).

In addition to these social and technological factors, we argue that a third force (currently overlooked in the literature) will strongly influence the diffusion of autonomous cars in cities: urban politics. History points towards the politics of the city and the politics of the state encompassing it, as key aspects of the integration of new forms of urban transport. More specifically, urban history shows that the attitudes that people had towards new means of transport in the city, were often less impactful than the interests of those who had political power (Hall, 2002; Mumford, 1961; Sheller and Urry, 2000). Similarly, the degree of safety and reliability of a new urban transport technology was frequently a less influential factor, than the agenda of politically powerful actors. In the past, mainstream forms of urban transport were repeatedly pushed into society with a top-down approach, by the elites that in those days the political system was favouring, at times in a draconian manner.

In the Baroque city, for example, the diffusion of the carriage was pushed forward by a minority of the population, the aristocracy. This form of transport was the output of the *weltanschauung* of elites which ignored the interests and the voice of the demos. As Mumford (1961: 368) remarks, in England ‘vigorous protests were made, and it was asserted that if brewers' carts were permitted in the streets the pavement could not be maintained; while in France, parliament begged the king in 1563 to prohibit vehicles from

the streets of Paris.' However, in the then strongly undemocratic political context, these dissents were not taken into account: the ruling class made horse-drawn carriages and stagecoaches part of the everyday urban experience of the Baroque city. The aristocracy held what was, at that time, an almost absolute political power and, therefore, could (and did) ignore the urban transport attitudes of the majority of the population. In addition, it ignored, for a long time, how dangerous that transport technology was in an urban environment. In 1781, Louis-Sébastien Mercier, a French writer author of the *Tableau de Paris*, a guide for Paris visitors and locals, wrote:

'Mind the carriages! Here comes the Prince behind six horses at the gallop as if he were in the open country. The threatening wheels of the overbearing rich drive as rapidly as ever over stones stained with the blood of their unhappy victims (Mercier, 1781: 55).'

A couple of centuries later, in the Modernist city, the introduction of cars as the new mainstream form of transport, was propelled by the private companies that were selling them, and related stakeholders. At the same time, governments were, with few exceptions, consciously developing political economies meant to support automobile-oriented cities, thereby favouring the agenda of large automobile manufactures. Emblematic is the case of the United States where Eisenhower embraced the idea that motorized vehicles and new roads were crucial for the economic growth of the nation, and started in 1956 what Hall (2002: 317) describes as 'the greatest public works program in the history of the world - $41 billion for 41,000 miles of new roads[2].' This does not mean of course that the public did not exert any influence. However, in the Modernist city, people, regardless of their attitudes towards cars, had little or no choice about how to move in urban spaces: a

[2] A radically different example is that of Sweden. In Stockholm, for instance, in the 1940s the government took control of urban development, favouring an urban design in synch with public transport rather than cars (see Hall, 1998).

handful of private companies, by invading the market, had made the car the main form of transport in the city.

With countries such as the United States, the Netherlands and the UK already developing policies to support the deployment of autonomous vehicles, similar dynamics are already taking place in contemporary cities. The national policy recently launched by the US Department of Transportation to accelerate the diffusion of autonomous cars, mirrors what was done in the past by Eisenhower to accelerate the diffusion of manual cars (US Department of Transportation, 2017). As Bissell (2018: 58) argues, the development of autonomous transport technologies is not simply a technological matter: it is situated within 'a complex range of forces at play, including the institutional interests which might be guiding these developments.' In addition to how the technology of autonomous driving will evolve and how people will react to it, the politics of the city and of the state that encompasses it, will also play a pivotal role in the transition to autonomous cars. The third factor is thus *political*.

In the next part of the paper, we observe the transition to autonomous cars in a city, using Dublin as a case study. It is beyond the scope of this study to explore the full spectrum of social, technological and political factors behind the diffusion of autonomous urban transport. We therefore focus empirically on the first factor discussed above (people's attitudes towards autonomous vehicles), and then show in the analysis of the empirics how social aspects are deeply connected to questions of technological innovation and urban politics, within processes of urban development. The following section presents the methodology of our study whose results will be discussed in section four.

3. Methodology

The empirical data that underpins this paper comes from a survey on public attitudes and adoption intentions regarding autonomous vehicles, conducted in Dublin, the capital of Ireland. As a medium-sized city, Dublin represents the most common type of urban settlement in Europe. It is a city in transition which has recently started a number of initiatives to reduce urban pollution and traffic, establish a knowledge-based economy, and cultivate creative start-ups. Dublin has also a smart-city agenda which includes the trial of autonomous vehicles. In essence, Dublin has the type of urban, social and economic environment that is likely to promote the diffusion of autonomous cars, and its study can be representative of a large group of European cities with similar characteristics.

The survey was administered online and in the field via a combination of outlets which included (a) printed leaflets with scannable QR-codes and questionnaire URL; (b) personal interviews using tablets, conducted by field assistants; (c) emails sent to students and staff of all major universities in Dublin; and (d) links shared on social media networks such as Twitter and Facebook. We also encouraged our respondents to forward the survey to other individuals in their network.

While this survey explored a wide range of geographical, sociological, psychological and urban themes, the argument that is here advanced draws upon data from three specific themes, outlined as follows. The first thematic area of the survey, discussed in this paper, explores public concerns and worries about autonomous vehicles. Under this theme, five questionnaire items focusing on the public's perception of the safety and the security risks of autonomous vehicles, were presented to the survey respondents on a 5-point Likert Scale. The participants were asked to indicate the extent to which they were worried about

a range of safety and security issues, such as the likelihood of equipment failure, the risk of the vehicle's computer system being hacked, as well as the danger of autonomous cars interacting with other road users like pedestrians and cyclists. Under the second theme, the respondents of the survey had to indicate their level of interest in autonomous vehicles, and the intention to use this new urban transport technology once available. The third theme of the survey, unpacked in this paper, investigates people's preferences for different modes of employment of autonomous vehicles. Here, respondents indicated their preference for one out of six possible mode options. The first three alternatives were (1) sharing, (2) ownership and (3) public transport, and the remaining options comprised a combination of these three modes, namely (4) ownership and sharing, (5) sharing and public transport, and (6) ownership and public transport.

The online survey which was administered between November 2017 and February 2018, attracted a sample of 1,233 adult respondents from a wide range of socio-demographic backgrounds, living in Dublin. Table 1 presents a summary of the background socio-demographic characteristics of the survey respondents. Summary statistics of the variables describing the sample characteristics are compared to those from the 2016 census held in Dublin. Females constituted 55% of the sample, while 2% of the respondents preferred not to indicate their gender. The respondents' age ranged between 18 and 84 years, with the average age being 33 years (compared to the average age of 37 years in Ireland). The proportion of individuals aged between 18 and 24 years in the sample (i.e. 44%) is significantly higher than that of the general population (13%), while there are fewer individuals aged between 65-84 years in the sample (i.e. 3%) compared to the general population (i.e. 14%), as it can be seen in Table 1. That the survey was administered mostly online certainly explains why it attracted a significant number of younger people. While we acknowledge that younger people (i.e. 18-24) are

overrepresented in the data, we also believe that this issue does not significantly affect the validity of the results. In fact, as we will later show in the analysis, opinions about autonomous cars are broadly similar across different age groups. That said, we have also presented the results of the survey according to the characteristics of the sample population (i.e., age, gender and current travel mode choices) in order to show where clear differences exist in the survey responses. The size of the overall achieved sample also allows comparisons to be made between those more and less likely to engage with autonomous vehicles when they become fully available in Dublin.

In the following empirical section, the results of the survey data are presented for the total sample first, and subsequently for specific relevant sub-groups of the sample. The aim is to show any variations in opinions and preferences regarding autonomous cars among the respondents within different sub-groups. Given the quantitative nature of the research, we acknowledge the limitations of this study particularly in relation to the psychological reasons why some people are, for instance, scared of cars controlled by an AI. Similarly, our survey tool cannot completely explore the ethical considerations that individuals develop in relation to sharing an autonomous car, or the extent to which existing challenges in urban mobility impact on the attitudes towards hypothetical autonomous transport systems. In addition, this type of quantitative research is not appropriate and meant to unpack the complexity of the political relationships among the many public and private actors and groups involved in the transition to autonomous driving. We invite social scientists to address these limitations via qualitative methods, and add tiles to the mosaic of autonomous urban transport.

Table 1: Background characteristics of the survey respondents (N= 1233)

		Distribution	
	Variable	Sample	Population (Dublin, 2016 Census)[3]
Gender	Female: Male: Prefer not to say	55%: 43%: 2%	51%: 47: Not available
Age-groups	18-24	45%	13%
	25-44	28%	46%
	45-64	25%	27%
	65-84	3%	14%
Education	Primary school	1%	11%
	Secondary/High school	20%	26%
	Bachelors (enrolled)	29%	Not available
	Bachelors (completed)	20%	20%
	Graduate (Master's or higher)	30%	15%
Ethnicity	White Irish	76%	74%
	Irish Travellers	0.4%	0.4%
	Other White	18%	12%
	Black or Black Irish	1.6%	1%
	Asian or Asian Irish	2.6%	4%
	Other	1.5%	3%
Income € (n= 1, 196)[4]	<20,000	20%	
	20,000-40,000	8%	
	41,000-60,000	14%	
	61,000-80,000	14%	
	81,000-100,000	14%	
	>100,000	29%	
Travel mode choice (work/school; n= 1,149) [5]	Private-car	28%	32%
	Public transit	40%	20%
	Car-sharing service	0.4%	Not available
	Bicycle	15%	10%
	Walking	16%	25%
	Other	0.6%	0.1%

4. The transition to autonomous cars in Dublin: concerns and intentions

The case of Dublin shows empirically that fears and anxieties towards autonomous cars do exist, but they do not diminish people's interest in them and, above all, the intention

[3]Source:http://census.cso.ie/sapmap2016/Results.aspx?Geog_Type=CTY31&Geog_Code=2AE19629143313A3E055000000000001#SAPMAP_T9_901

[4] Data on household income is not captured by the 2016 census.

