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Social implications of autonomous vehicles: a focus on time

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Abstract
The urban environment is increasingly engaging with artificial intelligence, a focus on the automation of urban processes, whether it be singular artefacts or city-wide systems. The impact of such technological innovation on the social dynamics of the urban environment is an ever changing and multi-faceted field of research. In this paper, the space and time defined by the autonomous vehicle is used as a window to view the way in which a shift in urban transport dynamics can impact the temporal experience of an individual. Using the finite window of time created by an autonomous vehicle, a theoretical framework is put forward that seeks to show how contrasting narratives exist regarding the experience of the window of time within the autonomous vehicle. By taking a theoretical approach informed by social theory, the dissolution of barriers between separate spheres of life is explored to highlight the increased commodification of time. In focusing on both the space and time created by the autonomous vehicle this approach seeks to highlight how artificial intelligence can provide a contemporary space in the urban environment while also opening a new window of time. The cognitive dissonance observed when comparing the narratives of autonomous vehicle stakeholders and the historical shift in time use leads to a belief that technology makes the user more free in terms of time. With this paper the autonomous vehicle is shown to be an ideal space and time to view the way in which the use of such technology does not increase free-time, but further dissolves the boundaries between what is and what is not work-time.

Keywords Autonomous vehicles · Time use · Urban space · Social acceleration · Autonomy · Artificial intelligence

1 Introduction

This paper seeks to contribute to the ongoing literature surrounding the societal implications of autonomous vehicles (AVs). In doing so, the paper will look specifically at the space and time that is created while being within an AV. The study of time use during transport is a heavily researched field yet with the introduction of AVs a new easily quantifiable window of time within a contemporary urban space comes into existence. Through engagement with theories of acceleration and autonomy in the postmodern setting this urban space will be explored through the lens of time. A theoretical framework will be put forward which seeks to focus specifically on the commodification of time within an AV, yet be translatable to wider instances of the commodification of leisure time. The social dynamics that are sub-consciously incentivised in capitalist structure can be better understood when viewing them within this contemporary and finite urban space. With current governance approaches cars are seen as self-evidently beneficial, and risks are governed retrospectively (Stilgoe 2017). As further implementation of artificial intelligence (AI) in the urban environment occurs it is crucial to protect those citizens on whom power and governance is enacted (Cohen et al. 2020; Cugurullo 2021). By viewing the shifting of urban time use within the AV such societal changes can be explored within a finite space and time.

The taking of a theoretical approach in this case is relevant due to the change in what it means to be within the space of a car in the urban environment. Previous studies (Julsrud and Denstadli 2017) have focused on time use in public transport as well as time spent driving, whereas this current shift brings to the fore a change not in the way time is spent in the same space, but a change in the space that allows for a change in the use of time. The disconnection of labour from space will be a core ideal to this paper, something that has become even more visible due to the impact

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of the COVID-19 pandemic. With the shift to more digitally mediated labour "the increased freedom and flexibility on offer to workers is countered by new "softer" forms of workforce surveillance and control" (Shapiro 2017 p.2954).

This manifestation of space within the AV is the key aspect which requires a contemporary theoretical approach as the diffusion of digital technologies in social life has produced dramatic shifts in the production and conception of space (Gairola and Roth 2019). The purpose of this paper is to emphasis and discuss the need for increased study in the fields relating to the social implications of AVs with a focus on time, specifically the way in which the time within an AV is a prime lens to view the impact of economic social structure on time use choices made by an individual. By addressing a gap in the relevant knowledge and adding to the body of information surrounding time use and AVs, this paper seeks to explore how the engagement with urban space is both driven and impacted by economic social structure. Within digital existence time is a factor of production and, therefore, a scarce good when considered as a resource within the capitalist process of production (Rosa and Trejo-Mathys 2017). Using the lens of time to engage with this space within an AV the paper seeks to examine how people choose to use this new window of time and what influences their decisions to do so.

While the safety benefits of AVs alone arguably warrant their continued research and development, such as quicker response times than human drivers (Taeihagh and Lim 2018), it is important to acknowledge that changing the dynamics of urban mobility incurs significant societal implications. For example, with the introduction of AVs, a new window of time comes into existence as potential free time. This time will be discussed within contemporary socio-economic structures and related to the new emerging market of the passenger economy and mobility as a service (MAAS). The paper will show that, as time becomes profitable as a scarce commodity in a technologically driven society, AVs have a significant role to play. The majority of current research emphasises how "AVs will reshape the way we live and design cities" (Duarte and Ratti 2018: (4), and the focus remains largely on the urban and physical environment. This emphasis on the ways in which AVs will change how humans live will be explored through the lens of *time*. Time being an area that remains unexplored in relation to current literature around AVs. We argue that to create an urban space that empowers humans, the design focus must be human-centred and not simply structural. Exploring the human impacts of innovation in transport systems can ensure that these systems are molded to best serve the needs of urban residents. Foresight is necessary to avoid oversights, such as those that can be seen in the history of the development of the car, through which cities were designed, from the 1920s onwards, with the primary function of accommodating cars instead of living residents (Sheller and Urry 2000).

