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Sustainable Accessibility and the Implementation of Automated Vehicles: Identifying Critical Decisions

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Abstract: The emergence of fully Automated Vehicles (AVs) is expected to occur in the next 10 to 30 years. The uncertainties related to AVs pose a series of questions about what the societal consequences of such technology are. Mainly, what are the consequences of AVs regarding accessibility? This paper uses Geurs and Van Wee's definition of accessibility to give an exploratory answer to this question. Using a scenario-based approach which allows identifying critical decisions that will emerge shortly (or are already emerging) concerning automated travelling, this paper proposes that AVs have great potential to both seriously aggravate and considerably alleviate accessibility problems. A great deal will depend on how these critical decisions will be approached and the choices that will be made. This debate is most needed because existing research on AVs tends to focus on how to make them a commercially viable and safe technological enterprise, and on what their benefits and drawbacks are regarding variables such as carbon emissions, energy consumption, and total miles travelled. Narratives of this nature can be problematic, as they are unlikely to promote sufficient awareness about the real disruptive potential of AVs. It is crucial that stakeholders realise the extent to which—if the governance of AVs implementation processes is not taken very seriously, and the identified critical decisions are not carefully approached—these machines can materialise a dystopian mobility future.

Keywords: automated vehicles; accessibility; sustainable transport

1. Introduction

Fully Automated Vehicles (thus equivalent to SAE's Level 5 of automation, see [1]) are those that can carry out all aspects of the driving task in any environment. According to Litman [2], the adoption of fully Automated Vehicles (henceforth just AVs) might start already in the 2020s while its generalised use in some countries might be witnessed in the 2040s. So far, most of the writings on AVs are focused on the technology itself, how it will work, and what it will offer. These writings tend to have an optimistic orientation. The existing literature is weak on the broader impacts (both positive and negative) of AVs on transport, networks, accessibility, equity, health, well-being, land use, energy and environment [3,4]. When considering the impacts of AVs, most publications tend to address only a few issues while paying little attention to whether these impacts might have mutually countered, cumulative, or synergistic effects. With some exceptions (such as [5–7]) reports that provide a more holistic approach are rare. This is problematic as a delay in co-creating a critical and transdisciplinary understanding about AVs might precipitate the emergence of the negative side of this technology. Transport technologies, land use patterns, and social arrangements maintain a complex system of systemic interactions [8]. This means that when transport machines can operate autonomously, there will be consequences not only for transport, but also for land use, how people conduct their lives, other technologies, and ultimately for government structures and planning and governance processes. Little or nothing is known about how this will unfold. As explained by Urry [9], the private car has to a large extent shaped contemporary society, and not necessarily in the best way. To this potent societal force and worldview co-created by the car he called the 'system of automobility'. The full range of additional objectionable features that a 'system of automated mobility' will bring is an almost complete unknown. This is yet another reason to consider the emergence of AVs in our societies carefully and to prepare for it. Reasons for this lack of knowledge include the fact that the implementation of AVs is surrounded by massive uncertainties regarding sociotechnical developments external to the transport sector (e.g., whether the possibility of working at home using increasingly better digital technologies will reduce the need for commuting). To these, we can add the unpredictable consequences of such developments for transport (e.g., which percentage of the time and money previously spent commuting will be spent travelling to new destinations), and the way significant stakeholders will approach these matters.

It is essential to raise awareness about how the emergence of AVs is being portrayed. The supposed inevitability of AVs becoming mainstream soon is being coupled with a technological optimism bias regarding these machines. For example, the British Department for Transport argues that AVs 'offer major potential benefits and could profoundly change our lives for the better' [10]. We feel that something more should be added to that statement: alongside massive benefits, AVs offer as well potential problems and could affect our lives quite negatively and therefore the process of implementation needs to be carefully scrutinised. This optimistic and uncritical attitude towards AVs is somewhat surprising because it is easy to find reasons to be sceptical about this technology. In our view, naïve technological optimism applied to AVs is quite problematic (for further insights on 'technological optimism' and 'technological solutionism' see [11]). It can be a costly mistake for which future generations will pay.

A relevant question to be asked is what makes AVs a highly disruptive technology. Wadud et al. [12] argue that it is not the automation per se what will lead to changes (for the better). They argue that reductions in energy consumption and carbon emissions will be the result of other technological advancements that will be facilitated by automation. In other words, AVs can be seen as a particularly powerful catalyst for many other disruptive technological innovations, and it is this cascading effect that makes the emergence of AVs so potentially disruptive. This seems to us a very important and insightful point raised by Wadud and associates, which we would like to take further, expand and adapt. This is, therefore, the core message of this paper: in our view, vehicle automation is likely to open the door to a large variety of technological, design-related, legal and cultural changes that can both seriously improve and drastically worsen the accessibility conditions experienced in urban environments. A great deal will depend on how automation will be used and the role that urban and transport planning will have in this transition. For the above-explained motivations, in this paper we propose an analysis of the likely pros and cons of AV in terms of accessibility, and what will be the critical decisions leading to alternative futures. Even though still quite limited in scope, an accessibility analysis can simultaneously consider a wide variety of issues, and so it seems to be a constructive start. A scenario-based approach is taken to help to identify (at least some of) these critical decisions.

