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Review Article

Autonomous technologies for daily personal mobilities

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Abstract: This article attempts to point to emerging future trends for personal mobilities, focusing on the current and upcoming uses of autonomous technologies for both physical and virtual mobilities. These uses will be based on electricity and the Internet, which also constitute mobility modes. The article presents first each of the four emerging mobility technologies: electric vehicles (EVs), mobile Internet, autonomous vehicles (AVs), and artificial intelligence (AI) via chatbots. This is followed by a discussion of habit changes in the adoption of the four new mobility technologies. The article then moves to discussions of individual, societal, and spatial implications of the two mobility autonomous technologies of AV and AI. For individuals, autonomous physical and virtual mobilities will both be typified by rather restricted roles and activities by users, such as passengers and text users respectively. At the social level autonomous mobility will have a major impact on education, both generally, requiring students to analyze texts rather than to author them, and professionally, with growing needs for computer experts rather than traditional garage workers. It is too early to assess some possible spatial impacts of chatbots, but AVs will imply several spatial implications, notably regarding the structure of urban streets and parking facilities.

Keywords: autonomy, personal mobilities, mobile Internet, electric vehicles (EVs), autonomous vehicles (AVs), artificial intelligence (AI).

Highlights:

- The emergence of autonomous technologies for personal mobilities.
- Current and future adoption patterns for autonomous mobility technologies.
- Individual, societal, and spatial implications for autonomous mobility technologies.

1. Introduction

Broadly speaking, the topic of future perspectives on geography may relate to several geographical scales. Thus, at the global scale, one may focus on the global climate crisis, or on the post-Coronavirus emergence of two economic-political cores, led by the US and China, respectively. This global scale of future geographical perspectives is coupled with mesoscale trends, consisting of domestic, national, and regional ones. Our attention in this article will be rather paid to the micro geographical scale of future geographies, pertaining to individuals anywhere worldwide, who operate daily within urban entities. Such urban entities may constitute either single independent cities or, alternatively, metropolitan multi-city urban entities.

The personal geographies for individuals within urban settings have been widened during the last two decades so that they include jointly nowadays, physical space, cyberspace, and hybrid space (see e.g., Kellerman, 2019). In the following sections, we will attempt to highlight these personal geographies considering several emerging technologies for personal mobility, technologies that have already become, or that may possibly, and at least potentially become standard ones in the upcoming years: electric vehicles (EVs), autonomous vehicles (AVs), mobile Internet, and artificial intelligence (AI). The first two technologies are about to transform physical mobility, whereas the two latter ones are already upgrading virtual mobility. Furthermore, AV and AI may possibly turn personal mobilities into fully autonomic ones, AV for physical mobility, and AI for virtual ones, both operated through electricity and the Internet.

The discussion of these four new mobility technologies in this article revolves around two basic notions: personal mobility and autonomy. Personal mobility constitutes 'the movement of the self by the self' (Kellerman, 2006, ix). Thus, personal mobilities constitute self-propelled, and thus autonomous, movements, ignited and directed by individuals, including self-moving, or walking, as well as technological self-propelled mobilities, both physical and virtual ones (Kellerman, 2023d). Autonomous technologies constitute sophisticated and upgraded automation technologies. Whereas automation refers to the self-operation of some specific machinery or system, such as the gear-changing system for cars, an autonomous operation implies automatic decision-making processes for numerous systems simultaneously, as is the intention for AVs (see Kellerman, 2018).We will attempt, in this article, to point to emerging future trends for personal mobilities, focusing on autonomous technologies for both physical and virtual personal mobilities, in what seemingly constitutes the first joint and comparative discussion of the four technologies of autonomous nature. As such, our discussions aim at the provision of an initial assessment of the technologies, and their social implications. By their very nature, the discussions will be partially speculative. Still, it is of important, in such an early elaboration, to point to commonalities and differences among these technologies.

Needless to state that adoption processes of new technologies are differentiated according to a variety of social and demographic dimensions. Furthermore, as the current status of AV points to, the development process of technologies is not necessarily linear, so that the development of a technology may slow down or even be stopped for a while. It is hoped that the joint discussion of autonomous technologies offered here will provide some guidelines for future scholarly work on the growing role of autonomy in mobility technological developments. Such future studies may add some depth to the early argumentations and interpretations presented in the following sections.

The operation of all four new autonomous technologies will be based on both electricity and the internet, which are themselves also forms of mobility. Moreover, both the already observed and future impacts of the new autonomous mobility technologies extend to many areas of life, from urban geography to individual and societal trends to education. Our following elaborations will be partially based on my recent publications on the currently emerging modes of personal mobilities (Kellerman, 2018; 2022; 2023a;2023b; 2023c).

The following sections of the article will first present each of the four emerging mobility technologies separately, followed by a discussion of habit changes with regard to the new four mobility technologies. The article will then move to discussions of the individual, societal, and spatial implications of the two autonomous mobility technologies of AV and AI.