The paper is structured as follows. First, the promise of manufacturers and advocates for AVs concerning how their product will create free time is critically evaluated. This time is framed by manufacturers as free time as a unique selling point. The critique of this promise stems from the existence of the passenger economy and MAAS as a consumer of time. Then follows an exploration of how time use in public transport is being moulded by an increased engagement with digital technology. The demand for time as a commodity is a determining factor in how this free time is used. The paper then turns the direction toward a more social theory oriented path. By exploring theories of autonomy and social acceleration, a theoretical framework is outlined to aid in viewing the increased economisation of leisure time. The question of time use in relation to technological progression and automation is examined from a conceptual perspective, by placing the space and time of the AV to the fore. This social theory is used as a framework to draw upon philosophical ideals to explore time use dynamics concerning automation. The relationships between choice and technology are outlined to apply this framework to the contemporary context of time use within AVs.

2 Time use and urban transport

The manifestation of AI in the built environment is not an abrupt phenomenon that changes the metabolism and design of the city but a long-term process of technological innovation (Cugurullo 2020). The AV becomes a contemporary space in which the effects on the temporal experience of an individual within the urban environment can be explored. In viewing the temporal impact of AVs on the urban environment it is necessary to register the way in which previous changes in urban transport dynamics were not neutral, in the sense that they came with uneven socio-environmental transformations which undermined the sustainability of the city (Cugurullo 2021). The impact of AVs will also shape changes in urban life, but these changes will inevitably be directed by pre-existing socio-economic structures.

The nature of current urban transport networks allows for a greater choice in how people choose to traverse the city. Commuters may now choose the way in which they will travel based on the functional uses of time that are possible, while they are in transit (Gripsrud and Hjorthol 2012). The relationship between the availability of e-activities and satisfaction has been noted in a study that focused on the satisfaction and time use of passengers using high speed rail systems in Japan. The authors claim that "the frequent work-related e-activities for business/work passengers suggest that trains

have the potential to become mobile workplaces" (Wang and Loo 2018: p.10).

The use of technology, while shown as an aid for increasing efficiency of work and creating more free time, conversely increases the frequency of interactions and spreads the locations in which work takes place. The workplace no longer exists as a singular location but is instead scattered and mobile. This fragmentation of physical space and cyberspace is not reflected in common ideas of time use (Janelle and Hodge 2000). While contemporary employers advertise their flexibility as a means of providing better conditions for their employees, the current economic structure encourages many companies to take away with one hand the helpful policies they lightly offer with the other (Hochschild 1997). This emphasis on self-assigned significance to the products of labour "ensures that individuals act on themselves so that power relations are interiorized—and then interpreted as freedom" (Han 2017: p.28). The boundaries between travel time and activity are becoming increasingly blurred in the information age (Lyons and Urry 2005). Previous studies have argued that the demand for travel depends on the value of the activities at the destination, which has to be sufficient to outweigh the time and money costs of the journey (Metz 2008). Attitudes toward public transport are improving, as it allows travellers to free their hands from the steering wheel and instead utilise this time to engage with the opportunities embedded in portable internet connected devices (Watts and Urry 2008). These reports engage with the increase in the functions of public transport due to internet connection and its potential productivity benefits. While the value of time in transport is increasing, the benefits and satisfaction of commuting by walking and cycling remain undervalued; they act as a buffer zone between the work and private spheres of life (Friman et al. 2013).