One note is needed before ending this introduction. In this paper, we did not aim at producing definite answers regarding the subject of AVs. Instead, we seek to stimulate debate and to provoke reactions. Our purpose is to initiate a discussion and to raise questions and doubts about a possible future where AVs will play an important role. This will hopefully help to inspire those responsible for the governance of the implementation process of AVs. We believe that only through this questioning becoming commonplace will a serious, lively and transdisciplinary debate about AVs occur. Above all, we find it central to steer away from the discussion about AVs—a severely disruptive technology with potentially massive implications for our future—becoming a closed and uncritical one among technical experts, developers and investors.

We need to be aware that the odds of the debate about AVs becoming monopolised by stakeholders with vested interests in the automation of the car industry are high. Indeed, Papa and Lauwers [13] alert that the transport sector is becoming increasingly more dominated by a paradigm defined by techno- and consumer-centrism, where the users of transport systems are seen as passive consumers of increasingly more sophisticated and streamlined technological solutions that are imposed upon them. The emergence of digital technologies in the transport sector is naturally aggravating this trend. The same authors advocate the need to rethink this situation, so that the transport system user is reconceptualised as a citizen (and not as a consumer) with an active voice in the process of collectively defining the future of transport. The present paper serves, therefore, to alert the reader to the necessity of paying attention to the critical decisions concerning transport automation. The shape of the future will be to a large extent defined by the choices made in those crucial decisions, which are already emerging or will emerge very soon.

This article is structured as follows. In Section 2 we introduce the theoretical background of the accessibility approach. In Section 3 we introduce the scenario-based methodology adopted. In Section 4 we report two scenarios and through this provide a systematic analysis of the emergence of AVs using the accessibility lens. More precisely, we will analyse the impacts of AVs on the four accessibility components proposed by Geurs and Van Wee [14]: the land use, the mobility, the temporal, and the individual components. In Section 5 we systematically present the critical decisions that will determine the likelihood of emergence of one scenario or the other. In Section 6 we articulate some conclusions and offer the outline for a future research agenda.

2. The Accessibility Approach

The accessibility approach has been widely documented in the planning literature and has a long historical record [15–20]. As mentioned, in this paper we will use as our key resource the work of Geurs and Van Wee [14]. These authors define accessibility as 'the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations using a (combination of) transport mode(s)'. The two authors define four main components of accessibility: land-use, transport, temporal and individual. The land-use component addresses the spatial distribution of opportunities and the relationship between supply and demand concerning these opportunities. The transport component expresses the characteristics of the transport system, and the disutility for an individual to reach a chosen destination. The temporal component relates to the timetabling of activities, ranging from work hours to shop opening times, and the time available for someone to participate in or take advantage of those activities. The individual component reflects the needs, abilities, perceptions and limitations experienced by individuals due to variables such as health status, income, gender, and level of education.

There are several reasons why the use of the accessibility approach is particularly appropriate to study the emergence of AVs and the consequences of such a phenomenon. First, the accessibility approach is oriented towards holism. It is based on the idea that for people to have access to a given event, activity, social contact, place, job or product, it is not enough to ask whether the person can physically travel. This simplification was accepted in early transport planning approaches excessively concerned with mobility and transport networks. These approaches have experienced increasing levels of criticism (see, for example, [21–24]). The accessibility approach has appeared as an evolution resulting from these criticisms. According to it, it is necessary to consider a wide range of accessibility components to determine whether people have enough ability to reach what they need or desire in the built or natural environments.

Second, the accessibility approach recognises that the absence or failure of any of the accessibility components is enough to block access to what people need or want. For example, it does not matter the extent to which a person is healthy, mobile, and financially able. If this person perceives something as not accessible to her for cultural or religious reasons, or lack of time, then she will not be able to experience access [25].

Third, and this is a corollary resulting from the previous, the accessibility approach recognises that investing in improving a given component might lead to no results regarding enhancing accessibility for a given place, person or social group. If what is blocking someone to have access to something is, for example, lack of health (or transport means, or financial resources, or time, it does not matter as this principle applies to any component that categorically blocks accessibility) then investing in improving any other component cannot lead to tangible results as the primary problem will remain.