2. The electrification of road transport

We currently experience, mainly in developed countries, a rather rapid growth in the adoption of private EVs. Thus, for 2023, the share of EVs in the global car market was expected to reach some 18%, following their share of 14% in 2022, and merely 4% in 2020 (IEA, 2023). China leads the adoption process of EVs, with EVs expected to reach some 40% of its car sales in 2003 (CleanTechnica, 2023). The contemporary trends in the technological development of EVs, coupled with their growing popularity, can bring about full electrification of private road transport sometime between the end of the 2020s and the mid-2030s, with trucks joining slightly later (whereas electric buses are already in use) (Kellerman, 2023c). As such, EVs are making much more progress than AVs (autonomous vehicles), which were supposed to reach the markets towards the mid-2020s, but their final development phases towards marketing maturity have slowed down since the eruption of the Coronavirus crisis.

The growing trend of EV adoption implies a revolution in both the public and private spheres. In the public sphere, there have not been available until recently any regular electric cars for personal use, though the very idea of electric cars emerged already in the 1820s for carriages. However, recent attempts to produce commercial EVs for private use, simultaneously by several major automakers, have taken place mainly as of the mid-1990s, and reached a first wide adoption by the Tesla Model 3, in 2017. The only electric component in road traffic so far are traffic lights, which have been introduced since the late nineteenth century (Kellerman, 2018).

Individuals make use of electricity produced in electricity plants for their home and office needs. It has been only for the production of road transport, that individuals, as well as commercial and public trucks, buses, and cars, serve as energy producers, through the purchase of liquid fuels (or gas) in gas stations. These fuels are, then, turned into energy by car internal combustion engines, and energy eventually produces car mobility. Thus, the use of EVs implies that the status of energy usage by individuals on the road system is that of energy users only, with the energy source produced in central electric power facilities and consequentially charged into car batteries.

The development of electric cars has had to cope with several challenges: the size and weight of the car batteries; the power capacity of car batteries; car prices, and the duration of car battery charging. The contemporary remaining challenges for EV development are power capacity and charging duration. As far as power capacity is concerned, the challenge is to increase the power capacity of car batteries so that the range of travel distance between charges will be extended. Currently, it was for Tesla to announce already a 1,400km battery, and for Mercedes to present a 1,000km one, both for rather expensive car models. These travel ranges are by far higher than the equivalent ones for full-tank gasoline-run cars or hybrid ones, but they imply high car prices, which might decline in the upcoming years, with future development efforts. Another long-standing obstacle to EV penetration has been the rather long battery charging time. The current battery full, or close to full, charging time may reach some 30-40 minutes, which is still much longer than the gasoline filling time for non-electric cars. Much effort takes place now, mostly in China and Israel, to develop technologies for faster battery charging. Beyond these immediate development challenges, the EV industry will have to cope, in the longer run, with supplies of rare minerals required for battery production, as well as with the required steady supply of electronic chips.

The electrification process of road transport constitutes a component of the wider emerging trend of smart cities, from at least two perspectives. First, electric engines imply a removal of the process of energy production using any type of fuel by car engines. In addition, current car models enjoy a widening installation of mostly computerized active security means in them. Thus, EVs may well be viewed as a transitional phase toward the upcoming introduction of AVs. However, until then, the introduction and mass adoption of affordable and rather attractive EVs, featured by low operational costs, may increase road traffic in the transitional years.

The upcoming full adoption of EVs may possibly lead to a quieter city. Urban typical noise, being produced by car traffic, whether in CBDs (central business districts) and in additional urban business centers or next to busy highways throughout metropolitan areas, has come to constitute a basic feature of modern cities (see e.g., Augoyard & Torgue, 2005). Quieter urban roads may potentially lead to some changes in the locational preferences for residence by urbanites, and, hence, potentially at least, to new mixes of urban land uses. Such a change may evolve only in the long run, given the complexity of factors that determine urban land uses.

Cities in which EVs will fully replace internal-combustion cars will be cleaner ones, with the quite heavy air pollution created by traditional cars disappearing from city streets (Rafael et al., 2020). Back in 2014, some 20% of the global carbon emissions were attributed to the transport sector (Taalbi & Nielsen, 2021). The heavy air pollution created by the damaging greenhouse gas emissions, typical of traditional cars, may disappear from city streets. However, air pollution created by electric power stations will grow, given the increased consumption of electric power for the charging of car batteries, thus bringing about a spatial concentration of the origins of such pollution. This development will accentuate the need to move to non-fossil alternative sources for the production of electricity, a trend that is already demanded by the global climate crisis.

3. Autonomous technologies for road transport

The use of autonomous technologies for road transport is about to be realized through the future adoption of AVs, which constitute driverless cars, either totally or partially. AVs were declared 'the next mobile revolution' (Maurer et al, 2016, p. v). The AV project constitutes, by definition, a complex one, involving numerous technologies (Mitchell et al, 2010), led by the Internet, in its mode of the Internet of things (IoT), for both car-to-car and car-to-traffic lights and infrastructure communications, side by side with AI, camera technology, radar, and other information technologies (ITs) (Kellerman, 2018).

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AVs may be widely adopted in selected countries in its first generation, possibly sometime between the late 2020s and the early 2030s, i.e., about one decade later than the pre-Coronavirus forecasts for such a wide penetration. The delay in the commercial introduction of AVs relates to the Coronavirus crisis, which has partially paralyzed the car production industry, as well as to the preference given to the development and introduction of EVs (Mitteregger et al., 2022). Experimentation with AVs has shownthe need to gradually improve further the functioning of AV technologies(see e.g., Latham & Nattrass, 2019; Nadafianshahamabadi et al, 2021). The global shortage of digital chips is an additional factor in the delay in the production of fully computerized cars.