The belief surrounding AVs is that they will reduce the time spent travelling, but accommodating demands created by the passenger economy could increase total vehicle use up to 11% (Sivak and Schoettle 2015). These demands stem from the desire of passengers to continuously increase work productivity. "Self-optimization and submission, freedom and exploitation, fall into one" (Han 2017: p.28). These internalised power dynamics, stressed by Han (2017), encourage the consumption of free time under the guise of individual optimisation. While travel time could be reduced if the entirety of vehicles on the road become autonomous, this transition will take time. Until then, estimates suggest that travel time will have increased by 3–9% by 2035 (Trommer et al. 2016). In a survey among 1000 US adults concerning their preferences and response to AVs, many stated that they expected that autonomous driving technology would not significantly affect their vehicle travel, those who did not anticipate changes were far more likely to travel more than less (Fleming and Singer 2019). The ability of AVs to serve as mobile bedrooms, playrooms, and offices may allow their users to rest or be productive while travelling (Cugurullo, 2021; Litman 2019). This transition of time from used time to free time allows it to become consumable. This transition will increase the value of time spent during transit. The increasing demand on time has been explored in Taiebat et al. (2019) in relation to vehicle travel elasticities, who found that households are more sensitive to time than they are to fuel costs and predicted that AVs would increase vehicle travel use by 2–47%, with the majority of the increase coming from higher income demographics. This change in time consumption accentuates the choices made by users of public transport. The choice to use this time as work time is now being actively encouraged by MAAS and the passenger economy that is being created by AVs.

The promises provided by manufacturers of AVs are focused on the new free time AVs will create for their users. This is one of their primary selling points used to attract new customers. It is estimated that commuters could save a combined 1 billion hours every day through the use of AVs (Bertoncello and Wee 2015). AVs are depicted in the media as spaces of relaxation and leisure. This can be seen in concepts, such as the Volvo 360c, which highlights the ability to enjoy the space of the AV and "relax or party on your journey, with all the creature comforts you need." (Volvo Cars 2022). While this is an effective way of enticing potential buyers, the marketing strategy also highlights the use of the AV as a work space, describing the AV as a "mobile, fully connected meeting place and workspace meaning you can get things done on the move" (Volvo Cars 2022). Erik Coelingh, a senior technical leader for Volvo, said, "with the car doing most of the work, you will be free to make the most of your time spent in the vehicle, you as a driver can get back your own time" (Thompson 2019). While the Volvo 360c is designed primarily as a private AV, the promise of free time is mirrored in the Waymo One. Waymo is a subsidiary of Alphabet which is currently operating an on-demand ride hailing service in certain areas of Phoenix, Arizona. The Waymo One product was made available to the general public on the 8th of October 2020 (Krafcik 2020). The creation of free time is used as an incentive to attract customers to Waymo's ride sharing service. On the company's website, passengers are encouraged to "relax and enjoy free time in the back of a spacious and clean car" (Waymo 2018) to draw people to the new market being described as the "passenger economy" (Lanctot 2017). AV manufacturers emphasis the power of automation to complete a task formerly completed by a human to depict that time as newly available to the user. By describing this time primarily as free time for relaxation and leisure, AV manufacturers make the use of their products more appealing to the general public.

According to a study published by Intel, the autonomous vehicle industry will create an $800 billion annual

revenue stream by 2035, increasing to $7 trillion by 2050 (Intel 2017). This is defined as the emerging market of the "passenger economy", which will stimulate value creation through the adoption of MAAS (Lanctot 2017). This includes the value of services and goods derived from the use of AVs, as well as intangible savings in terms of time and resources. The commodification of time in transit exists due to the continuous participation in adding to the global sea of data. While an increase in individuals' free time is touched upon by manufacturers of AVs, it is less prominent when examining governmental policy. The Netherlands, which has been determined to be the most prepared country in the world for the introduction of AVs, has made no mention of individual free time in their policy documents. Studies that examine the nation-level seem not to recognize or refer to the ways in which AVs will impact an individual's time, preferring to refer to wider-scale time savings for autonomous fleets. When examining AVs, the focus on time has been set to a scale larger than the individual. Such a scale fails to explore the internal dynamics of time use within an AV. An Intel presentation at South X Southwest festival in Austin referred to the free time created by AVs and marketed it as "more time for the things we care about" (Intel 2017). This is in line with the image presented by AV manufacturers worldwide. With the passenger economy as a future market for large corporations, emphasis has primarily been placed on the applications of AVs in the urban setting.

The focus on urban environments for the implementation of AVs is a global trend (Acheampong et al. 2021; Dowling and McGuirk 2020). In order for these vehicles to function effectively, they must be able to operate within the chaotic environment of a city. To draw commuters into a new mode of transport, the passenger economy places an apparent focus on time. The choices made by average commuters are often focused on maximizing the use of their travel time; 39% of Americans surveyed by Ford said they commuted by public transport to have time to multitask. The digital economy combined with the emerging passenger economy has the potential to create a large pool of value, generating global digital-media revenues of 5 billion euro per year for every additional minute spent on the mobile internet (Bertoncello and Wee 2015). Revenue that will stem from advertising as well as the creation of individual data from increased participation in the network of connected devices. This emerging market of time within an AV is highly sought-after. It is put forward that in fully automated vehicles, all occupants could safely pursue more productive or entertaining activities (Coalition for future mobility 2018). However, those that provide the service of an AV simply provide a space and time. While they can advertise potential ways such a space and time could be used, their contribution is merely to provide this new window.

