On the Topic of Autonomous Robots: Social and Economical Benefits

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Introduction:

The purpose of the Metalab is to help businesses and society understand and use artificial intelligence and the power of data to enable individuals and citizens to make well-informed decisions in an ethical and fair manner. Created under the École Supérieure des Sciences Economiques et Commerciales (ESSEC), the Metalab is a unique multidisciplinary ecosystem that combines expertise in hard sciences and social sciences to inform practices at the intersection of “Data, technology and society” and put people at the core of all decision-making processes.

At Metalab, our objective is to help businesses move from data-based decision-making to new decision-making models that combine the power of AI and human judgment. Many routine decisions based on structured data and subject to cognitive bias can be automated with the help of prescriptive analytics tools and AI. With other more strategic decisions, AI takes advantage of human judgment by generating various possibilities, the best of which is chosen by the decision-makers themselves. Hence, we believe that the biggest obstacle to the implementation of AI in businesses is not the lack of data scientists, but the lack of leaders trained in AI and keeping in mind that all the technical issues are human ones indeed.

In this way, ESSEC intends to build new bridges but also question the interactions between science and society, as well as the challenges linked to the governance of Artificial Intelligence and data ethics. By integrating the human factor into AI, we can produce commercial decision-making models guided by concern for their impact on society but also with clear objectives, understandable criteria and actionable processes.

Abstract:

In connection with the development aims of road transport systems the most important requirements to consider are as fol-lows at all times:

- minimization of the number and severity of accidents,
- reduction in the environmental impacts,
- improvement of road traffic parameters, such as average travel time, traffic flow capacity, etc

The objectives listed above are closely inter-linked and are essential elements. Moreover, a common aspect of them is rep-resented by the cost-efciency. It is obvious that all of these factors can be signicantly improved by applying adequate management and control of autonomous vehicles and intelli-gent infrastructures creating new ways for intelligent transport systems and smart cities. Accordingly, the advent of autono-mous technologies also entails social and economic aspects.

It is estimated that self-driving technology can save 30,000 lives per year in the USA only and of course huge property dam-age (Greenblatt, 2016). Schoettle and Sivak (2015) published an interesting analysis report of real-world crashes involving robotic cars. They

found that self-driving cars were not faulty in any crashes they involved in. Furthermore, the overall sever-ity of crash-related injuries has been lower for autonomous vehicles than for conventional cars.

It is highly predictable that driverless vehicles will totally change the traditional car-ownership model. Note that cars are not moving in most of their life cycles. Greenblatt (2016) says private cars are parked typically 95% of the time. If a cost-efcient shared-ownership (Csonka and Csiszár, 2016) or taxi model could be built up for autonomous vehicles, people will easily refuse to buy and maintain private cars. This phenom-enon will also inuence city parking and land use. Autonomous vehicles do not have to park in the vicinity of the traveler nec-essarily. Indeed, they can park themselves anywhere.

Beyond the economic benets, social gains will be also expectedly attained as all sectors of society will have the opportunity for mobility. People without driving license might “drive” a car, e.g. elderly and disabled persons or even chil-dren. Furthermore, as self-driving are able to circulate without human, they can be sent anywhere to pick up the passenger.

These changes will signicantly rewrite the current transport models which are based on traditional economic and demo-graphic parameters and do not consider the free mobility of autonomous vehicles at all.

Finally, an important point has to be also concerned. Namely, laws and regulations are important and critical aspects in the course of the autonomous technology evolution. Some opin-ions argue that legal questions are too complex and therefore will hinder driverless vehicles spread. Although the skeptical voices, it is important to opinionate that legal issues must be handled not as obstacles but as problems to solve as soon as possible. This is especially important as the legal system of our days only try to follow the development process of autonomous technology instead of supporting it and keeping pace with it.

This as well raises the problem of creazting on purpose bugs in the whole connected autonomous vehicles system. We need to dig more into this.

TABLE 1 Summary of Economic Effects (Industry and Economy-Wide)

Industry-Specific Effects				
Industry	Size of Industry (billions)	Dollar Change in Industry (billions)	Percent Change in Industry	$/Capita
Insurance	$180	-$108	-60%	$339
Freight Transportation	$604	+$100	+17%	$313
Land Development	$931	+$45	+5%	$142
Automotive	$570	+$42	+7%	$132
Personal Transportation	$86	-$27	-31%	$83
Electronics & Software	$203	+$26	+13%	$83
Auto Repair	$58	-$15	-26%	$47
Digital Media	$42	+$14	+33%	$44
Oil and Gas	$284	+$14	+5%	$44
Medical	$1,067	-$12	-1%	$36
Construction/ Infrastructure	$169	-$8	-4%	$24
Traffic Police	$10	-$5	-50%	$16
Legal Profession	$277	-$3	-1%	$10
Industry-Specific Total	$4,480	$418	9%	$1,312
Economy-Wide Effects				
Type of Savings		Dollar Change in Industry (billions)		$/Capita
Productivity		$448		$1,404
Collisions		$488		$1,530
Economy-Wide Total		$936		$2,934
Collision Value Overlap		$138		$432
Overall Total		$1,217		$3,814