[5] Commuting data in the 2016 census is aggregated for population aged 5 years and over by means of travel to work, school or college. It is therefore not possible to obtain data which applies specifically to the age range (i.e. 18-84 years) represented in the sample.

to use this emerging transport technology once it becomes available (see Figures 1 and 2).

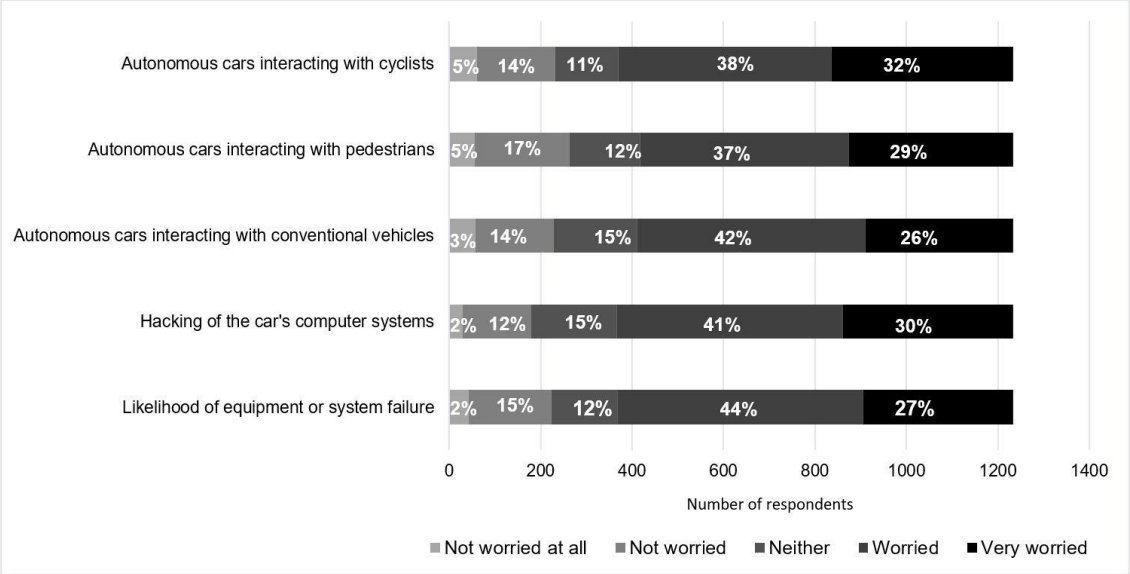

Figure 1: Summary of the data on people's fears and concerns regarding autonomous cars, based on a survey of 1,233 adults in Dublin, Ireland.

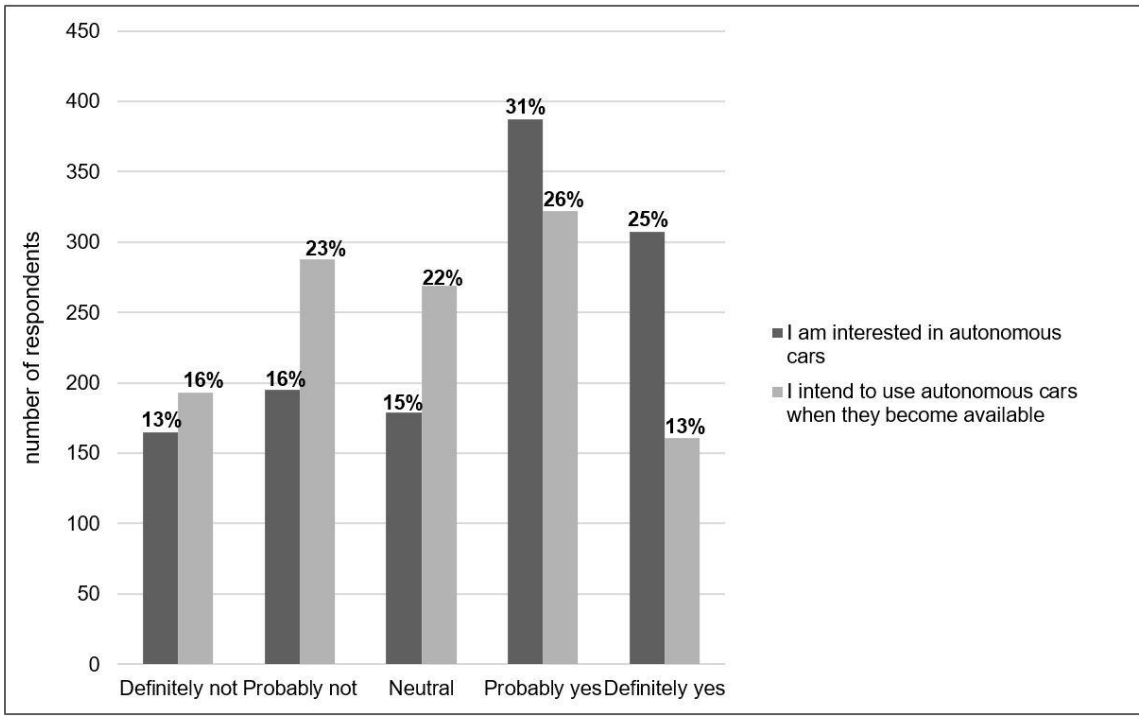

Figure 2: Summary of the data on public interest in and intention to use autonomous cars, based on a survey of 1,233 adults in Dublin, Ireland.

As shown in Figure 1, between 66% and 71% of the survey respondents indicated that they were either worried or very worried about all the five potential safety and security risks associated with autonomous vehicles. More specifically, about 70% of the respondents expressed concerns for the possibility of malfunctions and errors in the software of autonomous cars, in the event of technological glitches and cybersecurity attacks. Surrounding these fears is a broader fear of the injuries and fatalities that system malfunctions could cause. These concerns are not related only to passengers, but also to other motorists and vulnerable road users such as cyclists and pedestrians. Further insights from the empirical data on fears and concerns around autonomous vehicles are presented according to the gender (Fig 3) and age-group (Fig 4) of the respondents, and whether or not they currently use motorized or non-motorized (i.e. bicycling and walking) forms of transport (Fig 5). The results show that across all the five potential safety and security risks associated with autonomous vehicles, more females than males indicated to be 'very worried' or 'worried' about autonomous driving (see Figure 3). The results for the different age-groups (see Figure 4) and motorists and non-motorists (see Figure 5) are however similar, suggesting that fears and concerns regarding autonomous vehicles do not differ significantly in these sub-groups.

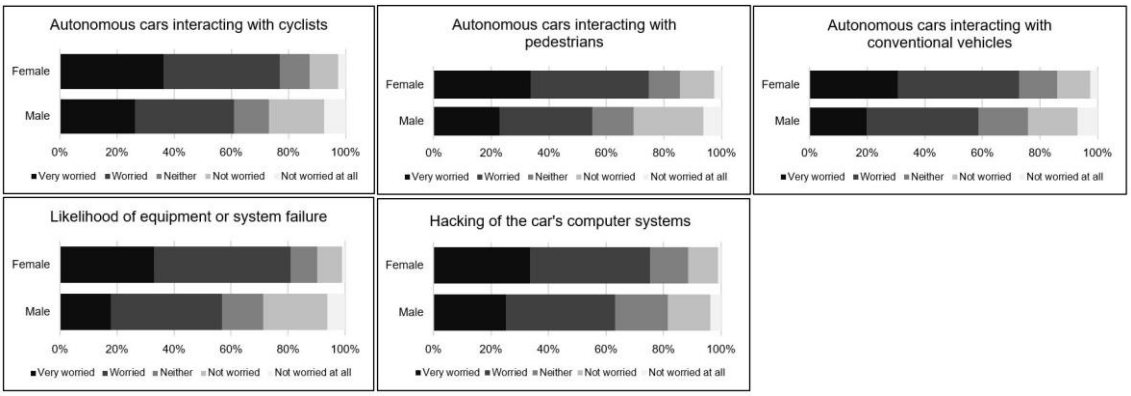

Figure 3: Summary of the data on fears and concerns regarding autonomous cars among males and females, based on a survey of 678 and 530 adult females and males, respectively, in Dublin.

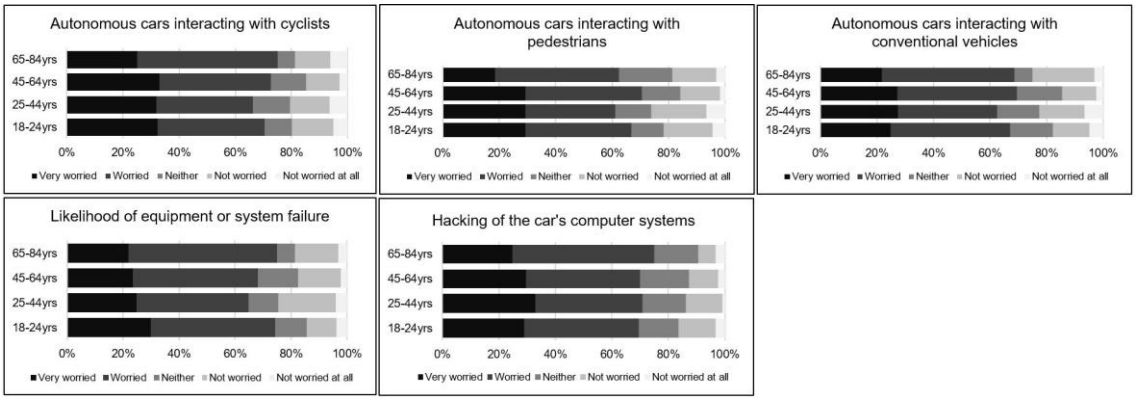

Figure 4: Summary of the data on fears and concerns regarding autonomous cars among age-groups, based on a survey of 1,233 adults in Dublin.