The framing of new free time thanks to the use of an AV is in contrast to the reality of the need for time as a frontier for continued economic growth. A key area of focus for this paper is the intersection of time and technology. The philosophy explored in the following section is drawn from social theory writings surrounding autonomy and acceleration in the postmodern age. The obsession with increasing productivity is indicative of the digital era. The idea that the best way to spend your time is by increasing productivity fails to recognize the human within the economic system. As the promises of AV manufacturers continue to saturate the media, it is important to critically evaluate these statements and view them through the structural lenses of modern society, which can present a contrast between promise and reality. This is explored through critical reflections stemming from theories of social acceleration and autonomy.

3 Theoretical framework

This section discusses the way in which theories of social acceleration and autonomist thought can be applied to the space and time within an AV. This framework is structured in view of the relationship between humans and technology. The goal of this framework is to better grasp the social dynamics that influence the way in which technology is fuelled by a continued economisation of time. Aspects discussed are first, the shifting space occupied by labour in the increasingly online mediated sphere, followed by a view into the primarily machine-driven impact of the filter bubble on choice. Flexible capitalism naturalises the disrupted workplace and creates a moral order that is full of dilemma, contradiction and disorder (Chen and Sun 2020). Autonomist social theories relate directly to the intersection of technology and labour, while theories of social acceleration explore the experience of temporality felt in the postmodern economic environment. At this junction, the human world is tied to the socio-economic structure in which we operate. Through determining value from time spent producing commodities, the place of an individual worker can be quantified amongst the inanimate workings of the overall machine of industry. With information being both the focus of consumption and production, producers of information know empirically how to utilise time. They have cut up time; they have broken it into hourly slices. The output changes according to the intention of the hour (Lefebvre 1992). Through wider economic structures, an individual's free time is bought and sold and relied upon to sustain continued growth, both in terms of wider economic growth and individual progression. In the wider structural definition of time as a frontier ripe for exploitation to sustain infinite economic growth, theories of autonomy draw a boundary between economic structure and human reality. The intrusion into social time

is a strong focus of autonomist theory of labour, and the shifting dynamic between technology and time use is a core element.

This theoretical framework combines aspects of autonomist thought with theories of social acceleration to provide an accessible tool through which the shifting temporal dynamics of labour in the contemporary urban environment can be explored. While in this specific case, the emphasis has been placed on the changing time-use when driving is no longer undertaken as a task (and how that new window of time within an AV becomes available), this same framework can be applied to other transitioning spaces within the urban environment. Current urban space is woven tightly together with cyberspace. This disconnection of labour from it is previously cemented physical space, lends itself to research when the lens of time is applied.

3.1 Social acceleration

Social acceleration provides tools to contextualise the experience of temporality at three differing scales. These three scales are also the primary drivers of social acceleration. Beginning with technological acceleration Rosa identifies how the speed of production has been increasing since the industrial revolution, this provides the overview of acceleration on a wide scale (Rosa 2017 p.71). The acceleration of social change is the second key driver. This relates to the feelings of acceleration experienced by society, and it goes hand in hand with David Harvey's theories of space time compression (Harvey 1990). Finally, there is the acceleration of the pace of life. This examines the feeling of the individual regarding the increased potential of life contrasted with the shrinking availability of time (Rosa 2017). The use of these theories when applied to the space and time created by an AV can begin to show the manipulative dynamics that are operating on the user.

In using Rosa's writings on social acceleration as an accompaniment for autonomy, a theoretical framework that explores the factors that impact both time at a socio-economic structural scale as well as at an individual scale is put forward. A clearer view of the forces that operate on the time within the space of an AV is beneficial in critically assessing the impact of technology on the economisation of time. The space of an AV allows for the reproduction of already existing labour dynamics. Temporal entrepreneurship allows individuals to enrich their experience of work time through choices of how best to increase productivity (Chen and Sun 2020). A critical point raised by Rosa shows the contrasting relationship between expectations of consumers regarding technology with their time budgets. "This pattern is also confirmed by the effects of the automobile on time resources: "The possession of a passenger car did change the amount of time spent underway, but not in the direction of less. Instead the acceleration-induced gain in time is invested in more frequent or longer travels, so that in time, budgets the time allotted for transportation seems to be invariant relative to the speed of movement" (Rosa 2017 p.69). This is a valuable perspective as it shows how the time made available by AVs is ripe for consumption via self-defined propensities to increase work productivity.