+ = Industry Gain - = Industry Loss
$/per capita and Total: All values added due net economic/consumer benefit

Introduction

A little under two decades ago, Sheller and Urry (2000) devised a compelling agenda for understanding how social life is configured through the car, paving the way for sustained scholarly focus on the complexity of the social dynamics of mobilities. Their argument that 'automobility is a complex amalgam of interlocking machines, social practices and ways of dwelling' (2000: 737) continues to be a vital analytical lens through which to evaluate the significance of the car, as the subsequent development of the field of mobilities research attests to, borne out in part through articles in this journal (Sheller, 2014, 2017). However, developments are currently afoot which compel us to revisit this relationship between automobility and social life.

Autonomous vehicles are one of the most highly anticipated technological developments of our time, capturing the popular imagination arguably more so than any other transportation technology over the past half century. A regular stream of media reportage bears witness to the fast pace of competitive development between companies seeking to develop autonomous vehicles, involving new partnerships of technology companies and conventional automotive manufacturers. Such popular intrigue is testament to the global significance of automobility, where, over the course of the twentieth century, cars have become firmly embedded into our urban cultures, setting in motion 'new socialities, of commuting, family life, community, leisure, the pleasures of movement' (Urry, 2004a: 28). Cars have come to reshape our subjectivities (Sheller, 2004), our everyday habits of dwelling (Sheller and Urry, 2000) and the evolution of our cities (Dennis and Urry, 2009). In short, cars are a 'way of life', rather than merely a transportation system (Urry, 2007). Given the significance of the car to contemporary social life, it is not surprising that the advent of autonomous vehicles has generated profound fascination.

The context for situating the current development of autonomous vehicles is the broader technological revolution in networked computing capacities through the rise of robotics and artificial intelligence (AI). Whilst automation as a quality of socio-technical systems is nothing new (Cotgrove, 1972), what *is* new are the

forms of machine intelligence characterized by data-driven computing rather than instruction-driven computing (Smith and Anderson, 2014). This quantum leap in machine intelligence has emerged through exponentially growing quantities of data and processing power together with the development of complex algorithms, leading to new capacities for self-organization, sense-making and problem-solving. Where conventional automated machines were fixed in place and programmed for specific repetitive tasks, the new robotics and AI that are enabling the development of autonomous vehicles are different. They are mobile, situationally aware and can adapt to and communicate with their environment (Winfield, 2012). In this regard, autonomous vehicles are one part of a broader ecology of networked infrastructures which include military drones and underwater submersibles (Mindell, 2011).

Armstrong (2014) argues that there has been insufficient attention paid to the social impacts of the current round of automation characterized by AI and robotics. Indeed, research on automation has principally been the preserve of engineering, with contributions from biology, neuroscience, psychology and AI. This tendency is reflected in the current research on autonomous vehicles. The majority of the social science engagement is concentrated on a narrow spectrum of issues such as the legal and governance aspects of licensing and standards for autonomous vehicles (Fagnant and Kockelman, 2015), and legal questions of machine ethics involving dilemmas of decision-making principles and subsequent valuation of liability (Bonnefon et al., 2016; Greene, 2016). Whilst the current research on autonomous vehicles has identified important issues, there has been a tendency to splinter off the ‘social dimensions’ as a discrete area of enquiry, such as fatalities and injuries, the impacts on pedestrian behaviour (Millard-Ball, 2018), congestion and fuel efficiency (Folsom, 2011) and the broader efficiency of transport systems (Alessandrini et al., 2015). However, as approaches informed by both science and technology studies (STS) (Sheller and Urry, 2016) and transitions theory (Geels et al., 2011) demonstrate, to splinter off such narrow ‘social’ dimensions potentially neglects the broader socio-technical complexities of

automated vehicles, and also risks a technologically determinist style of analysis which overlooks the multiple forces at play in the emergence of autonomous vehicles.