Fourth, and finally, the accessibility approach recognises that the accessibility components maintain multiple interactions that co-influence each other. For example, when extensive highways are built across the land, the tendency is for developers to start building more in peripheral locations where land costs are low. When large retail parks appear in peripheral areas, the tendency is for small businesses in central areas to struggle with economic viability and this ends up, in the long run, reducing the number of available services in these central areas. This is typically called the land use and transport interaction cycle [8]. This cycle is one of the key theoretical elements of the accessibility approach. It shows the extent to which the accessibility components are interrelated. This is why the accessibility approach is supportive of holism. Otherwise, these interrelations could be overlooked.

3. The Scenario-Based Methodology Used to Identify Critical Decisions

Publications on AVs can be classified into two types. The first type is focused on one or at most a few outcomes resulting from AVs emergence. In these publications, the use of analytical approaches and simulation models to qualitatively or quantitatively assess isolated impacts is reported. Studies of this type have explored, for example, environmental impacts or user benefits (see [7] for a complete literature review). Publications that analyse the broader implications of AVs constitute the second type. These more holistic writings tend to report the use of scenario-based analytical approaches (such as [26–29]) as this permits organising more effectively the vaster range of possibilities at stake. This method, which falls within the class of conjectural forecasting methods, is frequently associated with future research. The present study is aimed at being as holistic as possible and uses scenarios. It, therefore, falls under the second, more comprehensive, type. In accordance with the typologies of scenario building identified by Banister and Hickman [30], in this article we use a mix of exploratory (to *think the unthinkable*) and backcasting (to identify the critical decisions) approaches. Indeed diverse applications use different approaches that combine elements so that the process is customized for the particular situation under investigation. This flexibility in approach is characteristic of scenario building [30].

We define here the term scenario as a hypothetical future purposefully built to highlight the policy dilemmas and societal tensions to be expected as the subject under analysis—full automation of transport—transitions from being a theoretical speculation to becoming a daily reality individuals can (or have to) directly experience. In this study, we consider two scenarios: an optimistic and a pessimistic one. We have applied the term *critical decisions* to policy choices related to the governance process of developing and implementing AVs. These decisions are listed and presented in greater detail in Section 5. The scenarios will be described regarding implications of AVs on the four accessibility components already mentioned: the mobility, land use, temporal, and individual components.

The optimistic scenario is associated with an overall situation where well-being will be the highest when taking into consideration how much AVs can change societal dynamics and structures in the next decades. To a large extent, this scenario corresponds to what enthusiasts of AVs claim to be the future of automated mobility. So that this (overly) optimistic scenario can be contrasted and the importance of the choices made in the critical decisions highlighted, we crafted a pessimistic scenario. The pessimistic scenario reflects a society that is undesirable for the majority of people, where environmental impacts will be the higher, and where social tensions will be the highest when considering the potential that AVs will have to alter the state of affairs we experience today.

It is important to underline that these scenarios are being described as optimistic and pessimistic from the perspective of the majority, adopting a public interest perspective. We are aware that the notion of public interest is complex and forms of reasoning based on it or aimed at it encounter some unavoidable difficulties, as argued by Campbell and Marshall [31], who nevertheless also say that the public interest must be seen as a cornerstone for planning debates. We agree with this perspective. In line with this view centred on the public interest, and as we will see, automated vehicles have a considerable potential to aggravate social inequalities and therefore to be used against the public interest for the benefit of the privileged few. Finally, it is important to note that the scenarios are focused on the 'end-game' when widespread adoption of AVs has already occurred. This approach was adopted to highlight the critical importance of the decisions being made now and shortly, as these can quickly lead to the materialisation of the pessimistic scenario if not globally, at least in some places.

4. Two Scenarios for Autonomous Vehicles and Their Accessibility Implications

4.1. The Optimistic Scenario

4.1.1. The Mobility Component

In this scenario, AVs will be associated with a reduction in travel demand and the environmental impacts caused by the transport sector, and with an increase in road transport efficiency and safety. AVs will also be associated with a reduction in car travel demand and a decline of road capacity. Some downgraded roads will be used for other purposes besides transport (see the following subsection), and mode split will experience a significant change, that is, car use will be to a large extent replaced by public transport use, walking and cycling. The number of private vehicles will be smaller than today partially because AVs will be shared among large groups of users (Critical decision: sharing). They will be available mainly in areas not served by public transport (which will be automated as well). Public transport services will operate in a highly dynamic way, increasing or reducing supply according to demand as measured in real time (Critical decision: public transport). Digital control systems will be available to communicate to circulating AVs where the nearest or most appropriate parking space will be at all times, and what are the best routes to follow. The choice of which parking space will be taken by which vehicle will be performed cooperatively, taking into account urgency and priorities of needs (Critical decision: automated cooperation). AV will have sophisticated vehicular communication systems (for an overview of these see [32]) enabling them to cooperate at the network level with considerable benefits regarding safety, sustainability, and efficiency. Congestion at peak times will be significantly reduced because not only AVs will collaborate to maximise overall efficiency, but also because cruising for parking can constitute a significant portion of total traffic [33,34]. This form of cruising will cease to exist (Critical decision: environmental sustainability). In the case of traffic disruptions such as roadblocks, circulating AVS will behave as perfectly rational and fully informed agents due to the quality of their operating systems and due to the comprehensive data provided by the traffic information systems in place (Critical decision: network information systems).