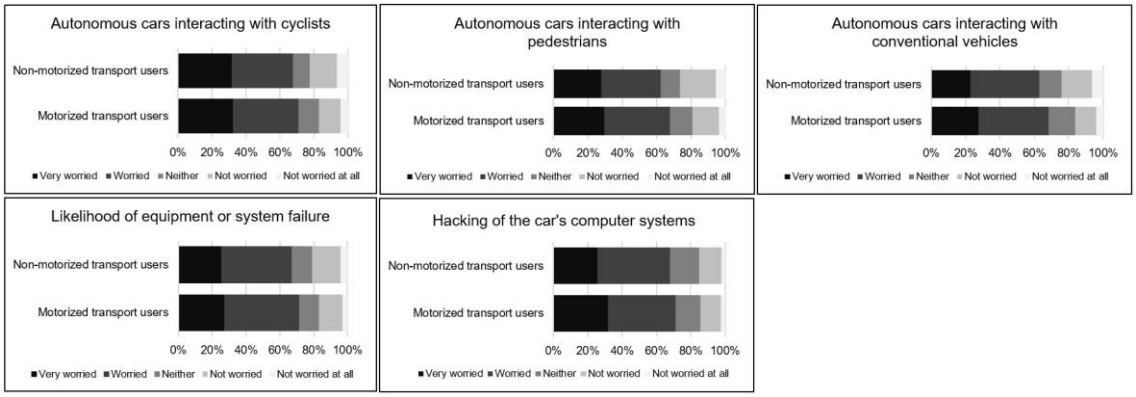

Figure 5: Summary of the data on fears and concerns regarding autonomous cars among motorists and non-motorists in Dublin.

PLEASE INSERT FIGURE 5

Yet, despite the presence of the above fears and concerns, a significant proportion of the survey respondents expressed interest in and intention to use autonomous cars once they

become available (see Figures 6 and 7). Indeed, nearly 6 in 10 individuals indicated that were probably interested (31%) or definitely interested (25%) in fully autonomous driving technologies. Moreover, close to 4 in 10 individuals stated that they intend to use autonomous cars. Only 15% and 22% of the respondents were indifferent in relation to their interest in autonomous cars and intention to employ them, respectively. The overall interest in autonomous cars and willingness to employ them, are therefore high in the population.

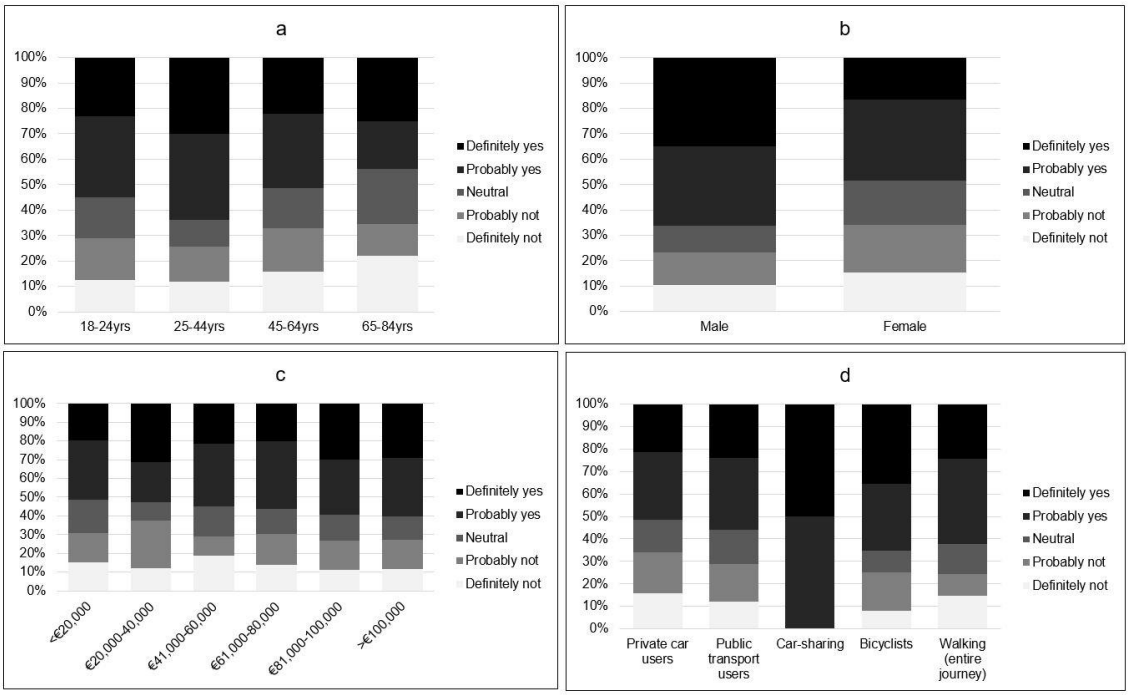

Figure 6: Summary of the responses to the statement *I am interested in autonomous cars*, according to the age-group, gender, income and current commuting mode choice of the survey respondents (1,233 adults in Dublin).

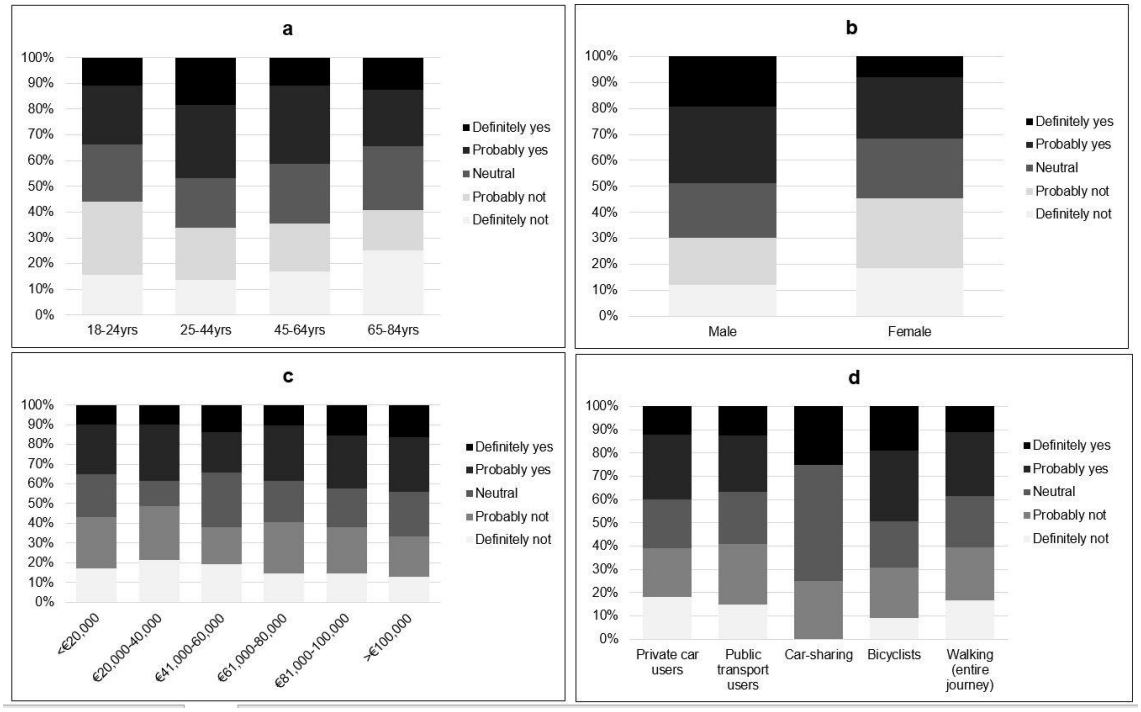

Figure 7: Summary of the responses to the statement *I intend to use autonomous cars when they become available*, according to the age-group, gender, income and current commuting mode choice of the survey respondents (1,233 adults in Dublin).

The results further show that younger people (i.e. 18-44 years) are more interested in autonomous cars (see Figure 6a). However, a much larger number of 25-24 and 45-64 year-olds intend to use autonomous cars when they become available. As shown in figure 7a, 47% and 41% of 25-24 and 45-64 year-olds, respectively responded 'probably yes' and 'definitely yes' to the question about whether they intend to use autonomous cars when they become available. Among those aged 18-24 and 65-84, 34% each gave the same indication as above regarding their intention to use autonomous cars. That relatively fewer 18-24 year-olds intend to use autonomous cars, might result from the fact that most of them are currently in university and therefore do not consider themselves ready to make long-term (and potentially expensive) travel mode choice decisions. This could be particularly the case when it comes to the choice of buying a car in the future. In addition, safety and security concerns regarding autonomous cars are dominant across the sample

population, and they could be the reason for the inertia towards the intention to actually use autonomous cars, in the total sample and among younger (18-24 year-olds) and older respondents (i.e. 65-84 year-olds) in particular.

Furthermore, more males than females expressed interest in and intention to use autonomous vehicles (see Figures 6b and 7b). No clear pattern emerges on the basis of the respondents' income and their current travel mode choice for work or school. However, what might appear surprising from the analysis, is that a higher percentage of individuals currently using non-motorized forms of transport are interested in and willing to use autonomous cars when they become available. For example, 30% and 36% of cyclists, and 38% and 25% of those who commute on foot indicated that they are probably and definitely interested in autonomous vehicles, respectively. With respect to use intentions, 30% and 20% of cyclists, and 27% and 11% of those who currently walk to work or school, indicated that they are probably and definitely willing to use autonomous car, respectively. Overall levels of motorization could thus increase in the future, due to the high number of cyclists and pedestrians willing to shift to autonomous urban transport.