In this positioning article, we demonstrate how the analytical tools of mobilities studies are ideally positioned to critically explore the sociological relevance of the autonomous vehicle. Mobilities studies approach the social and the technical as relationally constituted, exploring, in a holistic manner, why people move, the social meanings bound up with movement, and the nature and qualities of entities and relations that emerge through movement, from the intimacies of individual subjectivities to the complex assemblages of entire cities (see Cresswell, 2006; Urry, 2000). A mobilities perspective enables us to expand upon Stilgoe's (2018: 43) point that 'autonomous vehicles are not as heroically independent as their enthusiasts would have us believe, nor are they as autodidactic'. Analysing autonomous vehicles through a mobilities lens invites us to go far beyond the current preoccupation with utilitarian concerns with improving efficiency or rectifying errors, to instead consider the pressing social implications of a set of processes that have a long heritage (Kellerman, 2018).

Our article pursues a speculative mode of enquiry (Pink and Salazar, 2017). We aim to develop insights from mobilities research to broaden the spectrum of concerns for social scientists researching autonomous vehicles. The identification of such issues is also important for stakeholders and policy makers who are tasked with ensuring that future mobility systems develop with socially progressive politics at their heart. In focusing on the diversity of social issues, our aim is to be synthetic, rather than in-depth. However, to provide a sense of granularity, through our discussion, we flag research which has been conducted in specific sites. Our article unfolds in four parts, each of which addresses one set of transformations relating to the development of autonomous vehicles.

Transforming experiences

Mobilities researchers have demonstrated how understanding the embodied experiences of being in transit is vital for developing a fuller appreciation of why people travel in the way that they do. Sheller (2004) highlights the significance of affective and emotional dimensions of car travel for generating meanings and attachments. Her focus on discursive ideologies of freedom and individuality is supplemented by Thrift's (2004) discussions on driving in the city, emphasizing how vehicle manufacturers engineer bodily experiences into the design of cars. Yet how vehicles come to be experienced is not reducible to the material design. Mobilities researchers also emphasize how our ongoing relationships with transit give rise to more transitional experiential textures, as Bissell's (2018a) work on repetitious commuting journeys demonstrates. In this section, we develop these insights by raising four questions about how automated automobilities might transform the *experience* of mobility.

First, *how might autonomous vehicles transform how people spend their time on the road?* As with earlier studies of the automation of aviation and other forms of commercial transportation (Mindell, 2015), a central concern here are the practical activities that passengers actually do whilst being auto-driven (Laurier and Dant, 2012). Mobilities research highlights that, in contrast to assumptions about travel time being wasted time, people undertake multiple forms of work and leisure-related activity whilst on the move (Bissell et al., 2011). With specific reference to urban driving, Laurier (2002) shows how drivers use slow-moving traffic to undertake business-related work, dividing attention between navigating stop-start traffic, mobile phone calls and paperwork. Moreover, as Jain and Lyon's (2008) research with commuters shows, travel-related activities are often planned in advance by passengers before setting off for their journey.

Preliminary studies of autonomous automobility found that, with the driver released from driving, the autonomous car could become a new mode of both private and professional dwelling. Sheller (2007) notes how automotive designers have, for some time, sought to transform vehicles into mobile entertainment and communication pods – a trend that autonomous vehicles could accelerate.

Passengers in autonomous vehicles might undertake tasks involving significant cognitive labour with fewer distractions than Laurier's (2002) participants encountered. Autonomous vehicles also open up new possibilities for social interaction. As Lipson and Kurman (2016) suggest, interior cabins will likely be significantly reconfigured, providing greater flexibility for work, leisure and related social activities. Other studies prompt consideration of how the car might become a 'dwelling space' (Laurier and Dant, 2012: 237). Urry's (2008a) speculations on urban driverless 'pods', for instance, are suggestive of hi-tech cocoons in which passengers are cushioned from the external environment by smart grids and informational road systems on the one hand and surrounded by the web, email and social media on the other. Here, fully autonomous vehicles may represent a sanctuary, a zone of privatism, however minimal, between points of departure and arrival.

Second, *how might the interweaving of autonomous mobility and new digital communications come to underpin the coordination of digitalization, social networks and the mobile self?* Pairing De Souza e Silva's (2006) idea of 'hybrid space' and Licoppe's (2004) work on 'connected presence' invites us to consider autonomous vehicles as a kind of mobile communication device in and of themselves. In this vein, analysing inter-urban UK car commutes, Elliott and Urry (2010) develop the concept of 'miniaturized mobilities' to refer to how communications technologies used whilst on the move can create novel relations with others at-a-distance, involving multiple processes of coordination, (re)negotiation and synchronization with others. Ling and Donner (2013) underscore the often-impromptu nature of mobile communication. This trend may deepen with the advent of autonomous vehicles, shifting how people experience time, involving a transition from punctual time to negotiated time (Elliott and Urry, 2010).