4.1.2. The Land Use Component

Full automation will be associated with radical changes for the better in the built environment. Specifically, the reduction of private car use will be related to a decrease in urban sprawl (Critical decisions: land use policies, environmental sustainability). Besides this, other land use changes will be experienced in urban areas, namely those resulting from a new generation of parking policies that take maximum advantage of the potential of AVs (Critical decision: parking). As AVs will have the ability to geographically separate themselves from their users while heading to their designated parking spots, not only streets will see a massive reduction on the number of cars parked on them, but also parking areas will be very dense. This density will be possible because AVs do not need to open their doors once parked as there are no passengers inside having to leave the cabin [35]. This will contribute to saving urban space. Saved space will be used to embellish the built environment or to respond to other societal needs beyond the transport sector. A vast number of parking spaces, both parking lots and on-street parking spaces, will be transformed into new recreational, building, and green areas, or converted into cycling or pedestrian infrastructures (Critical decisions: land use policies, transport network design, environmental sustainability). People will feel very safe around AVs as these vehicles will be forced to stop in the case a pedestrian crosses their way [27] (Critical decision: inter-modal traffic regulations). Because of this, cities will experience considerable changes towards enhanced liveability, as urban environments will become much more pedestrian and cycling friendly. In summary, this combination of more space available and more safety will make the built environment extremely pleasant and more focused on quality of life and sustainability features.

4.1.3. The Temporal Component

AVs will offer great value for the time spent travelling. Passengers in AVs will be able to dedicate their time to activities such as resting, socialising, working, studying, eating, or merely contemplating the passing landscape. AVs will have the necessary appliances to facilitate and take the maximum benefit from these mobile activities. This will be highly appreciated by commuters and business travellers, but also by tourists. Travel time is already not merely a cost for train users (see for example [36]). AVs will bring this level of comfort and productivity to car trips as well. On average, travel time will be reduced and the time saved from travelling will be used to enjoy other activities and opportunities. The emergence of Shared Automated Vehicles, SAVs, also known as autonomous taxis or aTaxis, will provide to many a highly appreciated service. SAVs will offer extremely flexible services to their users, and this flexibility will allow individuals to organise their professional and personal activities with a great sense of freedom (Critical decision: sharing).

4.1.4. The Individual Component

Driving can be associated with high stress and be the stage for competitive, aggressive behaviour. This will cease to occur. Individuals will be free from the burden of driving and therefore will be able to relax, making the subjective experience of daily mobility fundamentally pleasant. Individuals that today do not drive due to the anxiety caused by this activity will be finally able to travel on their own (Critical decision: social exclusion). AVs will also represent a significant benefit regarding the reduction of car accidents [37]. This is a significant improvement as empirical findings suggest that about 90% of car crashes are caused by human error [38]. The death toll from these accidents is vast—just in the USA in 2015 it summed up to 35,200 fatalities [39], which corresponds to an average of 96 deaths per day. In the same year, in Europe, 26,100 people lost their lives in the same way, while it was estimated that about 100,000 people became permanently disabled due to brain or spinal cord injury [40]. AVs will finally provide to people a way of travelling and having access to what they need that do not systematically exposes them to these huge risks. The traffic regulations adopted will be highly protective of human life, and all users of the transport network will be equally protected by the software of AVs (Critical decisions: inter-modal traffic regulations, social exclusion).

AVs will also represent a benefit regarding higher accessibility levels for people with some form of health condition, disability, and visual impairment, or the elderly [35] (Critical decision: social exclusion). These individuals will stop finding it challenging or impossible to use a car on their own, which will be a massive benefit, particularly for those living in remote areas with inadequate public transport provision. These individuals will find their lives much facilitated as they will just have to enter the car and wait for the arrival to the destination without performing any particular action or effort. At least some AVs will be equipped with instruments that monitor the health status of the passengers and travel according to this situation (Critical decisions: sensitive data management, social exclusion). For example, the vehicle will automatically activate an urgency travel mode if the health condition of any passenger becomes unstable and rapid medical attention is needed. In these cases, nearby vehicles will automatically adopt manoeuvres and route choices aimed at facilitating the swift passage of the vehicle on urgency travel mode (Critical decision: automated cooperation). AVs will be handy to operate as medical vehicles to take people with not very serious medical conditions to hospital care when crewed medical vehicles are not available. Likewise, AVs will play a key role in delivering to people with inadequate health food supplies, medication and any other goods they will need without having to travel or rely on other people (Critical decision: social exclusion).