These findings should not be read in isolation from the broader technological challenges and political questions that underpin the transition to autonomous urban transport. The fact that the number of the individuals that are interested in fully autonomous cars (i.e. 59%) is higher than the number of those who are willing to use fully autonomous cars (i.e. 39%), for example, is a reflection of the concerns about the risks and dangers that people associate with autonomous vehicles (see Figure 1). Such fears and anxieties are rooted in currently unresolved technological problems, and it is likely that if the fields of computer science and engineering will manage to improve the now questionable safety of autonomous technologies, the related concerns that people have will decrease. Conversely, failing to address critical technological issues of safety, as well as the

potential occurrence of more fatalities akin to the case of Tempe, will probably steer people's opinions away from any intention to employ an autonomous car.

The same findings can also be read from a political perspective. Figure 2, for instance, shows that most participants do not have strong opinions about autonomous cars. A lot of people are interested in autonomous cars as a potential means of transport, but many of them are neutral when it comes to their intention to eventually use an autonomous car. Referring to the language of the survey, only the minority is in the Definitely category (26%). The majority is in the Probably zone (49%). This means that, in relation to autonomous vehicles, the opinion of a large share of the population is now malleable and, as such, sensitive to the inputs of politically powerful actors. In Dublin, the Road Safety Authority is promoting autonomous cars to reduce accidents. Similar pro-autonomous transport campaigns, as discussed in section two, are taking place in the US, the Netherlands, Singapore and the UK through the agency of state actors, together with a strong push from the private sector (car manufactures and ridesharing companies, in particular). In a social context in which people's opinion is still in the making and not rigid, local and national policies can easily steer the direction of the transition to autonomous transport, with considerable repercussions on the built environment which will be discussed in the next section.

5. Autonomous cars and the design of the built environment

The literature and the case study suggest that, at some point in the future, autonomous cars will be to some extent part of the transport portfolio of cities. This transition in urban transport is, in turn, likely to trigger broader changes in urban design. There is an intrinsic connection between modes of urban transport and the way the built environment is

designed and shaped. By looking at urban history, it is possible to see that across times and spaces, cities have been repeatedly designed and redesigned to accommodate the integration of new forms of urban transport. Examples of this phenomenon can be found in the historical urban-transport transitions discussed before. The shape of the Baroque city, for instance, was influenced by 'the technical improvements that replaced the old-fashioned solid wheel with one built of separate parts, hub, rim, spoke, and added a fifth wheel, to facilitate turning (Mumford, 1961: 368).' As Mumford (ibid) notes, the diffusion of stagecoaches in particular led to a redesign of the built environment, because the streets of the Medieval city were too crooked and narrow to fit this new form of urban transport. Stagecoaches were designed for velocity and, as such, required movement in a straight line. This was a key reason why, in early modern Europe, urban design evolved in a linear way, with buildings placed in a symmetrical way along horizontal lines (see also Benevolo, 1993; Calabi, 2001; Conforti, 2005).

Similarly, in the Modernist city of the 1920s, the flow of automobiles in urban settlements led to the development of highways and arterial roads which revolutionized the fabric of cities (Sheller and Urry, 2000). Through the cuts of the linearity of the vehicle lane acting as a medium for the consecration of the speed of the car, the city acquired remarkably novel shapes and dynamics. Moreover, the design of what Hall (2002: 295) terms 'the city on the highway', was characterized by an emphasis on peripheral urban settlements. Car-owners became able to travel long distances, individually, to get access to services such as retail, education and health, as well as to their workplace. For them, being based in or close to the city centre stopped being a necessity. During this phase of urban history, peripheral housing units (although already present since another transport revolution, the train) were built consistently away from the hearth of the city, through intense processes of suburbanisation.

It is important to note that, historically, these changes in urban design led by changes in urban transport, were not neutral, in the sense that they came with uneven socio-environmental transformations which undermined the sustainability of the city. In the Baroque city, since the then political system prioritized the interests of the aristocracy over those of the demos, the diffusion of the stagecoach and the concomitant redesign of the built environment, were deeply socially unjust. As Mumford (1961: 370, 371) laments, 'there was only one desirable station in this despotism; it was that of the rich. The rich drive; the poor walk. The rich roll along the axis of the grand avenue; the poor are off-center, in the gutter; and eventually a special strip is provided for the ordinary pedestrian, the sidewalk. The rich stare; the poor gape: insolence battens on servility.'

Likewise, in the Modernist city, the advent of cars exacerbated the divide between the upper and the lower class, by marking a spatially clear distinction between who was driving and who was not and, above all, between those who had access to clean suburbia and the green countryside, and those who were stuck in the urban areas that were most polluted by the smokes of industry and the smog of automobiles. While Nick Carraway, in Fitzgerald's novel *The Great Gatsby* (1925), is commuting from a wealthy suburban enclave in Long Island to New York, he traverses 'a valley of ashes - a fantastic farm where ashes grow like wheat into ridges and hills and grotesque gardens; where ashes take the forms of houses and chimneys and rising smoke and, finally, with a transcendent effort, of ash-grey men who move dimly and already crumbling through the powdery air (Fitzgerald, 2000: 26).' At that time, the entry of automobiles had meant the development of highways and arterial roads which were increasing the size of urban settlements, thereby taking up prime farmland and destroying precious ecosystems such as forests, rivers and lakes, with considerable repercussions in terms of biodiversity loss (Kenworthy and Laube, 1996). In addition, suburbanisation (intensified by the diffusion of cars) was

promoting long commutes, eventually establishing an energy intensive lifestyle which has since been causing an escalation of carbon emissions (Laakso, 2017).

In the near future, the changes in urban design and urban sustainability that autonomous cars will trigger, are yet to be determined. The future, as such, is still indefinite. However, there are different possible scenarios (Narayanan et al., 2020; Sultana et al., 2017; Yigitcanlar et al., 2019). An optimistic scenario in which the diffusion of autonomous cars reshapes the built environment in a way that promotes sustainability, sees this new transport technology being deployed via sharing services. Recent studies indicate that, especially in large metropolitan areas, people are open to the idea of sharing an autonomous car, instead of owning a private vehicle: an attitude which, as foresight analyses show, can decrease car ownership, thereby reducing the number of cars in the city (Fagnant and Kockelman, 2014; Firnkorn and Müller, 2015; Haboucha et al., 2017; Iacobucci et al., 2018). It has been estimated that a single shared autonomous car can replace up to 11 conventional cars and 4 taxis (Alonso-Mora et al., 2017; Fagnant and Kockelman, 2018; Maciejewski and Bischoff, 2018). With a decreasing quantity of cars operating in the city, computer scientists working in the field of simulation, have calculated that traffic can substantially drop (Guériau and Dusparic, 2018; Guériau et al., 2020; Hörl et al. 2019; Levin et al., 2017). In terms of urban design, given that cities are designed to accommodate a certain level of traffic and quantity of cars, the reduction of these two elements means that, in the future, some roads and parking spaces could become superfluous. Therefore, employing shared autonomous cars has the potential to make a portion of the built environment currently reserved for cars, obsolete (Soteropoulos et al., 2018; Zhang et al., 2017; Zhang and Wang, 2020). From an urban sustainability point of view, this is a window of opportunity. As current urban design strategies reserve up to 80% of the total area of cities for cars, even a small reduction of this percentage would

provide planners and policy-makers with a large quantity of urban space which could be redesigned and repurposed (Duarte and Ratti, 2018; Robertson, 2017). Superfluous vehicle lanes and parking spaces could morph, for instance, into bike lanes, pedestrian streets and urban gardens, thereby making cities greener, healthier and, above all, places for people rather than spaces for cars.

In Dublin, many people believe that the diffusion of autonomous cars will be environmentally beneficial (see Figure 8).

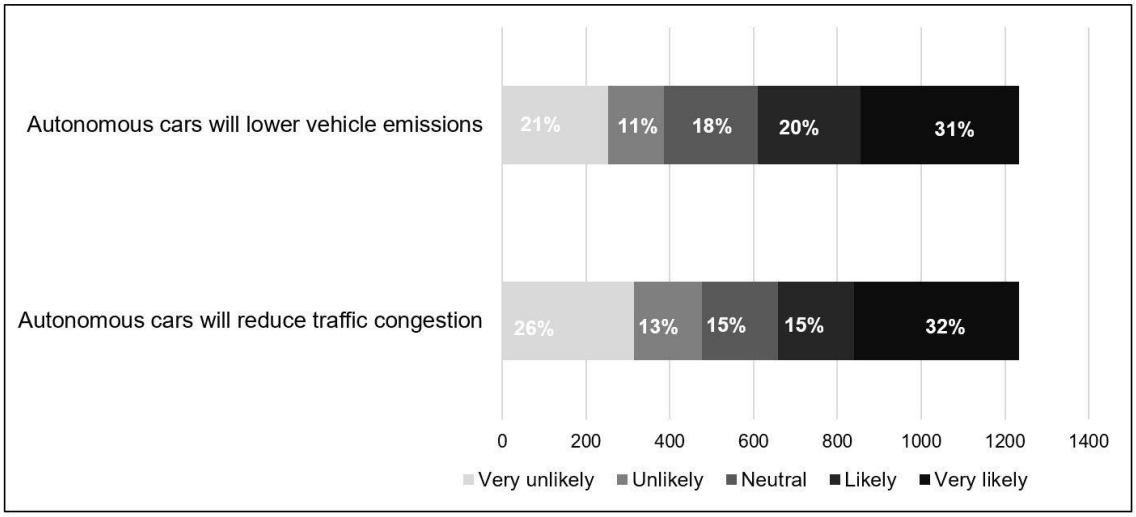

Figure 8: Summary of the perceived environmental benefits of autonomous cars, based on a survey of 1,233 adults in Dublin, Ireland

However, critical literature on the transition to autonomous transport, suggests that the opposite scenario might also be likely. The prospect of productive onboard activities that autonomous transport offers, for example, could lead to more and longer commutes. As Hawkins and Nurul Habib (2019: 69) note, most studies on autonomous cars expect that 'the associated decrease in travel disutility will cause people to travel more frequently and across greater distances.' Individuals could have the opportunity, for example, to

work while an artificial intelligence drives them autonomously from home to their place of work, on a regular basis. Autonomous cars might also be employed for leisure purposes, such as in the case of the Volvo 360C model, designed with a horizontal flat design mimicking the design of a bed, to encourage people to rest and sleep during long routes (Volvo, 2018). These experimental models, 'designed to help you relax or party on your journey, with all the creature comforts you need', could improve the experience of travelling in a car, to the point of increasing the demand for cars (Volvo, 2018: no page). This, in turn, would increase the demand for the energy and the urban spaces that are necessary to power cars and allow their transit. In essence, autonomous cars could aggravate the same sustainability issues initiated by their ancestors, replicating and expanding the negative socio-environmental transformations observed earlier in the context of the Modernist city.