Third, *how might strategic travel planning and scheduling change in a world of autonomous mobility?* Mobilities research has demonstrated the diverse ways that journeys through cities are planned and coordinated. As Bissell (2018a) suggests,

starting out on a new commute might involve experimenting with different modes of transport or routes which can help inform people's choice about which works best for them. Nascent work on autonomous vehicle systems indicates how decision-making practices and scheduling might be altered through increased convergence between autonomous vehicle systems and personal schedules (Lipson and Kurman, 2016). Here the choice of travel mode and decisions relating to timing and routing through a city might be devolved to an automated system that coordinates and makes decisions linked to personal schedules. This possibility is suggested in Urry's (2008a) predictions for shared on-demand vehicles where the passenger does not interact with the practice of driving at all. Automated travel planning becomes more complex when we consider how autonomous vehicles may interface with other urban mobility options, including trains, buses, cycling and walking, forming 'seamless journey' systems.

Fourth, *how might autonomous vehicles transform the sensory dimensions of being on the move?* From the intensities of anger in road rage (Katz, 1999), to the more pleasurable satisfactions emerging from handling vehicles (Balkmar and Joelsson, 2012), mobilities studies have shown that the experiential pleasures and pains of driving define our differential attachments to the car. The arrival of fully autonomous vehicles may diminish these sensations, possibly reducing the stressful intensities of urban driving, but also reducing the sensate pleasures of vehicle handling. Instead, different aesthetic experiences may emerge. Mobilities scholarship on passengering provides insights into what these might involve (Adey et al., 2012), for instance an enhanced capacity to appreciate environments moved through, or affordances to withdraw from attentive activity altogether.

Designers of driverless vehicles are currently engaging with the types of questions outlined above (Winner and Wachenfeld, 2016). We call on sociologists to contribute to emerging debates on the social dimensions of autonomous vehicles, focusing on the significance of the experiential dimensions through exploring how autonomous vehicles might change capacities for working and relaxing; the experience of co-presence whilst on the move; how travel planning and

coordination are experienced; and, the sensory pleasures and pains of being on the move.

Transforming inequalities

The second major contribution of mobilities studies that we develop here is the focus on the political dimensions of enablement and constraint. Mobilities scholars have underscored that technologies of transit are not neutral, but have the capacity to transform many forms of social difference. Mobilities research is also characterized by relational thinking which highlights how the mobilities of some come at the expense of the mobility of others (Adey, 2006). Relatedly, research on different forms of institutional governance have raised important questions about who controls, manages and regulates mobility, and, as a consequence, who is privileged and who is left out (Bærenholdt, 2013). Our starting point here is to stress that autonomous vehicle technologies have the potential to produce new – or perpetuate existing – forms of social inequality. Drawing from the insight that autonomous systems not only reflect but also refract unequal social relations between, across and within different social contexts (Lutz, 2014), we argue that it is important to investigate how patterns of inequality could relate to autonomous transport systems.

First, *how might the development of autonomous cars reflect the values and preferences of specific groups of people?* As mobilities scholars have demonstrated, the designing of travel technologies is never value neutral. Technologies of transit can bear the cultural imprints of those who developed them and these imprints can be involved in the creation or reproduction of asymmetrical power relations (Wajcman, 2002). We contend that there is a pressing need to better understand the social groups that are involved or marginalized in the design and implementation of autonomous vehicle technologies and transport systems. The issue of gender is of central relevance to this line of enquiry. The technological development of motor vehicles (Pflugfelder, 2018), the broad domain of transport planning (Redshaw, 2018: 88) and the

professions of robotics engineering and software development (Misa, 2010) have all been observed to be male-dominated. As such, there is the distinct possibility that women may continue to be marginalized in the ongoing evolution of autonomous vehicle systems, which may have broader social effects and constitute a form of exclusion in itself, where the masculinities of autonomous transport are more likely to be reconfigured than effaced (Balkmar and Mellström, 2018).

Second, *how might autonomous vehicles alter the quality and quantity of access that different social groups have to physical mobility?* Mobilities researchers have shown how differential access to mobility has broader social implications for civic participation (Hine and Mitchell, 2001). Even though predictions have been made about how autonomous cars might reduce the transport disadvantage experienced by some social groups such as the elderly (Holley-Moore and Creighton, 2015) and disabled (Claypool et al., 2017), there are a range of possibilities that sociologists must consider. Reflecting on Jensen's (2007) observations on how new mobility systems can intensify social segregation, we suggest that some networked automated transport systems may be multi-tiered in terms of the services, flows and affordances that they offer. For example, those described as the 'kinetic elite' (Elliott and Urry, 2010) may have greater access to autonomous vehicle services that can travel farther and faster than others, and these privileged services may also provide higher levels of flexibility and comfort.