Once AVs will become widely adopted, it will be for the Internet to dominate both car communications and road traffic via traffic lights, thus calling for possible future coordination between the very operations of AVs and the communications services provided for their individual passengers.

4. Mobile Internet

As compared to the other three technologies reviewed here, which are new in their development and adoption, the commercial Internet (which was developed as of 1969) has been with us for almost thirty years, since 1995, with its continuous sophistication, side by side with an enormous growth in the development of Internet-based applications since then. The Internet constitutes a comprehensive information and communications medium, facilitating global reach, and providing for communications, as well as for the storage and retrieval of all forms of information, whether textual, audial, graphic, or streaming. The Internet functions through the Web for information services and through communications platforms for interpersonal interactions, carried out by users who may be located either in fixed locations or on the move (Kellerman, 2020).

A sister technology for the Internet is IoT (Internet of Things), which permits appliances to act as Internet subscribers, being either remotely operated by humans or rather autonomously operated by appliances that communicate with each other, which is the case also for AVs. In 2021, over 83% of the world population maintained an active mobile broadband subscription, as compared to merely 11.2% of the world population owning a fixed telephone subscription. Furthermore, in 2022, 72% of the world population aged 10 and older owned a mobile phone (with or without broadband Internet) (ITU, 2022).

The Internet was originally developed in the US already back in 1969, within the project of ARPANET (Advanced Research Projects Agency Network), as an experimental alternative communications system for telephone services, originally developed for a potential replacement of the telephone system in case of nuclear disasters. The system was tested via a network that connected the security headquarters with the universities. Four major Internet technologies, including the Internet protocol, the router, the Web, and the browser, jointly led to the establishment of the publicly available and commercial Internet system, in 1995. Following the maturing of the Internet, IoT has advanced since the late 1990s and early 2000s (Ashton, 2009).

Smartphones have turned the Internet into a fully mobile communications mode. They constitute upgraded mobile phones, facilitating connectivity to the Internet as well as to Global Positioning Systems (GPS). Mobile telephone technology was originally invented already back in 1906 in the US by Lee de Forest (Agar, 2003, p. 167). However, the first limited mobile phone service was introduced in the UK much later, in 1940, followed by an even later universal adoption of mobile telephony, gradually as of the late 1970s, following the long-awaited release of proper wavelengths, and the emergence of relevant ITs, which brought about the miniaturization of mobile devices, as well as their automated operations.

Two additional features of mobile phones have contributed to their enormous success. The first feature was the invention of the transmission of written texts through SMS (short message service), which was originally introduced in 1993 in Finland, and which became widely adopted as of 2000. The second feature of mobile phones, leading to their success, was their turning into smartphones, first in Japan in 1999. Smartphones constitute mobile phones connected to the Internet via cellular connectivity, as well as through Wi-Fi (wide fidelity), side by side with their connection to GPS systems. The speed and volume of connectivity have increased over the years from 2G (second generation) to the currently available 5G (fifth generation), mainly in developed countries. Thus, mobile connectivity permits the fast transmission of heavy data files, such as movies or medical visual information. It further permits the integration of Internet connectivity into the operations of AVs.

The Internet has brought about instant and free-of-charge global communications by individuals, side by side with a variety of virtual daily activities carried out by individuals, replacing or joining equivalent physical ones, such as work, shopping, banking, etc. (Kellerman, 2014).

5. Artificial intelligence (AI)

AI-based text production by chatbots has recently come to center-stage attention, notably following the commercial introduction of the Chat GPT system (Chat GPT, 2022). Though such systems for artificial text production are still far from flawless status, they can produce already successfully some extensive and smart texts following their users' invitations. As such, AI constitutes an autonomous text production, which can be digitally transmitted elsewhere. Public debates on text production by chatbots so far have focused mainly on its implications for education systems, notably, the danger that AI-based text production may pose to academic studies, which are based on students' own writings (e.g., Mandelaro, 2023).

AI technology has made it possible for text production systems to become autonomous and intelligent text producers, based on available Internet-stored information stemming from numerous sources, mainly books, articles, statistical data, and websites. This autonomy for information systems is not the first one in the world of communications. The autonomy of text production has followed the operational autonomy of text transmission, which has typified communications technologies for over a century already, thus enabling instant transmissions of information audibly over the phone, turning, more recently, to much wider capabilities, thus permitting the transmission of information in all its modes (audial, visual, and textual) through the Internet.

Wide adoption of chatbots for automatic text production may possibly bring about some radical quantitative growth in information production, storage, and transmission. Alternatively, chatbots may be adopted for the production of some specific texts only, and if so then the question will, obviously, be the production of which classes of information will be turned over to chatbots. Chatbots may further possibly be able to produce websites automatically, potentially bringing about a tremendous expansion of the Web by numerous automatically created websites, which may not necessarily come into full, or even partial, usage by Internet subscribers.

In any case, the tremendous growth of produced texts will require wider storage availabilities, whether locally or through clouds, and these remote storage servers, or server farms, may in turn require maintenance and high electricity consumption for the servers themselves, as well as for the cooling of their farms or facilities through air conditioning.