A limitation of the above scenarios, however, is that they are too extreme in their vision of the urban future. The first one, in which the diffusion of autonomous cars is enabled by sharing services, pictures essentially an environmental and social urban utopia where public and natural spaces abound. The second one projects instead a dystopian image of mass suburbanisation, biodiversity loss and energy consumption. Although useful as a thought experiment, utopianism tends to miss a possible middle ground between extremes. In the case of the transition to autonomous transport and how cities will be consequently redesigned, we argue that the outcome will not be a black-and-white utopia or dystopia, but rather a complex urban geography full of tensions, differences and ambiguities. This is because, as we explained in section two, the diffusion of autonomous cars is being determined by a tripartite combination of social, technological and political factors which will also unevenly affect the design of future cities.

First, people's attitudes will continue to play an important role, by influencing the extent to which an individual is, for example, open to share an autonomous car with other passengers or instead prefers to own one (Acheampong and Cugurullo, 2019). Second, technological innovation will also have a recurring impact, since the act of sharing an autonomous car, to keep the same example, is enabled by hyper-fast mobile networks (like 5G), phone apps and fleets of shared autonomous cars, whose functionality and reliability depend upon progress in the disciplines of computer science and engineering. Such technological questions are interconnected to technical challenges in the fields of urban design, urban planning and architecture. How the latter disciplines will develop design strategies to accommodate the technological innovation cultivated by the former disciplines, is an open question. As Batty (2018) notes, there is an evident tension between artificial intelligence and the planning of cities. While the employment of AI to manage urban infrastructures (transport, energy and security, for instance) focuses on the 'automation of the routine' in real time, urban planning deals with the long-term development of cities and human societies, facing behaviours and events that are often unexpected even to those who generate them (Batty, 2018: 5). In essence, the shape of cities in an era of autonomous cars, will be partly determined by the relationship between what Kitchin (2014) terms the *real-time city* and historically future-oriented urban disciplines.

Third, there is the impact of urban politics. With the automation of the management of cities' infrastructure and services (like transport) as one of its key foci, smart urbanism arguably represents the mother of autonomous urban transport. As geographical studies have shown, the smart-city phenomenon 'does not occur in a vacuum' and is ultimately filtered and processed through national political economies and local urban politics (Datta, 2018; Karvonen et al., 2018: 4; Kong and Woods, 2018; McFarlane and

Söderström, 2017; Mouton, 2020; Shelton et al., 2015). In neoliberal contexts, smart-city agendas, although potentially conducive to urban sustainability, have favored the economic interests of elites, to the detriment of social justice and environmental preservation (Grossi and Pianezzi, 2017; Martin et al., 2018, Trencher, 2018; Wiig, 2016). Following an economic rationale, smart-city initiatives have frequently prioritized the diffusion of those technologies that can be monetized and offer the highest return on investment, integrating them in a minority of urban areas within what Hodson and Marvin (2010) term *premium ecological enclaves* (Kummitha, 2018). This business-centered framework has been implemented disregarding the natural environment, with ecosystems being erased to make room for new smart buildings and districts, through patterns of urban design akin to those of the Modernist city (Cugurullo, 2018). In terms of urban politics, history has repeated itself in the shape of smart-city projects developed in a top-down manner, with little or no inputs from the public regarding what technologies should become part of the built environment, like centuries before in the Baroque city (although see Calzada, 2018; Cowley et al., 2018).

The politics of the city where autonomous cars will be operative, is thus meant to impact on both the shape and the sustainability of the built environment. Recent studies indicate that cities which have traditionally invested in spaces for walking and cycling, are likely to maintain the same agenda and use autonomous vehicles as an opportunity to reduce spaces for cars, while local governments supporting automobile-oriented cities will tend to keep a business-as-usual approach, thereby exacerbating commuting and urban sprawl (Botello et al., 2019). The phenomenon will therefore be context-sensitive and its unfolding will have profound social and environmental implications (Bissell et al., 2018; Latham and Nattrass, 2019). What the lineage of autonomous transport, intended as the latest manifestation of smart urbanism, suggests is that a smart-city agenda which pushes

for the diffusion of autonomous cars under a neoliberal regime will not prioritize and hence achieve urban sustainability.

Overall, these three factors (the *social*, the *technological* and the *political*) can be conceptualized as three vectors leading to possible urban futures. It is unlikely that, everywhere in the world, all vectors will be aligned along the same vision of the future. Moreover, it is also unlikely that every vector will consistently push towards a single urban future. For instance, from a social point of view, some individuals might prefer to share an autonomous car, while others would like to opt for private ownership. A situation in which everybody presents exactly the same social attitude is extreme and, as such, unrealistic. In the next section we explore this point empirically in our case study, revealing how people in Dunlin intend to use autonomous cars, and then discussing how their social attitudes are connected to contextual technological and political questions.

6. The transition to autonomous cars in Dublin: preferred modes of employment

The case of Dublin demonstrates empirically that the local population manifests different attitudes towards different modes of adoption which, in turn, will influence the realisation of different urban scenarios (see Figure 9).

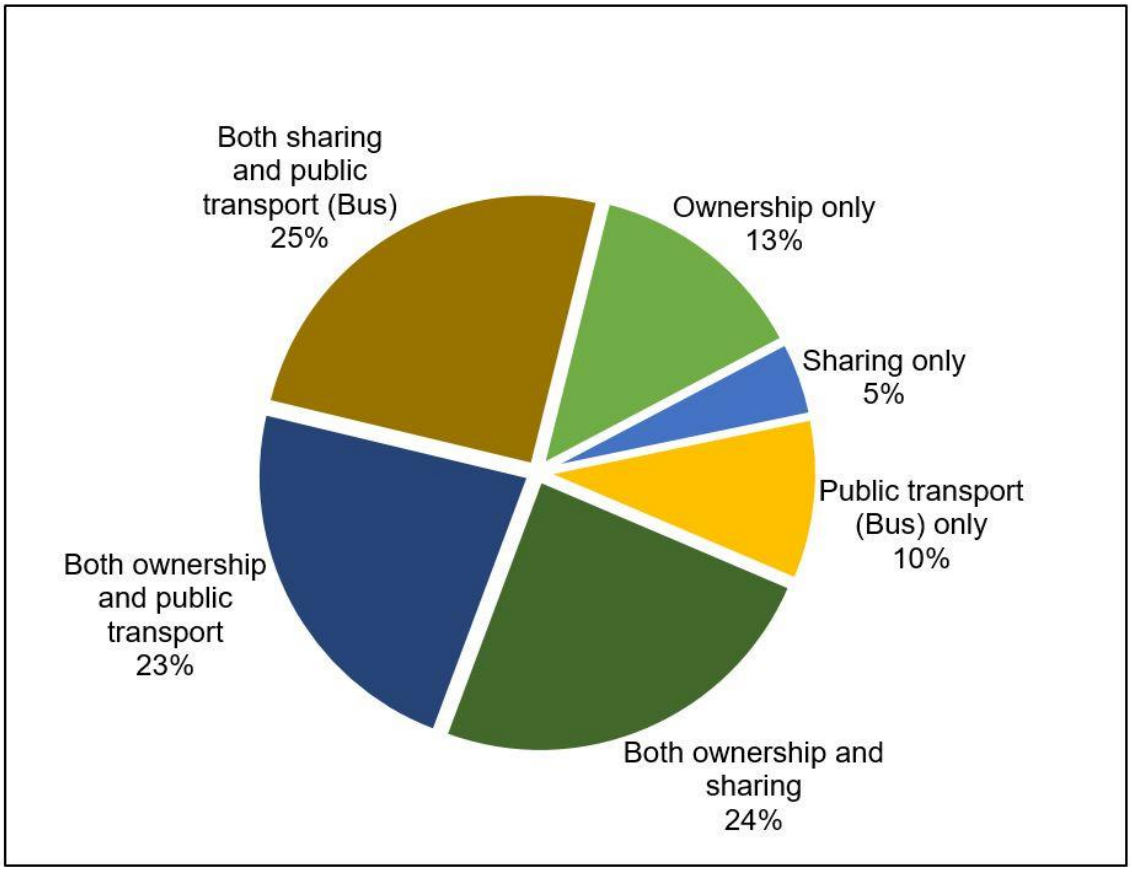

Figure 9: Summary of the data on the preferred modes of employment of autonomous cars, among different individuals. This figure is based on a sub-sample of 919 individuals who expressed interest in autonomous cars from the total pool of respondents (1,233 adults in Dublin).

As depicted in Figure 9, modal preferences are heterogeneous. The results of the survey show that preferences for single mode options, such as *ownership only* (13%), *autonomous car-sharing only* (5%) and *autonomous bus services only* (10%), are low in the population. Willingness to use *autonomous car-sharing services only* is the least preferred option among the respondents. Conversely, preferences for combined mode options are relatively higher. For example, the survey indicates that 24% of the respondents would prefer to own an autonomous car *and* use autonomous car-sharing services. Similarly, 23% and 25% of the respondents opted for the combined options of

(a) owning an autonomous car while using autonomous public transport, and (b) using both shared autonomous cars and autonomous public transport, respectively. Thus, according to these findings, once autonomous cars become fully available, their employment is likely to take place through a combination of different modes which serve different travel needs of the population. What the data suggests in terms of urban design is a non black-and-white scenario: shared autonomous cars, autonomous public buses and privately owned autonomous cars will overlap in the same city. Therefore, while sharing and public transport will push for the production of less car-centric urban spaces, car ownership will continue to do the opposite.