4.2. The Pessimistic Scenario

4.2.1. The Mobility Component

The motor-city concept that has characterised urban development in the 20th century will come to its full expression here. AVs will create new 'geographies of exclusion' [41] where the gap between the highly-mobile IT-connected societal groups and the disadvantaged will grow wider than ever. In this scenario, the transport sector will experience a significant increase in carbon and toxic emissions and energy consumption (Critical decision: environmental sustainability). The limitations of AVs to interact with pedestrians and cyclists (critically analysed by [27]) will dictate a sharp separation of different transport modes. When this separation is not possible, the rights of automated motorised traffic will dominate and pedestrians crossing in front of AVs will be seriously penalised by the law (Critical decision: inter-modal traffic regulations). Those travelling in AVs will experience high accessibility levels. However, there will be high car dependence as well. Transport severance effects will be a serious problem for those who do not use (automated) cars [42,43]. This will happen because AVs will be given priority and the implementation of such a complex technology will require making sacrifices in other fronts, namely in terms of decreasing the quality of pedestrian and cycling infrastructures (Critical decisions: parking and transport network design) and in terms of taking away some of the civil rights of users of active modes of travelling (Critical decision: social exclusion). This will reduce walking and cycling to minimum record levels as people will find insufficient opportunities to use active transport modes in this new context, mainly due to the aggressive driving styles that will be adopted by AVs. Their operating systems will be aimed at increasing competitive advantage (Critical decision: automated cooperation). The use of (automated) cars will, therefore, rise to maximum historical levels and the car industry will become more profitable than ever before. AVs will not be fuelled by renewable energies. Likewise, their production will not use renewable resources (Critical decision: environmental sustainability).

AVs will induce a massive increase in total miles travelled by the fleet. Several mutually reinforcing factors will contribute to this. First, to better separate pedestrians from AVs, it will become necessary to adapt and expand the motorised transport network (Critical decisions: transport network design, environmental sustainability). This will lead to the construction of additional ring roads and other dedicated links. In turn, this will lead to considerable levels of induced traffic [44]. Second, the high attractiveness of AVs will induce a massive mode shift away from public transport (argument explored by Wadud, MacKenzie, and Leiby [12]) (Critical decisions: public transport, environmental sustainability). This will be accompanied by a decrease in safety and practicability of walking and cycling, which in turn will contribute to reinforcing the mode shift towards AVs even further. Third, shared AVs will dramatically increase overall mileage and congestion because of their need to travel empty to pick up their next traveller. AVs will travel much more than any car previously did as machines are not bound to the time or energy constraints of any human driver to be kept in motion. In places where parking costs are high, some AVs will remain empty but in action for several hours in the so-called "eco-save mode" (note the irony) to avoid making their users to pay the parking fees (Critical decision: environmental sustainability).

The introduction of AVs will be associated with massive transport infrastructural investments and collective costs. A vast range of digital systems and communication devices will have to be implemented to provide information for automated decision-making and increase the safety margin against accidents. Roads and roundabouts, crossroads and streets will have to experience some medium to significant modifications to make sure that circulation of AVs is safe (Critical decision: transport network design). Significant expenses will have to be placed in the prevention of digital viruses and hacking. This will significantly increase (automated) mobility costs at the same time that it will leave behind a growing number of people who will be unable to afford the use of AVs. The use of cars that are not automated will be forbidden (except in special circumstances) due to safety reasons (Critical decision: inter-modal traffic regulations). In other words, at the same time that motorised mobility becomes automated in a compulsory way, fewer people have access to it and, instead, experience the downsides of a society that will not cater to their accessibility needs (Critical decision: social exclusion).

To aggravate this situation, AVs will not be programmed according to collective-oriented, sustainable, or ethical values. AV will not cooperate among themselves at all, but use their technological capabilities only for the advantage of their passengers (Critical decisions: sharing, environmental sustainability, and network information systems). They will drive aggressively, with little concern for emissions and, even worse, with relatively low concern for the safety of non-passengers. Different types of AV will be available, some more expensive and therefore faster, more aggressive, and less prone to make cooperative choices and others less expensive, slower, less aggressive and programmed to make choices that protect the rights of way and the safety of people travelling in other, more privileged, vehicles (Critical decisions: automated cooperation, social exclusion). Materialising the concerns of Millard-Ball [27] in this scenario, different car brands will develop an approach where cars from the same brand cooperate but compete with cars from other brands. This will lead the competition among car manufacturers to be harsher than ever, with a range of adverse consequences on the aggressiveness of marketing campaigns targeted directly to individuals (Critical decision: sensitive data management).