Third, *how might networked autonomous vehicle systems change the organization of urban spaces?* In developing questions about accessibility, we suggest that the transformation of urban spaces as a result of autonomous vehicles has the potential to lead to geographies that are both more equitable but also highly uneven. This is particularly evident in the divergent views about how autonomous vehicles may reconfigure land use. Some modelling forecasts of autonomous transport, for example, highlight its potential to decrease the number of vehicles on the road and the need for urban parking space (Fagnant and Kockleman, 2014). However, these possibilities are highly dependent on a shared form of

autonomous travel, which may not be realized as extensively as some have predicted. Correspondingly, there is also the possibility that autonomous forms of transit may actually reduce ridership on public transport (Anderson et al., 2016: 39), which could increase car numbers. Recent research has also examined the potential for autonomous transport systems to contribute to urban sprawl, which may have negative environmental and social consequences (Gruel and Stanford, 2016). However, autonomous transport may make travel time more pleasurable and productive, and thus this could make the distance between home and work a less significant factor for where people opt to live (Duarte and Ratti, 2018: 11).

Fourth, *how might networked autonomous vehicle systems alter the types of power that people are subjected to?* Automated vehicle technologies – whether they partially or fully leave the task of driving to automated systems – all transfer, at some level, human control of vehicles to software involving digital algorithms. Although these algorithms are originally designed by other humans, the former are irreducible to the latter's planned intentions. This is significant because it may affect how human mobilities are subjected to surveillance and how surveillance itself can be mobilized. Through the mechanism of 'sorting' (Adey, 2004), networked driverless technologies have the capability to track and regulate who and what is being transported and where, when and with what frequency these movements are taking place. Owing to the way automated technologies rely on algorithms, this surveillance and decision-making may take on a more concealed and diffuse form. As a growing body of research has explored (Burrell, 2016), the effects that algorithms have on people's lives can often be opaque. Because it is not always immediately known when algorithms are active and how they operate, this potential for the intensified algorithmic governance of mobility prompts us to posit that autonomous vehicles may give rise to a 'black box' variant of mobilities (cf. Latour, 1987), posing new challenges to how inequalities are constituted and can be addressed.

Fifth, and relatedly, *how might the 'black box' aspect of automated vehicle systems alter the valuation of human life in different spheres of society?* As

Laurier and Dant (2012: 240) have noted, motorists in the age of autonomous cars may no longer be held morally accountable for most, if not all, of the actions of their vehicles since adherence to formal and informal road rules is left to automated technologies. Correspondingly, this shift in responsibility may have broader effects on the way in which some human lives are valued over others. A heated debate is underway about how the decision-making algorithms of autonomous vehicles might choose to preserve some lives at the cost of others (Greene, 2016). These debates also relate to the influence that different industries (e.g. auto-manufacturers, insurance companies) are having in the development of legislation governing autonomous vehicle crashes. Correspondingly, it is also important to consider how legislation around automated vehicles can impact upon the scope and presence of certain industries, such as the possibility that autonomous vehicles might significantly reduce the market for insurance (McDonald, 2013).

Finally, *how might autonomous vehicles intensify different axes of social inequality?* This question relates to the inequalities that are already manifest in the emergence of autonomous technologies. Just like previous mobility systems, access to this new technology is likely to be unevenly distributed across classed and racial lines. Such inequality can be witnessed through how autonomous vehicles are being discussed and represented in news media. As Hildebrand and Sheller (2018) show in relation to car previews by manufacturers, social differences, such as gender, race and class, are in varying levels present in how autonomous vehicle technologies are currently depicted, and these not only inform future realizations of driverless systems, they also can position certain groups as being more technologically 'competent' or advanced than others (cf. Walkerdine, 2006).

In light of these questions, we call on sociologists to contribute to the emerging debates on the social dimension of autonomous vehicles by focusing on social inequalities. We have suggested that social inequalities can be productively explored in terms of how automated vehicles may reflect the values of developers;

they might alter the quality and quantity of mobility for different social groups; they might change the organization of urban spaces; they may change the types of power people are subjected to; they might alter how human life is valued in different spheres of society; and they may intensify different axes of social inequality.