However, these findings must also be interpreted in relation to interconnected technological and political questions. Figure 9 shows that *ideally* citizens would like to use autonomous cars in a variety of ways, such as public transport, private ownership, car sharing and multiple combinations which are desirable for them, but *realistically* they will have to choose among the options that are functional and actually available in the city. In terms of technology, Dublin has not developed yet the minimum technological requirements that are necessary to enable the deployment and sharing of fleets of autonomous cars. State-of-the-art mobile networks such as 5G, for instance, which shared autonomous vehicles need in order to handle big data, are currently being tested only in parts of the city. Therefore, even if 54% of the population intends to share an autonomous car (as a single mode and in combination with other modes), practically they cannot do so, due to contextual technological barriers that go beyond their direct agency. Similarly, individuals can choose *among* different options of employment, but they cannot choose *what* transport options will be in practice available. The latter choice is ultimately down to the politically powerful actors who have agency in the politics of urban transport. Here context matters. The smart-city agenda of Dublin, for instance, as several studies show,

is deeply neoliberal in nature (Coletta et al., 2018; Kitchin et al., 2018). In this neoliberal context, therefore, the modes through which autonomous cars will be included in the transport portfolio of the city, are very likely to be determined by a network of actors from both the private and the public sector, with citizens having only marginal direct influence (if any influence at all).

7. Conclusions

Building upon empirical research conducted in Dublin, in unison with a broad-based review of the literature, this paper has argued that the transport portfolio of cities is gradually including autonomous cars. There is a plethora of possible scenarios on the horizon. If the advent of autonomous cars is aligned with sharing services, for example, car ownership and so the number of cars in the city can potentially decrease. As a result, many urban spaces currently designed for cars could become obsolete, thereby becoming prone to being repurposed as cycling lanes, gardens and public places which would increase urban sustainability. However, the development of highly comfortable cars driven by an artificial intelligence promising productive and recreational onboard activities, could increase the demand for cars, and so the amount of urban spaces and energy that is necessary to sustain them.

The transition to autonomous transport and the consequent redesign of the built environment, will be determined by several interconnected factors. Social attitudes, for instance, are influencing the extent to which a given population will adopt autonomous cars, as well as the modes whereby this new transport technology will be employed. The paper has empirically shown that, in Dublin, people are generally concerned with the safety of autonomous vehicles and, yet, inclined to use them once available. Moreover,

they are maturing diverse modal preferences which range from sharing to car ownership, and from public transport to a mix of different modes. This social dimension, together with the rapid technological evolution of autonomous driving and how disciplines like urban planning, urban design and architecture are evolving accordingly, is shaping heterogenous urban futures. Different technologies of autonomous transport and different attitudes towards them are likely to coexist. Besides, even if autonomous cars are going to become the main form of urban transport, this will not happen overnight. There will be decades of overlap between cars driven by AI and conventional cars. What we expect are thus complex urban geographies featuring shared and private autonomous cars, human drivers and artificial intelligences competing for urban spaces, with repercussions on the design and sustainability of the city which will depend on the local context.

The paper has emphasized that, in addition to these social and technological aspects, another factor will be crucial: urban politics. Urban history shows that changes in urban transport have been traditionally followed by changes in urban design which, in turn, have been followed by changes in urban sustainability (Hall, 2002; Mumford, 1961; Sheller and Urry, 2000). Underpinning this chain of urban transformations, historically, has been the politics of the city. This phenomenon can be observed in the past by exploring the Baroque city and the Modernist city and the escalation of urban changes which were triggered by the diffusion of stagecoaches and cars, respectively. Such changes, while connected to social and technological factors, were also shaped by the then political contexts in which elites pushed forward new transport technologies, in a top-down manner, without considering the interests of the demos and those of the natural environment. Today, within neoliberal contexts, similar dynamics are being observed in smart-city initiatives, and are likely to affect the deployment of autonomous cars and their impact on the design of the built environment. On these terms, autonomous driving is

revolutionary only from a technological perspective. Its current deployment in cities echoes past patterns of urban transport development.

Social aspects, technological challenges and political forces should not be understood and analytically approached in isolation, but rather as interconnected factors. The empirical findings discussed in the paper, while revealing people's attitudes towards autonomous cars, also resonate with broader political questions. When it comes to the intention of actually using an autonomous car, for example, most of our respondents (71%) are simply not sure: many people are currently in a limbo of neutrality and uncertainty. Within this limbo, it will not be difficult for politically powerful actors to impose their view and, thus, the ongoing pro-autonomous transport campaigns carried out by both state actors and car manufactures might find little resistance. This conclusion relates to a bigger tension between the hypothetical freedom that the individual has in the adoption or rejection of a new smart technology (like, in this instance, an autonomous car), and the pressures that influential stakeholders (such as multinational tech companies and top-level politicians) exert in the diffusion of that technology.

On the one hand, as Greenfield (2018: 308) laments, a lot of people tend not to be informed about how smart technologies actually function: they do not critically evaluate their utility, preferring instead to follow the 'momentum' of technological innovation and embrace the newest device on the market. On the other hand, there is the neoliberal state which often exploits human irrationality, by nudging the individual (Whitehead et al., 2019). The tension lies in the fact that individuals are still free to act, but their actions are (a) not fully based on knowledge and rationality, and (b) directed by nudges. For Han (2017), this condition is advanced by neoliberalism as a technique of government, which preserves human freedom while subtly influencing the psyche to steer human behaviour. Philosophically speaking, the question is whether or not this really counts as freedom, or

if the individual has become, to paraphrase Gray (2016), a *marionette* incapable to discern the world and moving according to the nudges of a well-hidden puppeteer. In pragmatic terms, connecting the above theories to the case of autonomous cars, the manifestations of this political condition can be somehow paradoxical and inexplicable situations like those discussed in this paper: our survey participants are afraid of cars driven by an artificial intelligence, and yet ready to employ them. Similarly, today most people use cars despite the fact that this is a dangerous transport technology responsible for more than one million deaths every year. Such situations are, at first glance, difficult to explain because they lack rationality. However, they make perfect sense when we see them framed by a neoliberal political context which cultivates irrationality and nudges people towards the consumption of highly monetizable technologies.

Moreover, the political context determines the everyday spectrum of choices available to the individual. This is another important intersection between the *political* and the *social*. Even if our findings show that citizens desire to both own and share autonomous cars, as well as to use them in combination with public transport, such desires will ultimately clash against the actually available transport options in the city. In neoliberal contexts, these options will be the product of an urban politics influenced more by market forces, rather than public opinion. From a sustainability perspective, a likely outcome is the perpetuation of injustice. When neoliberalism shapes the politics of urban transport, what follows is often a neoliberal mobility marked by inequality, privatisation, segregation, deregulation and uneven access (Culver, 2017). As Henderson (2018) notes, neoliberal mobility can be already observed in the diffusion of autonomous cars, in the shape of private transport-services accessible only to an elite living in premium enclaves. This is a type of mobility which has been strongly critiqued and resisted by scholars working in the field of *mobility justice* invoking the right to the city, specifically in relation to issues

of urban transport (see Sheller, 2018). The literature on mobility justice stresses that a means of transport, like a car, is not an apolitical artefact and, for this reason, the transition to sustainable mobilities requires us to recognize the political dimension of transport technologies, and to enable public participation in the politics of urban transport (Nikolaeva et al., 2019).

In conclusion then, if academia wants to understand how autonomous cars can help cities become more sustainable, examining the mechanics of this new transport technology and the attitudes of its potential users, will not be enough. Critical urban political research is much needed on the complex network of politically influential actors and groups that are behind the introduction of autonomous driving technologies into urban transport. Such analytical approach unavoidably leads to an engagement with the 'complexity of transport governance' and the merging of public and private forces in the 'diverse, networked and increasingly complex decision-making landscape' where decisions over the roll-out of autonomous cars are made (Legacy et al., 2019: 92; Monios and Bergqvist, 2019). However, there is a paucity of this type of research and, as lamented by scholars like Stilgoe (2018) and JafariNaimi (2018), the autonomous car is largely understood and treated as an apolitical artefact. This lacuna calls not simply for more contributions from fields such as urban geography, political science and political philosophy but, above all, for more collaborations among disciplines. As this paper as shown, the chain that links changes in urban transport, the redesign of the built environment and related socio-environmental transformations, is made of interconnected political, technological, social and environmental elements, and academic research should, therefore, reflect this interconnection and diversity by means of interdisciplinary studies.

Finally, this paper has pointed out that when at the basis of an urban transport revolution is a political system which disregards social justice and environmental protection, the

redesign of the built environment that will follow cannot lead to urban sustainability. This means that making autonomous transport technologies and the attitudes of their users more environmentally friendly and socially just, will not be enough unless the political environment does not change too. Of course, this is a much harder task. Autonomous cars are made of metals and plastics which can be easily reshaped within days, whereas the attitudes of people towards modes of transport can evolve within months. Changing a political system, however, takes years. Yet, this is not a good reason to avoid the political question. Particularly in terms of urban sustainability, several studies stress that there is a positive correlation among participatory democracy, social justice and environmental preservation (Horne et al., 2016; McLaren and Agyeman, 2015). Autonomous cars can lead to sustainability, and cities can reach that destination if behind the wheel is not simply an artificial intelligence, but a strong democratic political system.

Bibliography

Acheampong, Ransford A., & Cugurullo, Federico (2019). Capturing the behavioural determinants behind the adoption of autonomous vehicles: Conceptual frameworks and measurement models to predict public transport, sharing and ownership trends of self-driving cars. *Transportation Research Part F: Traffic Psychology and Behaviour*, 62, 349-375.