What will be the role of individuals in the digital transmission of artificially produced texts? People who will make use of AI-based applications/bots for text production, followed then by the digital transmission of the artificially produced texts to others, will turn from persons who move their own information to movers of machine-produced information, possibly still attributed to the information sender. Assuming transmissions of fully AI-produced texts, the status of the transmitting people will be like that of people who move some material industrial products using any kind of terrestrial, aerial, or maritime vehicles for their transport.

Still, there are two major differences between the moving processes of products, on the one hand, and artificially produced information, on the other. First, the transmission of information is rather automatic and autonomous (though the autonomous movement of products is also on its way through AVs (see e.g., Kellerman, 2018)). Second, industrial products are produced in large identical quantities, whereas every transmitted packet of artificially produced information will be unique. Thus, the role of individuals in AI-produced text transmission or mobility will be a double one: first, these individuals will constitute initiators of the information production process, and then, they will serve as controllers of its transmission.

Upcoming mature automatic text production may nullify the need for editorial tools, notably, those developed for grammar and text styling, for human text production processes. AI may assist in the upgrading of currently widely available automatic language translation tools, since these tools still lack full accuracy in the translation of full texts, as compared to their accuracy in the translation of single words. Academic authorities may require the use of different fonts or text colors for differentiation between automatic and human portions of texts.

6. New habit and habitus formations for future personal mobilities

The current and upcoming adoptions of the four new technologies for personal physical and virtual mobilities imply the emergence of new habit formations for the performance of these mobilities. Successful new habit formations may lead to the adoption of new mobility technologies. Such adoptions may involve also value changes, associated with the successful adoption of a new technology (Van de Poel, 2021), such as a decline, or a change, in the importance of the value of automobility (Urry, 2004; Freund and Martin, 1993; Kellerman, 2018), when AVs will be adopted. With a significant portion of a given national or even metropolitan society changing its habits, a wider societal change in a given habitus may evolve, as well (Bourdieu, 1977).

'"Habits", that is learnt behavioural patterns, which proceed automatically in response to relevant cues, offer a potential means of maintaining new behaviours' (Judah et al, 2013, p. 1). The study of habit formation in psychology normally focuses on individual voluntary habit formations related to issues such as personal diets, personal bodily care, smoking habits, and the like, side by side with habits related to other daily activities, for example, media and commodity consumptions. Despite their individual nature, such personal habit formations might also be related to wider societal concerns, such as global climate change (Marien et al, 2019; Gardner & Rebar, 2019). 'Habits are slow to develop and change in comparison to other implicit processes' (Carden & Wood, 2018, p. 117). The eventual adoption of a new habit may imply some automated behavior, overruling any conflicting motivations, even once the stimulus for the new habit is not there anymore (Marien et al, 2019). However, the maintenance of a habit for a long time is not guaranteed, as daily behavioral contexts may change (Gardner & Rebar, 2019; Carden & Wood, 2018). Furthermore, the continuation of a new behavior requires maintenance (Judah et al, 2013).

Thus, there seems to be at least some chance for habits to be preserved by individuals continuously, but this may not be guaranteed a priori. In the past, the introduction of video telephones back in the 1970s, failed to make them become widely adopted, whereas their repeated introduction in the 2000s, as part of personal computers (PCs), followed by smartphones, succeeded. The same was true for portable computers (Kellerman, 1993). Thus, it is not guaranteed that all four new mobility technologies will be widely adopted. This is so, especially regarding AVs, which will revolutionize car use by individuals, turning them from drivers to passengers.

7. Autonomy dimensions for individuals

The following three sections of the article will elaborate on the implications of the wide adoption of the upcoming autonomousmobility technologies of AV and AI, beginning with impacts on individuals, followed by those on society, and space, in this order.

Individuals operate and manipulate the Internet by themselves, for all their information and communications uses and applications, which are pursued via the Internet. However, the very moving of information from origin to destination is performed automatically. The future AV manipulation and operation activities by individuals will be much more restricted. Passengers will only be able to instruct autonomous cars regarding their desired destinations, while IoT and additional technologies will autonomously perform car 'driving'. Thus, the upcoming use of AVs for road transport will make individual travel in some way become like individual communications, in that AV and smartphone users will merely determine the destination of the respective transmission or travel, whereas the sending of information, as well as the moving of human bodies, will be performed automatically. The restricted role of individuals on the move via AVs will be like the restricted role of individuals making use of chatbots, in which they only type the word or phrase for which they ask a chat bot for a ready-made text.

Cars are there for the movement of people and materials, but not for the movement of information, which is transmitted electronically at the speed of light. The opposite case of moving materials through the Internet has so far only one precedent, namely the movement of money, which has become almost completely electronic, as Thrift (1995, p. 27) noted: 'nowadays money is essentially information'. One might speculate that sometime in the future, AI applications will make it possible for materials to be recorded electronically by information machines, such as smartphones, and then be transmitted to a destination in which the transmitted signals will be reshaped materially. The use of printers to produce three-dimensional products may be recognized as the first step in this direction.