Transforming labour

The third contribution of mobilities studies that we develop is the focus on transformations to labour. Much emphasis in the study of mobilities has explored how mobilities can facilitate different kinds of work. Where we have already discussed the potential transformations to the relationship between moving and working in terms of vehicle affordances, here we are interested in how systems of mobilities themselves require different forms of labour. In this regard, much has been said about how the development of mobility systems goes hand-in-hand with the development of new regimes of labouring, especially emotional labour (Lin, 2016). Mobilities scholars have also shown how the increased prevalence of mobility has intensified employment in new fields, such as hospitality (Duncan et al., 2013) and 'global work' (Jones, 2008). Zooming in on the car specifically, different forms and intensities of labour are involved in the manufacture, maintenance and repair of automobiles (DeLyser and Greenstein, 2015), widening the significance of how automobility is enmeshed within wider publics. In this section, we develop these insights by questioning how the development of systems of autonomous mobility might transform labour.

First, *how will autonomous vehicles transform workforces?* There is currently much debate about whether automation will lead to a large-scale 'jobless' future through the displacement of workers (Ford, 2015), or whether a possible jobless future will be averted by the creation of new jobs that do not currently exist (Mindell, 2015). Notwithstanding this uncertainty, Brynjolfsson and McAfee (2014) warn that that the jobs created by intensified automation will require different skills from those that are displaced. Furthermore, different employment sectors will

experience different effects. For instance, autonomous vehicles may change the labour skills required in the trucking sector. However, rather than entirely autonomous vehicles from the outset, current research indicates that the role of the driver is likely to change from vehicle control to monitoring (Lipson and Kurman, 2016). It is possible that the precise combination of skills required for such autonomous vehicles will involve spatial variations, changing at different stages of the journey. For instance, highway driving with minimal variations might involve a high degree of automation, whereas city driving might require a higher degree of direct human control for navigating a more complex streetscape.

Second, *how will autonomous vehicles impact on transportation employment?* Many predict that the long-term consequences for the transportation labour force are likely to be negative, given that the economic rationale for driverless vehicles is to reduce labour costs and increase safety (Validakis, 2013). In the trucking industry, predictions are for fewer workers with one operative potentially overseeing multiple vehicles. Displacement as a result of autonomous vehicles in the trucking industry introduces the wider question of automation and skill change. It has been argued that AI and changing technologies will demand the constant updating of digital skills (Brynjolfsson and McAfee, 2014). Thus, it will be important to examine variation in levels of engagement with and extension of digital skills, as well as the professional, personal and community factors which both support and limit the flourishing of such technical upskilling. Where some have argued that digital literacy will need to be a core subject at all levels of education, others have pointed out that such education and upskilling are happening in more ambient ways, through the ways in which people engage with different digital technologies in their everyday lives (Richardson and Bissell, 2017).

Third, *what are the spatial variations in changes to labour?* Although many applications of autonomous vehicles are speculative or in the testing stage, nascent applications provide evidence which can help to pinpoint some of the key issues for workforces that may become prominent as more automated

applications develop. For instance, the resources sector in Australia has recently witnessed significant shifts to driverless operation which has both restructured labour and displaced it (Ellem, 2016). Autonomous trucks have reduced the workforce largely involved in manual work required in the Pilbara and have created new jobs in control centres located in capital cities. Therefore, whilst new jobs might be created by vehicle automation, these new jobs might be in a different location to where the technology is operating. The precise location of these new jobs can be influenced by a range of factors including the expertise required, the proximity to related service providers, and economic efficiencies. Ellem's (2016) research indicates a tendency for control and supervisory jobs to move from rural and regional to metropolitan centres. Furthermore, the relocation of new 'supervisory' roles need not be bounded by the nation-state. Offshoring of the control of automated operations might be a cost-effective method for companies involved in implementing autonomous technologies, but it introduces a host of other social problems, including regulatory challenges, lack of transparency of operation, in addition to the more obvious issue of domestic job loss (Urry, 2014).

Fourth, *how will autonomous vehicles impact on labour relations?* In current debates on the future of mobility, there are uncertainties about whether taxis will be fully automated, or will involve a human operative. Indeed, removing the driver from platform transportation companies such as Uber is already an area of heavy investment (Bissell, 2018b). Notwithstanding these aspirations for fully driverless vehicles, experts indicate that this is unlikely in the short term. Therefore, in the meantime, the issue of employment rights for operatives of increasingly automated technologies is important. This involves questions about the kinds of algorithmic control that drivers are subjected to, with potentially less control over the labour process. Furthermore, some platform companies are undercutting traditional transportation providers by lowering workers' rights (Glöss et al., 2016). Designated as independent contractors, these workers have no rights to sick leave, annual leave, or maternity pay, and from a legal perspective have little

protection from the organizations that they provide their labour for. It is vital therefore in the transition to autonomous mobilities that the kinds of employment that are created are scrutinized for their labour standards.

In light of these questions, we call on sociologists to contribute to the emerging debates on the social dimension of autonomous vehicles by focusing on labour impacts. We have suggested that transformations to labour can be productively explored in terms of the changing skills that might be required to be mobile; the changing employment opportunities for transportation labour; the spatially diverse impacts of autonomous vehicles on employment; and changes to labour relations.