Alonso-Mora, Javier, Samaranayake, Samitha, Wallar, Alex, Frazzoli, Emilio, & Rus, Daniela (2017). On-demand high-capacity ride-sharing via dynamic trip-vehicle assignment. *Proceedings of the National Academy of Sciences*, 114(3), 462-467.

Awad, Edmond, Dsouza, Sohan, Kim, Richard, Schulz, Jonathan, Henrich, Joseph, Shariff, Azim, Bonnefon, Jean-François & Rahwan, Iyad (2018). The moral machine experiment. *Nature*, 563 (7729), 59-64.

Bagloee, Saeed Asadi, Tavana, Madjid, Asadi, Mohsen, & Oliver, Tracey (2016). Autonomous vehicles: challenges, opportunities, and future implications for transportation policies. *Journal of Modern Transportation*, 24(4), 284-303.

Batty, Michael (2018). Artificial intelligence and smart cities. *Environment and Planning* B DOI: https://doi.org/10.1177/2399808317751169

Bättig, Michèle B., & Bernauer, Thomas (2009). National institutions and global public goods: are democracies more cooperative in climate change policy?. *International organization*, *63*(2), 281-308.

Benevolo, Leonardo (1993). *The European City*. Oxford: Blackwell

Bissell, David (2018). Automation interrupted: How autonomous vehicle accidents transform the material politics of automation. *Political Geography*, 65, 57-66.

Bissell, David, Birtchnell, Thomas, Elliott, Anthony and Hsu, Eric L. (2018) Autonomous automobilities: The social impacts of driverless vehicles. *Current Sociology*, http://doi.org/10.1177/0011392118816743

Botello, Bryan, Buehler, Ralph, Hankey, Steve, Mondschein, Andrew, and Zhiqiu, Jiang (2019). Planning for walking and cycling in an autonomous-vehicle future. *Transportation research interdisciplinary perspectives*, 1, 100012.

Calabi, Donatella (2001). *La citta' del primo Rinascimento*. Roma: Laterza

Calzada, Igor (2018). (Smart) Citizens from Data Providers to Decision-Makers? The Case Study of Barcelona. *Sustainability*, 10(9), 3252.

Coletta, Claudio, Heaphy, Liam, & Kitchin, Rob, (2017). From the accidental to articulated smart city: The creation and work of 'Smart Dublin'. *European Urban and Regional Studies*, 0969776418785214.

Conforti, Claudia (2005). *La citta' del tardo Rinascimento*. Roma: Laterza

Cowley, Robert, & Caprotti, Federico (2018). Smart city as anti-planning in the UK. *Environment and Planning D: Society and Space*, DOI: 0263775818787506.

Cowley, Robert, Joss, Simon, & Dayot, Youri (2018). The smart city and its publics: insights from across six UK cities. *Urban Research & Practice*, 11(1), 53-77.

Cugurullo, Federico (2018). Exposing smart cities and eco-cities: Frankenstein urbanism and the sustainability challenges of the experimental city. *Environment and Planning A: Economy and Space*, 50(1), 73-92.

Culver, Gregg (2017). Mobility and the making of the neoliberal "creative city": The streetcar as a creative city project?. *Journal of transport geography*, 58, 22-30.

Datta, Ayona (2018). The digital turn in postcolonial urbanism: Smart citizenship in the making of India's 100 smart cities. *Transactions of the Institute of British Geographers*, 43(3), 405-419.

Daziano, Ricardo A., Sarrias, Mauricio, & Leard, Benjamin (2017). Are consumers willing to pay to let cars drive for them? Analyzing response to autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 78, 150-164.

Duarte, Fábio, & Ratti, Carlo (2018). The Impact of Autonomous Vehicles on Cities: A Review. *Journal of Urban Technology*, 1-16.

Fagnant, Daniel J., & Kockelman, Kara M. (2014). The travel and environmental implications of shared autonomous vehicles, using agent-based model scenarios. *Transportation Research Part C: Emerging Technologies*, 40, 1-13.

Fagnant, Daniel J. & Kockelman, Kara M. (2018). Dynamic ride-sharing and fleet sizing for a system of shared autonomous vehicles in Austin, Texas. *Transportation*, 45(1), 143-158.

Firnkorn, Jörg, & Müller, Martin (2015) Free-floating electric carsharing-fleets in smart cities: The dawning of a post-private car era in urban environments? *Environmental Science & Policy*, 45, 30-40.

Fitzgerald, F. Scott (2000). *The Great Gatsby*. London: Penguin Books

Fridman, Lex, Brown, Daniel E., Glazer, Michael, Angell, William, Dodd, Spencer, Jenik, Benedikt, Terwilliger, Jack, Patsekin, Aleksandr,

Kindelsberger, Julia, Ding, Li, Seaman, Sean, Mehler, Alea, Sipperley, Andrew, Pettinato, Anthony, Seppelt, Bobbie D., Angell, Linda, Mehler, Bruce, & Reimer, Bryan (2019). MIT advanced vehicle technology study: Large-scale naturalistic driving study of driver behavior and interaction with automation. *IEEE Access*, 7, 102021-102038.

Gray, John (2016). *The soul of the marionette: A short inquiry into human freedom*. London: Penguin Books

Greenfield, Adam (2018). *Radical technologies: The design of everyday life*. London: Verso Books.

Grossi, Giuseppe, & Pianezzi, Daniela (2017). Smart cities: Utopia or neoliberal ideology?. *Cities*, 69, 79-85.

Government of the United Kingdom (2018). *Centre for Connected and Autonomous Vehicles*. [Online] Available: https://www.gov.uk/government/organisations/centre-for-connected-and-autonomous-vehicles [Accessed 16/12/2018]

Government of the Netherlands (2018). *Self-driving vehicles*. [Online] Available: https://www.government.nl/topics/mobility-public-transport-and-road-safety/self-driving-vehicles [Accessed 16/12/2018]

Guériau, Maxime, & Dusparic, Ivana (2018). SAMoD: Shared Autonomous Mobility-on-Demand using Decentralized Reinforcement Learning. *21st International Conference on Intelligent Transportation Systems (ITSC)*, 1558-1563.

Guériau, Maxime, Cugurullo, Federico, Acheampong, Ransford & Dusparic, Ivana (2020). Shared Autonomous Mobility-on-Demand: Learning-based approach and its performance in the presence of traffic congestion. *IEEE Intelligent Transportation Systems Magazine.*

Haboucha, Chana J., Ishaq, Robert, & Shiftan, Yoram (2017). User preferences regarding autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, 78, 37-49.

Hall, Peter (1998). *Cities in civilization*. London: Weidenfeld and Nicolson

Hall, Peter (2002). *Cities of tomorrow*. Oxford: Blackwell Publishers

Han, Byung-Chul (2017). *Psychopolitics: Neoliberalism and new technologies of power*. London: Verso Books

Hawkins, Jason, & Nurul Habib, Khandker (2019). Integrated models of land use and transportation for the autonomous vehicle revolution. *Transport Reviews*, 39(1), 66-83.

Henderson, Jason (2018). Google buses and uber cars: The politics of tech mobility and the future of urban liveability. In Ward, Kevin, Jonas, Andrew E.G., Miller, Byron, and Wilson, David (eds) (2018). *The Routledge handbook on spaces of urban politics*. London: Routledge

Hodson, Mike, & Marvin, Simon (2010). Urbanism in the anthropocene: Ecological urbanism or premium ecological enclaves?. *City*, *14*(3), 298-313.

Hörl, Sebastian, Balac, Milos, & Axhausen, Kay W. (2019). Dynamic demand estimation for an AMoD system in Paris. *2019 IEEE Intelligent Vehicles Symposium (IV)*, 260-266.

Horne, Ralph, Fien, John, Beza, Beau B., & Nelson, Anitra (Eds.). (2016). *Sustainability Citizenship in Cities: Theory and Practice*. London: Routledge

Hudson, John, Orviska, Marta, & Hunady, Jan (2019). People's attitudes to autonomous vehicles. *Transportation Research Part A: Policy and Practice*, 121, 164-176.

Iacobucci, Riccardo, McLellan, Benjamin, & Tezuka, Tetsuo (2018). Modeling shared autonomous electric vehicles: Potential for transport and power grid integration. *Energy*, 158, 148-163

JafariNaimi, Nassim (2018). Our bodies in the trolley's path, or why self-driving cars must* not* be programmed to kill. *Science, Technology, & Human Values*, 43(2), 302-323.

Karvonen, Andrew, Cugurullo, Federico & Caprotti, Federico (eds) (2018). *Inside Smart Cities: place, politics and urban innovation*. London: Routledge

Kenworthy, Jeffrey R., & Laube, Felix B. (1996). Automobile dependence in cities: an international comparison of urban transport and land use patterns with implications for sustainability. *Environmental impact assessment review*, 16(4), 279-308.

Kitchin, Rob (2014). The real-time city? Big data and smart urbanism. *GeoJournal*, 79(1), 1-14.

Kitchin, Rob, Coletta, Claudio, & Heaphy, Liam (2018). Actually Existing Smart Dublin: Exploring smart city development in history and context. In Karvonen, Andrew, Cugurullo, Federico & Caprotti, Federico (eds) (2018). *Inside Smart Cities: place, politics and urban innovation*. London: Routledge

Kummitha, Rama Krishna Reddy (2018). Entrepreneurial urbanism and technological panacea: Why Smart City planning needs to go beyond corporate visioning?. *Technological Forecasting and Social Change*. DOI: https://doi.org/10.1016/j.techfore.2018.07.010

Kyriakidis, Miltos, Happee, Riender, & de Winter, Joost C. (2015). Public opinion on automated driving: Results of an international questionnaire among 5000 respondents. *Transportation research part F: traffic psychology and behaviour*, 32, 127-140.