4.2.2. The Land Use Component

Cities will see their densities decreasing and their activities sprawling (Critical decisions: land use policies, environmental sustainability). The patterns of both urban and rural areas will begin to converge, increasingly abating the differences between them [45]. Due to the difficulties experienced with the sprawling of activities and heavy congestion, some car brands will start selling automated motorhomes. These vehicles will be almost invariably on the move, responding to the mobility and housing needs of families who cannot manage to have a grounded home and a car at the same time. These mobile families will spend the majority of their time together either on the move or in peripheral parking areas where these vehicles are permitted to stay overnight to recharge and perform maintenance tasks. When their vehicles experience a mechanical fault or have an accident, these families will often see themselves in dire circumstances as all aspects of their lives depend on their motorhomes (Critical decision: social exclusion).

At the street space level, crossing in front of an AV will become an offence (Critical decision: inter-modal traffic regulations), and we will see the return to a high separation of pedestrians and cyclists from motorised travel (Critical decision: transport network design). The concept of living streets will, therefore, be dismissed entirely (Critical decisions: environmental sustainability, land use policies), as by default this means a mix of different modes of transport with a strong focus on pedestrians [46,47]. This will have substantial negative consequences on sustainability, local communities, and human well-being.

4.2.3. The Temporal Component

Travel time will not be seen as a cost anymore. Instead, a growing number of activities will take place inside vehicles while they travel. As a consequence, vehicle miles travelled will continuously increase. Some studies (such as [48]) demonstrated that a system of SAVs might save members ten times the number of cars they would need for self-owned personal-vehicle travel but would incur about 11% more travel. Parallel to this phenomenon on increased time spent travelling, the lack of engagement in the driving tasks will lead large numbers of passengers to experience extreme irritation and a sense of powerlessness during trips. This will happen because the AVs in which people travel will be making route choices they disagree with, driving too fast or too slow, and interacting with other vehicles and pedestrians and cyclists in ways that will make the time spent inside AVs very onerous. This will be particularly true for those who can only afford the lower commercial range of AVs (Critical decisions: social exclusion, automated cooperation, inter-modal traffic regulations).

4.2.4. The Individual Component

AVs will increase individual mobility costs because these cars will be more complicated than today's. They will not only have all the elements human-driven cars have, but they will also have a highly advanced computer, a new user interface, and a variety of sensors, cameras and antennas. This means that, at least in the initial stages of implementation, AVs will be unaffordable for many [48]. This will leave a large number of people unable to pay for them and will create a negative outlook on AVs among the majority of people. They will be seen as instruments of domination of the elites and corporate powers. As driving will become restricted by law due to safety concerns (for an explanation of this argument see [2]), the emergence of AVs will represent a severe accessibility problem for those who cannot afford their use and a grim financial burden for those who can but not belong to the upper economic strata (Critical decision: social exclusion).

AVs software will be exposed to hacking threats, to intricate safety and legal issues, and to personal data transmission and misuse [49]. AVs will, therefore, lead to renewed campaigns aimed at scrutinising people's activities with the aim of addressing such problems (Critical decision: sensitive data management). While some minority pressure groups will raise questions concerning robotics, artificial intelligence, law and human rights with significant ethical and legal ramifications [50,51], influential marketing campaigns and habituation will lead individuals to become increasingly more accepting of being scrutinised and being exposed to these risks. As Kesselring notes [52], we already live in a mobile risk society. This means that in the same way that individuals accept today car crashes as relatively frequent events, and they just hope that these events will not happen to them or their loved ones; in the future individuals will also expect that the AV where they travel will not be hacked or their data used against them by ill-intentioned individuals or organisations [2,53]. All these problems will be manifested, and people will accept them as the new normal. Those excluded from automated mobility due to their lack of financial resources will be much more resilient to these problems. However, their low life value tags (this concept will be explained soon) will be a source of tension for them, as they will know that in the case of accidents with AVs where one life will have to be sacrificed to save another, relatively little consideration will be given to their safety (Critical decision: inter-modal traffic regulations). This will be particularly worrying for those under serious debt.