Human car driving, as well as information manipulation, involves ergonomic dimensions but with a significant difference between cars and phones. Car driving requires the use of material entities, such as the wheel, pedals, sticks, and buttons, whereas information manipulation, as well as information production via AI, involves the use of ergonomically designed screens, which frequently carry images of material devices, notably buttons. Thus, the latter requires literacy but no operational licensing. Once AVs are adopted then the interaction of passengers with cars will be equal to their interaction with communication devices and information technologies, namely using fingers only for screen touching, without any licensing.

Both communicating and traveling may be viewed also as human experiences, beyond their operational context, since both involve intervals. In traveling the interval is the travel time between origin and destination, whereas for communications it is the time passing between information sending and the receipt of the awaited response, notably during synchronous chatting sessions. When driving, the freedom to use travel time for other activities is restricted to talking with fellow passengers, talking with people located elsewhere over the phone, or listening to the radio or recorded information (see e.g., Thrift, 2004). However, future AV passengers and current communicating individuals can use the interval time for a wide variety of activities. AV passengers will still be spatially restricted to their vehicles while communicating persons can move freely with their phones carried along with them. Traveling in general implies the moving of one's body from one point in space to another, whether through a traditional human-driven car or through AVs, whereas in communications one's information moves from point to point with the sender remaining in a fixed location, or him/her being on the move from point to point independently from the destination of a sent message. This spatial difference between travel and communications intervals may keep the two classes of intervals as differing experiences. Intervals, operationally and experientially alike, are irrelevant for chatbot operations, typified by their immediate response.

Currently, electric cars are usually more expensive than gasoline-powered ones, though the gap is continuously decreasing. The same may apply to the future early penetration phases of AVs. However, one may assume that once car manufacturers will cover their development costs, future car prices, for both EVs and AVs, may decline, as has been the case for technological developments so far, such as for PCs. However, AI chatbot subscriptions have been either free or reasonably priced from the outset of the technology.

8. Technological autonomy and mobile society

Following our previous discussion of individuals and the autonomy dimension of their personal mobilities, our elaborations will move now to society at large, focusing on some societal effects of an AV and AI-based mobile society. These societal implications of technological autonomy, in both physical mobility through AVs and in virtual one through AI, may emerge in numerous life dimensions, ranging from education, professional development, and security, all of which do not necessarily include a specific spatial character. The rather specific spatial changes will be highlighted in the following section.

A major area of societal change in an AI-based society will be education. Chatbots will lead to a change in education in general, notably in high schools and universities, whereas AVs will lead to changes in some specific branches of professional education. The artificial production of information may sharpen the role of creativity in text writing, notably in academic studies. Whereas chatbots may, potentially at least, do well with the provision of some edited literature reviews and other existing knowledge, the interpretation and analysis of these materials, followed by the introduction of new approaches and ideas, will still be the role of human text writers. The assessment of written texts, notably those written by students, will, thus, become more focused on these latter, and rather personally authored, components of texts. Thus, students in general may require some preparedness for higher levels of creativity.

The professions dealing with electricity and information systems for electric and autonomous cars will possibly grow tremendously, as compared to their current continuously growing importance. The dependence of car systems on electricity and communications may bring about some drastic changes to the industry of car service and maintenance, and their spatial facilities, the garages. Already now, traditional cars are connected to computers in garages to identify and locate their malfunctioning parts. Future cars will require electricity and Internet specialists for their maintenance, with cars having fewer moving parts, and using low quantities of oils or none for their functioning and maintenance. Thus, the education of future garage workers, as well as that of professional drivers, will change, requiring them to develop new skills (Nikitas et al, 2021). On the other hand, however, car electricity and Internet systems may become widely similar to those of other electricity and Internet (IoT) operated and controlled systems, so there may emerge some wide flexibility of employment for proper workers in these areas. Furthermore, the similarity of operational and control systems between cars and other mechanical systems may permit their standard and large-scale production, thus providing for lower prices for cars.

AVs nay may bring about some required infrastructural changes, as well. As things look like in the early 2020s, it seems that the need to assure the security of the electricity and Internet systems, which will serve the upcoming road transport systems, will constitute their most important societal dimension. The Internet has become a leading target for personal and organized crime, as well as for attacks by state agencies, carried out by hackers of all kinds. Thus, Internet-dependent road transport may become highly vulnerable, given the risk of road accidents once the Internet connectivity of cars is damaged. Similarly, the electronic, again mostly Internet (IoT)-based controls of alternative energy sources, such as solar or wind systems, may too be hurt by hacking. These systems therefore also need strict cyber protection.

A rather wide spatial decentralization of energy production systems, side by side with the establishment of numerous routing channels for Internet signals, is called for under the growing risks of damaging attacks. Future technological developments may possibly permit independent electricity production by cars through solar systems installed on car roofs, along with car connectivity to satellite-driven Internet systems, rather than to terrestrial servers spread locally and regionally, which are more vulnerable to physical attacks.

One may further expect behavioral changes in an AV-based society, as well. Thus, contemporary daily commuting through car driving, or via public transport riding, permits workers to enjoy a buffer time between work and home (see e.g., Kellerman, 1994). However, once drivers will turn into AV passengers, more time may be devoted to working while riding, so the buffer between home and work may be mostly eliminated, with passengers arriving at home directly from their continued work while riding AVs (Kellerman, 2018).