Laakso, Senja (2017). Giving up cars–The impact of a mobility experiment on carbon emissions and everyday routines. *Journal of Cleaner Production*, 169, 135-142.

Latham, Alan, and Nattrass, Michael (2019). Autonomous vehicles, car-dominated environments, and cycling: Using an ethnography of infrastructure to reflect on the prospects of a new transportation technology. *Journal of Transport Geography*. doi.org/10.1016/j.jtrangeo.2019.102539

Legacy, Crystal, Ashmore, David , Scheurer, Jan, Stone, John & Curtis, Carey (2019) Planning the driverless city. *Transport Reviews*, 39 (1), 84-102.

Lee, Yi-Ching, & Mirman, Jessica (2018). Parents' perspectives on using autonomous vehicles to enhance children's mobility. *Transportation Research Part C: Emerging Technologies*, 96, 415-431.

Levin, Michael W., Kockelman, Kara M., Boyles, Stephen D., & Li, Tianxin (2017). A general framework for modeling shared autonomous vehicles with dynamic network-loading and dynamic ride-sharing application. *Computers, Environment and Urban Systems*, 64, 373-383.

Maciejewski, Michal & Bischoff, Joschka (2018) Congestion Effects Of Autonomous Taxi Fleets. *Transport*, 33, 971-980.

Martin, Chris, J., Evans, James, & Karvonen, Andrew (2018). Smart and sustainable? Five tensions in the visions and practices of the smart-sustainable city in Europe and North America. *Technological Forecasting and Social Change*, 133, 269-278.

McLaren, Duncan, & Agyeman, Julian (2015). *Sharing cities: a case for truly smart and sustainable cities*. Boston: MIT Press

Mercier, Louis-Sébastien (1781). *Tableau de Paris. Tome premier*. Samuel Fauche, Neuchâtel. [Online] Available:https://books.google.ie/books?id=J0kGAAAAQAAJ&printsec=frontcover&dq=Tableau+de+Paris&hl=en&sa=X&ved=0ahUKEwivs8GTpPndAhVOmbQKHUPFBI8Q6AEIKTAA#v=onepage&q&f=false [Accessed 16/12/2018]

Milakis, Dimitris, Van Arem, Bart, & Van Wee, Bert (2017). Policy and society related implications of automated driving: A review of literature and directions for future research. *Journal of Intelligent Transportation Systems*, 21(4), 324-348.

Monios, Jason, and Bergqvist, Rickard (2019). The transport geography of electric and autonomous vehicles in road freight networks. *Journal of Transport Geography*, http://doi.org/10.1016/j.jtrangeo.2019.102500

Mouton, M. (2020). Worlding infrastructure in the global South: Philippine experiments and the art of being 'smart'. *Urban Studies*, DOI: 0042098019891011.

Mumford, Lewis (1961). *The city in history: Its origins, its transformations, and its prospects*. New York: Harcourt, Brace & World

Nakicenovic, Nebojsa (1986). The automobile road to technological change: diffusion of the automobile as a process of technological substitution. *Technological Forecasting and Social Change*, 29(4), 309-340.

Narayanan, Santhanakrishnan, Chaniotakis, Emmanouil & Antoniou, Constantinos (2020). *Shared autonomous vehicle services: A comprehensive review. Transportation Research Part C: Emerging Technologies*, 111, 255-293.

Nikolaeva, Anna, Adey, Peter, Cresswell, Tim, Yeonjae Lee, Jane, Nóvoa, Andre and Temenos, Cristina (2019). Commoning mobility: Towards a new politics of mobility transitions. *Transactions of the Institute of British Geographers*, 44 (2), 346-360

Parra, Ignacio, García-Morcillo, Alvaro, Izquierdo, Rubén, Alonso, Javier, Fernández-Llorca, D. & Sotelo, Miguel Angel (2017). Analysis of ITS-G5A V2X communications performance in autonomous cooperative driving experiments. 2017 *IEEE Intelligent Vehicles Symposium (IV)*, 1899-1903

Penmetsa, Praveena, Adanu, Kofi Adanu, Wood, Dustin, Wang, Teng, & Jones, Steven L. (2019). Perceptions and expectations of autonomous vehicles–A snapshot of vulnerable road user opinion. *Technological Forecasting and Social Change*, 143, 9-13.

Potoglou, Dimitris, Whittle, Colin, Tsouros, Ioannis & Whitmarsh, Lorraine (2020). Consumer intentions for alternative fuelled and autonomous vehicles: A segmentation analysis across six countries. *Transportation Research Part D: Transport and Environment*, 79, 102243.

Robertson, Margaret (2017). *Sustainability principles and practice*. Routledge, London

Ros, German, Ramos, Sebastian, Granados, Manuel, Bakhtiary, Amir, Vazquez, David, & Lopez, Antonio M. (2015). Vision-based offline-online perception paradigm for autonomous driving. *2015 IEEE Winter Conference on Applications of Computer Vision* (pp. 231-238). IEEE.

Sheller, Mimi (2018). *Mobility justice: The politics of movement in an age of extremes*. London: Verso Books.

Sheller, Mimi, & Urry, John (2000). The city and the car. *International journal of urban and regional research*, 24(4), 737-757.

Shelton, Taylor, Zook, Matthew, & Wiig, Alan (2015). The 'actually existing smart city'. *Cambridge Journal of Regions, Economy and Society*, 8(1), 13-25.

Singapore Smart Nation (2018). Self-driving vehicles: future of mobility in Singapore. [Online] Available:https://www.smartnation.sg/initiatives/Mobility/self-driving-vehicles-sdvs--future-of-mobility-in-singapore [Accessed 16/12/2018]

Soteropoulos, Aggelos, Berger, Martin, & Ciari, Francesco (2018). Impacts of automated vehicles on travel behaviour and land use: an international review of modelling studies. *Transport Reviews*, 1-21.

Stilgoe, Jack (2018). Machine learning, social learning and the governance of self-driving cars. *Social studies of science*, 48(1), 25-56.

Sultana, Selima, Salon, Deborah, & Kuby, Michael (2017). Transportation sustainability in the urban context: a comprehensive review. *Urban Geography*, 1-30.

Tachet, Remi, Santi, Paolo, Sobolevsky, Stanislav, Reyes-Castro, Luis Ignacio, Frazzoli, Emilio, Helbing, Dirk & Ratti, Carlo (2016). Revisiting street intersections using slot-based systems. *PloS one*, 11(3).

Taeihagh, Araz, & Lim, Hazel Si Min (2018). Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. *Transport Reviews*, 1-26.

Talebian, Ahmadreza, & Mishra, Sabyasachee (2018). Predicting the adoption of connected autonomous vehicles: A new approach based on the theory of diffusion of innovations. *Transportation Research Part C: Emerging Technologies*, 95, 363-380.

Trencher, Gregory (2018). Towards the smart city 2.0: Empirical evidence of using smartness as a tool for tackling social challenges. *Technological Forecasting and Social Change*. DOI: https://doi.org/10.1016/j.techfore.2018.07.033

US Committee on Traffic Accident Statistics (1930). *Report of the Committee on Traffic Accident Statistics* [Online] Available:

https://books.google.ie/books?id=MQrxdvjM6mYC&q=car+accident+statistics+1920&dq=car+accident+statistics+1920&hl=en&sa=X&ved=0ahUKEwiZ5pikleXdAhXQKlAKHWpYB_IQ6AEIKTAA [Accessed 16/12/2018]

US Department of Transportation (2017*). Preliminary Statement of Policy Concerning Automated Vehicles*. [Online] Available: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/automated_vehicles_policy.pdf [Accessed 16/12/2018]

Van Brummelen, Jessica, O'Brien, Marie, Gruyer, Dominique, & Najjaran, Homayoun (2018). Autonomous vehicle perception: The technology of today and tomorrow. *Transportation research part C: emerging technologies*. DOI: https://doi.org/10.1016/j.trc.2018.02.012

Volvo (2018). *360C* [Online] Available: https://www.volvocars.com/intl/cars/concepts/360c

[Accessed 16/12/2018]

Whitehead, Mark, Jones, Rhys, Lilley, Rachel, Howell, Rachel & Pykett, Jessica (2019). Neuroliberalism: Cognition, context, and the geographical bounding of rationality. *Progress in Human Geography*. 43 (4), 632-649.

Wiig, Alan (2016). The empty rhetoric of the smart city: from digital inclusion to economic promotion in Philadelphia. *Urban Geography*, 37(4), 535-553.

World Health Organisation (2015). *Global status report on road safety 2015* [Online] Available: http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/ [Accessed 16/12/2018]

World Health Organisation (2018). *Road traffic injuries* [Online] Available: http://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries [Accessed 16/12/2018]

Wu, Jingwen, Liao, Hua & Wang, Jin-Wei (2020). Analysis of consumer attitudes towards autonomous, connected, and electric vehicles: A survey in China. *Research in Transportation Economics*, 100828.

Yigitcanlar, Tan, Wilson, Mark & Kamruzzaman, Md (2019). Disruptive impacts of automated driving systems on the built environment and land use: An urban planner's perspective. *Journal of Open Innovation: Technology, Market, and Complexity* 5 (2), 24.

Zang, Shizhe, Ding, Ming, Smith, David, Tyler, Paul, Rakotoarivelo, Thierry & Kaafar, Mohamed Ali (2019). The Impact of Adverse Weather Conditions on Autonomous Vehicles: How Rain, Snow, Fog, and Hail Affect the Performance of a Self-Driving Car. *IEEE Vehicular Technology Magazine*, 14(2), 103-111.

Zhang, Wenwen, and Guhathakurta, Subhrajit (2017). Parking spaces in the age of shared autonomous vehicles: How much parking will we need and where?. *Transportation Research Record: Journal of the Transportation Research Board*, (2651), 80-91.

Zhang, Wenwen, and Wang, Kaidi (2020). Parking futures: Shared automated vehicles and parking demand reduction trajectories in Atlanta. *Land Use Policy*, 91, 103963.