Some selective AVs will operate with more defensive algorithms than others based on people's ability and willingness to pay for extra safety (Critical decision: automated cooperation). A precedent of this has already been reported in the USA where SUV and pickup trucks are being bought to protect their passengers while putting at more significant risk other people—this phenomenon was named the 'arms race on roads' [54]. AVs will bring extra severity to this arms race. As already briefly mentioned, the value of human lives will be assessed by AVs using an automated tagging system linked to a centralised database. The objective of this innovation will be to—in case of an inevitable accident—optimum decisions being made regarding whose lives should be sacrificed. Those people whose salaries are higher and who have better insurance coverage will be identified by AVs as having more valuable lives than those on low pay, unemployed, or without insurance (Critical decisions: social exclusion and sensitive data management). The lives of the elderly, immigrants from undesirable origins and refugees will have an even lower value, as well as the lives of those who refuse to carry their tag. The tag will be linked to people's bank accounts, credit ranking, and health insurance. Some companies will be specialised in changing the value of people's lives in the tagging system so that AVs will take special care to protect them in case of an accident. High life value tags will be a much sought-after product, as it will lead the AVs they encounter to protect them better, giving them right of way, faster driving, among other privileges.

It is today well-accepted that the lack of physical activity is a global pandemic responsible for many deaths every year and car-based transport is one of the causes of that problem. Walking and cycling can significantly contribute to solving this problem [55–57]. Aggressive AVs and transport severance effects will lead individuals to become more physically inactive, and obesity will increase further.

5. Discussion: Identification of Critical Decisions

The scenarios presented above led to the identification of critical moments where decisions concerning AVs will be particularly important. These will be moments in which decision-makers will be actively (even though not necessarily fully aware of it) shaping our futures towards either the pessimistic or the optimistic scenarios. Table 1 systematises these Critical decisions to facilitate raising awareness about this. Our significant contention here is that it will be through the accumulation of poor decisions that a grim future will be co-created and that it is possible that there is not enough awareness about the high stakes at play. Neoliberal forces are actively working towards a future that looks worryingly similar to the pessimistic scenario we proposed.

Table 1. Some key decisions concerning Automated Vehicles.

Critical Decisions Themes	Optimistic Outcome	Pessimistic Outcome
Sharing	AVs will not be primarily advertised and sold as private property for those who can afford it. Instead, the notion of automated car sharing will be promoted from the start.	AVs will be promoted by developers as private property for the elites who can afford them. It will be seen first as luxury items and this will create negative path-dependency during several decades.
Social exclusion	The use of AVs will be open to a vast share of the population due to policies aimed at fighting social exclusion potentially induced by transport automation. Measures will be considered to avoid the creation of circumstances where AVs become compulsory replacements for conventional homes as people will not be able to pay for a car and a house mortgage.	The use of AVs will be exclusive to those with the ability and willingness to pay for what will be considered a privileged mode of transport. Conversely, vulnerable societal groups will be encouraged to use AVs as a place to live and travel under constant scrutiny.
Environmental sustainability	The development and implementation of AVs will be regulated taking into account strong environmental concerns.	AVs will be developed and implemented with little concern for sustainability. Marketing campaigns will distract people from environmental issues and focus their attention on individual benefits associated with automated transport.
Automated cooperation	The operating systems of AVs will be programmed using as guidelines cooperative, altruistic and ethical principles.	The operating systems of AVs will be programmed using as guidelines competitive, aggressive and defensive principles.
Public transport	Public transport services will be protected and sponsored by National and Local policies so that the (probable) high appeal of AVs does not exclude these public services from the transport system.	National and local policies focus on AVs too much and fail to support public transport providers against the competition represented by AVs. As a result, public transport becomes increasingly marginalised and ceases to operate in a growing number of places.
Inter-modal traffic regulations	AVs will be programmed to respect unconditionally all forms of human life. Instead of focusing on which lives should be saved in the case of accidents involving AVs, the focus will be on changing traffic regulations to make accidents less likely (e.g., through lower speeds). Pedestrians and other vulnerable road users will be protected by the spirit of the law.	The debate on inter-modal traffic regulations will focus on the value of human lives when taking into account characteristics of individual road users. First these characteristics will be age and probability of survival, but later on will be characteristics such as income, quality of insurance coverage, citizenship status, and criminal record. The rights of users of AVs will be protected by the spirit of the law.
Network information systems	Investments will be made so that all AVs can use network data to make more sustainable and efficient decisions regarding route choice and parking at a fleet level.	There will be little to no developments dedicated to co-creating public information systems that will facilitate overall efficiency and sustainability at fleet level and as a result vehicles will be equipped (or not) with information gathering devices based on the willingness and ability to pay off their users.
Sensitive data management	Personal data and all forms of information that might be used against individuals or organisations will be carefully managed or not recorded, and always with the purpose of providing for the needs of vulnerable individuals or in the name of the public interest.	Growing quantities of data will be stored and used for commercial or societal control purposes. AVs will be understood as data extraction devices, making it compulsory for their users to reveal increasingly larger and more sensitive private information.
Parking	Parking policies will facilitate the conversion of no longer needed parking places into new recreational, green, and building areas, or into transport infrastructures for active modes of transport.	Parking policies will remain as they are, that is, when not in use AVs will use on-road parking spaces and existing parking areas that consume highly desirable land that could be used for more sustainable or social purposes.