9. Spatial effects of mobility autonomy

Given the striking presence of cars in visible space, some attention has been given already to spatial, notably urban, possible future impacts of AVs (e.g., Kellerman, 2018; Duarte & Ratti, 2018; Milakis & Müller, 2021). This is not the case, however, as far as the recently introduced textual chatbots are concerned.

AI will possess a major role in the operation of AVs (Kellerman, 2018). However, it is still too early to begin to assess the implications of AI text production on urban mobility systems. Early applications, though, present mainly the use of Chat GPT for the enhancement of urban mobility services, notably, but not only, through the production and operation of websites for urban hired personal mobilities, such as cycling (see e.g., Potor, 2022).

Digital systems will continue to possess spatial material anchoring, as far as their hardware is concerned. However, some additional spatial and temporal flexibility may be expected, as far as the individual users are concerned. The basic human dimensions of time and space have become almost irrelevant in relation to human activity in general when it comes to machine-typed texts transmitted over the internet, since text input and transmission can take place anywhere and at any time. Of course, this also applies to automatically produced texts. In other words, automatic text production and transmission can take place at any time, any place and at any distance. It is difficult to assume that the transmission of automatically produced texts is only preferred at certain distances.

In the AV city, the road system may not necessarily be changed, as compared to current road systems, since many, but not all, AVs will have the same physical structure as traditional human-driven cars have. However, if smaller AVs will be eventually preferred by car owners or passengers, then city government may prefer to construct narrower road lanes, once traditional wider cars will not be present on the road system anymore. Full adoption of smaller cars may be helpful for traffic in older neighborhoods with narrow streets, and this may further upgrade the value of real-estate in such neighborhoods (see e.g., Mitteregger et al., 2023). The traditional traffic lights may turn into traffic control sensors, thus becoming invisible to the innocent eyes of pedestrians and passengers. At least potentially, pedestrians too may not need traffic lights anymore for road crossings since smartphones may possibly inform them when road crossing is safe. The numerous traditional road signs for drivers may disappear as well.

The autonomously mobile city may consist of three layers in which automated mobility modes will operate: underground (for autonomous metros and cables), surface (for AVs and autonomous metros), and aerial (for drones as well as for communications waves including those for the integrated controls of city traffic) (Kellerman, 2018).

The urban spatial changes, which may accompany the possible wide adoption of AVs, may possibly be like those of the tremendous urban expansion, which accompanied the wide adoption of traditional cars at the time, gradually as of the early twentieth century, and which was termed as 'the first wave of urban sprawl' (Gutierrez, 2021). In a possible second wave of urban sprawl, as foreseen in numerous studies for the wide adoption of AVs, people may prefer to use autonomous taxis rather than their own private cars, so that cities may become more expanded in their aerial size (Gutierrez, 2021; Nadafianshahamabadi et al, 2021; Liu et al, 2021; Guan et al, 2021). However, it is still debated whether the number of cars and the number of trips will increase once AVs will become the dominant mode of personal mobility (e.g., Dannemiller et al, 2021), or whether they may remain stable (Cugurullo et al, 2021).

Cugurullo et al (2021) recently speculated that a mixed model of AV use will emerge, consisting of both privately owned cars and shared ones. This may possibly bring about, at least for a transitional period, a separation between AVs and traditional car traffic (Lee et al, 2022). Side by side with the possible reduction in the number of private cars, the problem of parking availability, which typifies contemporary city life, may also be resolved. Furthermore, the parking pattern of AVs will permit smaller distances for the separation of parked cars in depots rather than in parking lots.

The free parking space, combined with the availability of more efficient AVs, could lead to a renewed concentration of offices and businesses in city centres. However, the opposite possibility of a rather wider dispersal of employment areas may also become possible, as commuters will not mind traveling longer while working during travel time. Thus, it is difficult, as of yet, to foresee the possibly new or renewed spatial organization of business in metropolitan areas in the future era of full AV adoption (Heinrichs, 2016).

10. Conclusion

This article attempted to point to emerging future trends for personal mobilities, focusing on the upcoming introduction of autonomous technologies for both physical and virtual mobilities. These autonomous technologies will be based on both electricity and the Internet, which also constitute mobility modes by themselves. The article first presented each of the four emerging mobility technologies: electric vehicles (EVs), mobile Internet, autonomous vehicles (AVs), and artificial intelligence (AI) via chatbots. This was followed by a discussion of habit changes that may emerge from the adoption of the four new mobility technologies. The article then moved to discussions of individual, societal, and spatial implications of the two mobility autonomous technologies of AV and AI. It was argued for individuals that autonomous physical and virtual mobilities will both be typified by rather restricted roles and activities by users, notably as passengers and text users respectively. At the social level, the adoption of autonomous technologies for mobility will have a major impact on education, both generally, requiring students to analyze texts rather than to author them, and professionally, with growing needs for computer experts rather than traditional garage workers. It is too early to assess some possible spatial impacts of chatbots, but AVs will have several spatial implications, notably regarding the structure of urban streets and parking facilities.