Transforming systems

Mobilities studies have demonstrated that to adequately understand the significance of technologies of transit in society, it is vital to consider how they operate within larger interlocking systems, rather than imagined as discrete entities. Urry's (2004b, 2008a) work on mobilities that combines aspects of socio-technical systems thinking with complexity theory is exemplary in this regard. He argues that to understand the pervasiveness of the automobile to contemporary life requires grasping the locked-in 'path dependencies' that the system of automobility created during the twentieth century. In this regard, mobilities researchers have emphasized the exploration of interconnections of the automobility system with other mobilities systems that organize material flows and encounter each other in specific sites, giving rise to dynamic, hybrid systems that combine objects, technologies and socialities. Indeed, changes in systems of automobility might also be driven by non-transport-related sectors across multiple dimensions (Sheller, 2011). It is not only industry and policy interests that open up windows of opportunity in socio-technical transitions, but also progress in technology and science: for instance, energy storage and the various design scenarios in which electric vehicles serve as roving battery storage for distributed renewable energy grids. These other dimensions within system change will also matter in the unfolding of this new system of mobility. Automobility is thus

dependent upon systems of ‘immobile’ material worlds, involving different forms of relatively static infrastructures, alongside cultures of motoring and notions of the body. In this section, we develop these insights by raising questions about the development of systems of autonomous automobility.

First, *what sort of system might emerge?* Urry (2008b) describes how the automobility system is a ‘nexus system’, that is, one that requires many elements to work synchronously. There are suggestions that two distinctive models are emerging in this nexus. On the one hand, semi-autonomous vehicles built by existing car manufacturers for private buyers may gradually reach higher degrees of automation but likely not full automation for some time. On the other hand, there may be fleets of shared (possibly electric) vehicles marketed by digital-tech companies, which may be brought into more public systems with a higher degree of automation if controlled within a ‘smart city’ infrastructure. These ‘transition pathways’ (Fraedrich et al., 2015) for the future of autonomous systems involve differing levels of ownership and sharing, and both are occurring simultaneously and in competition, thereby creating a hybrid system (Oswald, 2016; Smolnicki and Sołtys, 2016).

Second, *what might the drivers of change be in these systems?* Here, we suggest three drivers of change – political, financial and cultural – that are necessary to understand the transitions involved in automated vehicles systems. Political resistance manifests in legislative and policy pressure on automobiles, where competition for road and parking space leads to initiatives and disincentives that counter the benefits of motoring (see also Merriman, 2016). A notable example is congestion charging in London, a deliberate effort to dissuade automobile use for commuting in the urban core, which incentivized cycling and public transport in its place (Shove and Walker, 2010). In cities such as London demographic factors are pivotal in shaping future travel demand, notably population growth and the location of additional inhabitants, with investment decisions away from increasing road capacity having a direct response on choice (Metz, 2015). It is also in major urban centres where car sharing schemes are making the most inroads due to

congestion and the cost of storing a car idle for 95% of its lifespan while commuters are at work or home (Frenken and Schor, 2017). Local government authorities in Sydney, for instance, champion local car sharing policies and interventions, brought about by parking shortages, buttress alternative practices in using automobiles (Dowling and Kent, 2015).

The financial burden of driving is also a driver of systemic change. Since cars are a significant financial asset, participants in sharing economies indicate that economic motivations are stronger for car and ride sharing than other sectors (Böcker and Meelen, 2017). Electric, autonomous vehicles able to interface with the city's digital infrastructure are in a prime position to cater to this cohort and would also provide a response to the youth licensing decline in the global north, attributed to changes in life stage patterns – that is, young adults living with their parents longer and having children later – and the affordability of motoring alongside the growing costs of e-communication technologies and services (Delbosc and Currie, 2013). If autonomous mobilities cause licences to become redundant, the resulting trend of people unable to manually drive will further engrain driverless futures.

Relatedly, a key factor in a transition to an autonomous system is the identity implications in the conversion of what are understood to be intimately private assets to public 'shared' ones. A generational, and cultural, driver is relevant in the shift in attitudes around ideas of ownership in vehicle use. Younger generations are replacing the freedom and flexibility of cars with smartphones and computers, the latter being more compatible with public transport systems where attention can be wholly given to digital activities (Newman, 2012).