Table 1. *Cont.*

Critical Decisions Themes	Optimistic Outcome	Pessimistic Outcome
Land use policies	The built environment will be seen as a place to live and experience quality of life. Mobility will be seen as something that should promote quality of life. These guiding principles will be unchanged in the face of pressures coming from enthusiasts of AVs.	The built environment will be reshaped to accommodate the complex and ever-increasing needs of AVs and their users against the needs of other social groups.
Transport network design	Transport networks will be designed in ways that will be safe for all. In urban settings there will be great care to provide for the needs of sustainable transport modes.	Transport networks will experience massive restructuring to accommodate the unique needs of AVs. Other transport modes will not see a comparable level of protection and investment.

6. Conclusions and Future Research Directions

This paper assesses the possible consequences of the advent of fully automated vehicles (AVs) for personal transport using the accessibility approach. It concludes that AVs have the potential to represent a significant perturbation to transport systems, urban form, and social practices. In fact, this technology threatens to profoundly disrupt how transport systems are conceptualised, built, and used. Two scenarios were considered to show the extent to which this disruptive potential can lead either to positive or (exceptionally) adverse outcomes. Scepticism and prudence regarding AVs are therefore highly recommended. The four accessibility components proposed by Geurs and Van Wee [14] (the land use, transport, temporal and individual components) were used as exploratory devices to bring greater precision and detail to the two scenarios. From this exercise, it becomes clear that one of the leading risks of AVs is that, if the implementation is mismanaged, they will reinforce the problems of car dependency, and its environmental, health-related, and social negative consequences.

It is timely to consider the means of implementing a planning policy and guidance strategy so that if AVs are forthcoming as currently foreseen, then they will be implemented in a manner which is equitable and seeks to promote well-being. Extra care should be placed on avoiding the potential negative consequences of these machines. In practical terms, this means that all decisions concerning AVs that might have a bearing (and even if indirectly) on shared transport solutions, mobility-induced social exclusion, environmental sustainability, automated cooperation, automation of public transport and protection of public transport against competition by AVs, inter-modal traffic regulations, network information systems, sensitive data management, parking and land use policies, and transport network design, should be seen as critical for the future of our societies in general and for the advent of AVs in particular. Table 1 shows how these decisions can be approached so that the optimistic scenario is the one most likely to materialise in the future.

The promotion of automated travelling can too quickly be seen as a significant business leading to considerable profits. Therefore, commercially driven corporate goals are more likely to lead the implementation process of AVs than humanitarian ones. Public sector intervention is thus considered necessary to protect the public interest. We believe it to be unlikely that a laissez-faire approach will lead to the optimistic scenario being the one materialising. This means that, as part of the socio-technical system [58], AVs raise significant questions concerning governance, and in particular concerning how public bodies should promote the advantages and manage the disadvantages and risks of this technology.

Because of the high unpredictability that characterises the emergence of AVs, land use and transport-related policies need to increase the adaptability of the transport system and its ability to react to unexpected changes via land-use regulations and/or mobility-management measures [59]. In this sense, local governments have a crucial role to play in preparing the legal, transport, and urban systems to accommodate AVs in an evolutionary and adaptive way to their local environment and cultures. A state of vigilance should be adopted to ensure that autonomous vehicles enhance, rather than hinder, the liveability of built environments. Paying attention to the critical decisions shown in Table 1 is therefore strongly recommended. Similarly, on-going assessments of (preferably) small and incremental developments towards automation are recommended so that U-turns remain possible to perform if unexpected and undesirable outcomes emerge.

Future research on this topic is most needed. Two research ideas will be proposed. First, we would like to encourage an analysis aimed at determining which scenario is the most probable: the pessimistic or the optimistic one. This is unlikely to be a generalizable conclusion. Therefore, it will be relevant to identify which cities and countries are more exposed to the risk of materialising the pessimistic scenario. For example, one can hypothesise that places where neoliberal policy making is more established, where social exclusion and inequality are stronger, where the land use characteristics are more prone to segregation of transport modes and to severance effects, will have a greater probability of moving towards the pessimistic direction. Taking into consideration the key decisions we proposed will probably help to structure research aimed at achieving this purpose. Second, we would like to suggest the need for research directly concerned with avoidance of the pessimistic future. This research should be embraced with enthusiasm particularly in those places where the probability of the pessimistic future to materialise is higher. Before concluding, we would like to insist that this research should primarily be focused on governance issues and not on technological fixes. In our view, the future of AVs will not be primarily dictated by technology itself, but by how this technology will be governed.

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