The development of autonomous technologies looks like a major future trend, encompassing a wide variety of life spheres: industrial production, housekeeping, maritime and air transport, combat military activities, and more. Each of these life spheres includes spatial dimensions, which might be transformed using autonomous technologies. The autonomous operation of physical and virtual mobilities, which we discussed in this article, may bring about some transitions that may be related to those typifying other spheres of life. It all depends on the pace of technological developments, on the one hand, and the pace of their adoption by individuals, on the other.

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References

Agar, J. (2003). Constant Touch: A Global History of the Mobile Phone. Icon Books.

Ashton, K. (2009). The 'Internet of Things' thing, *RFID Journal*. http://www.rfidjournal.com/articles/view?4986

Augoyard, J-F. & Torgue, H. (2005). Sonic Experience. McCartney, A. & Paquette, D. (trans.) McGill-Queens University Press. https://doi.org/10.1515/9780773576919

Bourdieu, P. (1977). Outline of a Theory of Practice. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511812507

Carden, L. & Wood, W. (2018). Habit formation and change. Current Opinion in Behavioral Sciences, 20, 117-122. https://doi.org/10.1016/j.cobeha.2017.12.009

Chat GPT. (2022). https://openai.com/blog/chatgpt/

CleanTechnica. (2023). https://cleantechnica.com/2023/05/31/35-plugin-vehicle-market-share-in-china-china-ev-sales-report/

Cugurullo, F., Acheampong, R.A., Gueriau, M. & Dusparic, I. (2021). The transition to automatic cars, the redesign of cities and the future of urban sustainability. *Urban Geography*, 42, 833-859. https://doi.org/10.1080/02723638.2020.1746096

Dannemiller, K.A., Mondal, A. & Asmussen, K.E. (2021). Investigating autonomous vehicle impacts on individual activity-travel behavior. *Transportation Research Part A,* 148, 402-422. https://doi.org/10.1016/j.tra.2021.04.006

Duarte, F. & Ratti, C. (2018). The impact of autonomous vehicles on cities: A review. *Journal of Urban Technology,* 25, 3-18. https://doi.org/10.1080/10630732.2018.1493883

Freund, P. and Martin, G. (1993). The Ecology of the Automobile. Montreal: Black Rose Books.Gardner, B. & Rebar, A. (2019). Habit formation and behavior change. *Oxford Research Encyclopedia, Psychology*. http://www.oxfordre.com/psychology

Guan, J., Zhang, S., D'Ambrosio, L.A., Zhang, K. & Coughlin, J.F. (2021). Potential impacts of autonomous vehicles on urban sprawl: A comparison of Chinese and US car-oriented adults. *Sustainability*, 13, 7632. https://doi.org/10.3390/su13147632

Gutieerrez, C.I. (2021). A new wave of urban sprawl: Influence of autonomous vehicles on the policy toolkit and property tax revenues of local governments. *Journal of Urban Technology,* 28, 155-174. https://doi.org/10.1080/10630732.2021.1959784

Heinrichs, D. (2016). Autonomous driving and urban land use. In: Maurer, M., Gerdes, J.C., Lenz, B. & Winner, H. (eds). Autonomous Driving: Technical, Legal and Social Aspects, Springer Open, 213-231. https://doi.org/10.1007/978-3-662-48847-8_11

IEA (International Energy Agency), (2023). Demand for electric cars is booming, with sales expected to leap 35% this year after a record-breaking 2022. https://www.iea.org/news/demand-for-electric-cars-is-booming-with-sales-expected-to-leap-35-this-year-after-a-record-breaking-2022

ITU (International Telecommunication Union). (2022). Key ICT indicators for developed and developing countries, the world and special regions (totals and penetration rates). Statistics. https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx

Judah, G., B. Gardner & Aubger, R. (2013). Forming a flossing habit: An exploratory study of the psychological determinants of habit formation. British *Journal of Health Psychology,* 18, 338-353. https://doi.org/10.1111/j.2044-8287.2012.02086.x

Kellerman, A. (1993). Telecommunications and Geography. Belhaven Pinter (John Wiley).

Kellerman, A. (1994). Commuting as Experience and its Ramifications for Telecommuting. Netcom, 8, 225-234. https://doi.org/10.3406/netco.1994.1219

Kellerman, A. (2006). Personal Mobilities. London and New York: Routledge. https://doi.org/10.4324/9780203087169

Kellerman, A. (2014). The Internet as Second Action Space. London and New York: Routledge. https://doi.org/10.4324/9781315765105

Kellerman, A. (2018). Automated and Autonomous Spatial Mobilities. Edward Elgar. https://doi.org/10.4337/9781786438492

Kellerman, A. (2019). The Internet City: People, Companies, Systems and Vehicles. Edward Elgar. https://doi.org/10.4337/9781788973595

Kellerman, A. (2020). Globalization and Spatial Mobilities: Commodities and People, Capital, Information and Technology. Edward Elgar. https://doi.org/10.4337/9781789901221

Kellerman, A. (2022). Post-Coronavirus personal spatial mobilities: A speculative view. *Journal of Urban Technology*, 29, 145-158. https://doi.org/10.1080/10630732.2022.2044743

Kellerman, A. (2023a). Homo Viator 2020s: Electrified and Internet-based personal mobilities. *GeoJournal,* 88, 2553-2562. https://doi.org/10.1007/s10708-022-10764-8

Kellerman, A. (2023b). Chatbots and information mobility: An agenda for thought and study. *Environment and Planning B: Urban Analytics and City Science*, 50, 2023 https://doi.org/10.1177/23998083231181595

Kellerman, A. (2023c). The electrification of road transport and its urban effects. *Environment and Planning B: Urban Analytics and City Science* 49, 2022:1593-1596. https://doi.org/10.1177/23998083221088291

Kellerman, A. (2023d). Understanding Personal Mobilities. Cheltenham UK and Northampton MA, US: Edward Elgar (forthcoming).