These three aspects are known as 'peak car', a phenomenon spanning political, economic and cultural standpoints (Cohen, 2012). 'Peak car' is an idiom for the twenty-first-century downturn in driving in some age demographics and nations leading to commentators gathering evidence of a saturation point being reached in private vehicle use (Headicar, 2013). Peak car seems to suggest that the

automobility system is transforming already over generations through the gradual disincentive to drive and the contemporaneous adoption of immersive digital technologies able to buttress lives on the move (Goodwin and Van Dender, 2013). Significantly, this transformation is most marked in urban areas with congestion and alternatives to motoring both acting together to dissuade automobile use. The automobile is no longer the core asset younger generations acquire and the direct and ongoing costs are also supportive of autonomous systems founded on sharing, leasing and flexible ownership (Metz, 2013). These trends suggest autonomous mobilities will coincide with the demand saturation for automobility.

Third, *how might the development of autonomous vehicle policies involve citizen participation?* Taking on board the disincentives that Lipson and Kurman (2016) flag, which delimit motorists simply trading in their vehicles for driverless ones, alternative systems require forethought and planning. Since automation is not simply a technical issue (Hopkins and Schwanen, 2018), transitions require the involvement of multiple publics. There are a range of different sites of public participation from 'above' and 'below' (Jensen, 2013), involving design, regulation, user adoption and 'tinkering', although these processes of public participation are complex by virtue of entrenched place-specific politics (Legacy, 2016). Furthermore, if 'black box mobilities' arise wherein citizens do not necessarily understand the minutiae 'under the bonnet' of the systems they come to rely on in everyday life, then 'trust architectures' will need to provide assurances of safety and reliability of the sort found in the automation of healthcare (Mohan and Aramudhan, 2017). In order to reach mass adoption, infallibility is a crucial component in terms of a social contract between driverless systems and users.

In light of these questions, we call on sociologists to contribute to the emerging debates on the social dimensions of autonomous vehicles by considering how the systems of autonomous vehicles might change. We have suggested that these transformations can be productively explored in terms of thinking about hybrid systems which consider the diverse political, financial and cultural dimensions that

make up these systems. We also underscore the significance of how policies developed to facilitate autonomous vehicles require citizen participation.

Conclusion

This article provides a provisional outline of what we envisage to be an exciting and diverse agenda through which to explore the emergence of autonomous vehicles for sociology. Such an agenda is vital in order to avoid the restrictive remit of overly technocratic or utilitarian modes of analysis that risk neglecting the diverse and complex ways that automobility constitutes an entire 'way of life'. We have argued that a mobilities approach provides the most optimal conceptual tools to connect the study of autonomous vehicles to these different domains of life to explore their mutual constitution, given its commitment to holistic analysis of mobility systems. Although the prevalence of media commentary about the rise of the autonomous vehicle can give the impression that the version of the future that will unfold has already been decided upon, there is absolutely nothing inevitable about the ways that mobilities systems transform. As mobilities studies have consistently emphasized, there is no singular driver of change that is the 'hidden hand' supposedly guiding how mobility systems transform. The historical contingency of situated automobility cultures and economic and regulatory regimes means that such transformations are also likely to be geographically distinctive.

The power of mobilities studies has been to analyse combinations of practices, discourses, materialities and affects as a way of thinking about the complexity of transformations, indicating how previous 'superorganic' modes of explanation for the changing nature of systems are inappropriate to the complexity of their emergence (see Duncan, 1980). Complexity theorist par excellence Manuel DeLanda underscores this well when he acknowledges that rather than having a centralized locus of control, complex systems are better apprehended as 'eddies and vortices nested inside more eddies and vortices' (DeLanda, 1991: 8). This challenges us to explore and trace the multiplicity of forces at play in the

development of autonomous vehicles. As Dennis and Urry's (2009) writing on the development of the automobility system underscores, small changes can lead to huge tipping points. Furthermore, these small changes can emerge unexpectedly from previously overlooked parts of a system. Whilst we have not currently witnessed a transition to the autonomous car system, there are many small changes currently taking place that might potentially have huge consequences. Such small changes might be witnessed, for instance, in particularly powerful plans or visions that suddenly seize the enthusiasm of an invested party, illustrating how the current work of speculating on the design of future technologies has important performative powers.

A recognition of the latent powers of small changes to manifest big changes also demonstrates the power of social scientific thought in the emergence of autonomous vehicle systems. Rather than feeling a resigned incapacity to act in the face of the supposedly powerful vehicle developers, we need to be more confident in believing that thought does make a difference. If we want new systems of transportation to emerge that are socially progressive rather than reinforcing already entrenched inequalities and repressive ideologies, then we have a responsibility to generate new ways of thinking about autonomous futures that feed into processes of consultation at every stage of the planning process. We encourage sociologists to grasp this opportunity to be at the forefront of influencing how autonomous vehicle systems will develop