Lathem, A. & Natrtrass, M. (2019). Autonomous vehicles, car-dominated environments, and cycling: Using an ethnography of infrastructure to reflect on the prospects of a new transportation technology. *Journal of Transport Geography*, 81. 102539. https://doi.org/10.1016/j.jtrangeo/2019.102539

Lee, S., Jang, K.M., Kang, N., Kim, J., Oh, M. & Kim, Y. (2022). Redesigning urban elements and structures considering autonomous vehicles: Preparing design strategies for wide implementation in cities. *Transportation Research Part A*, 148, 402-422. https://doi.org/10.1016/j.cities.2022.103595

Liu, P., Xu, S-X, G.P. Ong, Tian, Q. & Ma, S. (2021). Effect of autonomous vehicles on travel and urban characteristics. *Transportation Research Part B*, 153, 128-148. https://doi.org/10.1016/j.trb.2021.08.014

Mandelaro, J. (2023). How will AI chatbots like ChatGPT affect higher education? News Center, University of Rochester. https://www.rochester.edu/newscenter/chatgpt-artificial-intelligence-ai-chatbots-education-551522/

Marien, H., Custers, R. & Aarts, H. (2019). Studying human habits in societal context: Examining support for a basic stimulus-response mechanism. *Current Directions in Psychological Science*, 28, 614-618. https://doi.org/10.1177/0963721419868211

Maurer, M., Gerdes, J.C., Lenz, B. & Winner, H. (eds). (2016). Autonomous Driving: Technical, Legal and Social Aspects. Springer Open. https://doi.org/10.1007/978-3-662-48847-8

Milakis, D. & Müller, S. (2021). The societal dimension of the automated vehicles transition: Towards a research agenda. *Cities*, 113, 103144. https://doi.org/10.1016/j.cities.2021.103144

Mitchell, W.J., Borroni-Bird, C.E., & Burns, L.D. (2010). Reinventing the Automobile: Personal Urban Mobility for the 21st Century. MIT Press. https://doi.org/10.7551/mitpress/8490.001.0001

Mitteregger, M., Bruck, E.N., Soteropoulos, A., Stickler, A., Berger, M., Dangschat, J.S., Scheuvens, R. and Banerjee, I. (2022). AVENUE21. Connected and Automated Driving: Prospects for Urban Europe. Springer Nature. https://link.springer.com/book/10.1007/978-3-662-64140-8

Mitteregger, M., Bruck, E.N., Soteropoulos, A., Stickler, A., Berger, M., Dangschat, J.S., Scheuvens, R. and Banerjee, I. (2023). AVENUE21: Planning and Policy Considerations for an Age of Automated Mobility. Springer Nature. https://link.springer.com/book/10.1007/978-3-662-64140-8

Nadafianshahamabadi, R., Tayarani, M., & Rowangould, G. (2021). A closer look at urban development under the emergence of autonomous vehicles: Traffic. Land use and air quality impacts. *Journal of Transport Geography* 94, 103113. https://doi.org/10.1016/j.jtrangeo.2021.103113

Nikitas, A., Vitel, A-E., & C. Cotet, C. (2021). Autonomous vehicles and employment: An urban futures revolution or catastrophe? *Cities*, 114, 103203 https://doi.org/10.1016/j.cities.2021.103203

Potor, M. (2022). How chatbots are driving changes in urban mobility. Chatlayer. https://chatlayer.ai/how-chatbots-are-driving-changes-in-urban-mobility/.

Rafael, S., Correia, L.P.,Lopes, D., Bandeira, J., Coelho, M.C., Andrade, M., Borrego, C. & Miranda, A.L. (2020). Autonomous vehicles opportunities for cities air quality. *Science of the Total Environment*, 712, 136546. https://doi.org/10/1016/j.scitotenv.2020.136546.

Taalbi, J. & Nielsen, H. (2021). The role of energy infrastructure in shaping early adoption of electric and gasoline cars. *Nature Energy*, 6, 970-976. https://doi.org/10.1038/s41560-021-00898-3

Thrift, N. (1995). A hyperactive world. In: Johnston, R.J., Taylor, P.J., & Watts, M.J. (eds). Geographies of Global Change: Remapping the World in the Late Twentieth Century. Blackwell, 18-35.

Thrift, N. (2004). Driving in the City. *Theory, Culture and Society*, 21, 41-59. https://doi.org/10.1177/0263276404046060

Urry, J. (2004). The 'system' of automobility, *Theory, Culture and Society*, 21, 25-39. https://doi.org/10.1177/0263276404046059

Van de Poel, I. (2021). Design for value change. *Ethics and Information Technology*, 23, 27-31. https://doi.org/10.1007/s10676-018-9461-9

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