3.2 Autonomy

Autonomy is the independence of social time from the temporality of capitalism (Berardi 2003). In an essay written in 2009, Franco Berardi, an academic at the forefront of autonomist theory, argues that in the twentieth century, the necessity to accelerate labour time to sustain economic growth first colonised the global space, soon followed by the colonisation of the domain of time external to labour time (Berardi 2009). As previously mentioned, the intrusion into social time is a strong focus of autonomist theory of labour and relates directly to the Marxist labour theory of value. The alienation of workers from the products of their labour has been expanded to the greying of lines between what is labour time and what is free time. While societal structures define free time purely due to the necessary existence of its opposite—work time—the current driving forces of technology have been dissolving the borders between two previously separate spheres of life (Elias et al. 2017). When the metric of self-worth is directly linked to productivity, the time of an individual emerges as a space for commodification done by the owner to themselves. The study of temporalities in the urban environment is relevant as our engagement with spatial dynamics is impacted due to increased engagement with cyberspace. City-wide internet access provides the ability to work anywhere regardless of place or time and has removed the necessity of the physical setting of the workplace. The unalterable permanence and incessant frictionless operation of this dissolution of structural barriers between what is work and what is not are both produced by and a product of technological change (Crary 2014). The limitless growth required by neoliberal social structures ensures that time is exploited as a frontier to sustain this progression. As the need for infinite frontiers eats into the realm of technologically created cyberspace, the realm of space is infinite, yet cyber time is rooted firmly in the finite reality of humanity (Berardi 2019). With these ideas in mind, the context of the AV is appropriate to engage with a contemporary space that facilitates a direct change in time use dynamics. While the AV operates within the urban environment, the realm of cyberspace is omnipresent and thus the user of the AV is existing within cyberspace as they are transported through the urban environment. This constant presence of cyberspace is what allows for the dissolution of the physical boundaries of work and non-work.

3.3 Time within the AV

Crary (2014) argues that the disconnect between time and the need for growth is the reason we are moving ever closer to a 24/7 society that needs to eradicate sleep, as it is an inefficient use of time. Our time is determined through externally imposed and self-imposed societal structures (Adorno and Bernstein 2000). The message supplied by manufacturers of AVs is one of relaxation and luxury, while their control is not over the use of time, their provision of space allows for the potential for oases of acceleration to exist as necessary features for continued social acceleration. The deceleration ideals they put forward and the way they function act as refuelling points for people to temporarily engage with so that during this retreat they can re-energise, upon their return they can continue to engage with acceleration in life (Rosa 2017). Autonomist theory shows that the impact of technology on society is not as it is presented by the manufacturers and drivers of that development, while social acceleration aids us in understanding the forces that are at play within the AV, and their impact on the window of time that the AV facilitates. The disconnect between continued technological progression and human lifestyles can be shown using time as a focal point for study. It is the AV that operates as a key transition window in providing a space for this transition of time-use to be observed.

The visual aid shown in Fig. 1 is intended to contextualise the space within which the AV exists. Within this context of the contemporary urban environment, the presence of cyberspace is a constant. Urban space is within this as city boundaries are dynamic and changing, yet the emphasis on inter connectivity only grows. Within the box of urban space there is a Venn diagram showing two overlapping circles. On the left there is the "Space of non-labour". This is a simplified means of showing spaces of living and leisure that are not tied to the physical place of work. On the right is shown the "Space of Labour". This is intended to represent the physical setting of the workplace. Where the two circles overlap is the space of the AV. The intention of this diagram is to highlight the way in which the AV bridges the gap between the spaces of labour and non-labour. This illustration is a simplified means of highlighting the spatial significance of the AV.

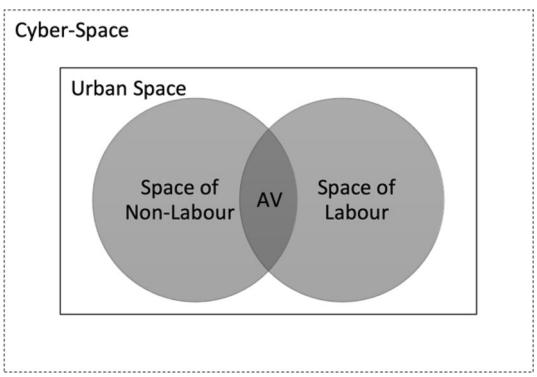

Fig. 1 Visualising the way in which urban space sits within cyberspace. Source: authors' original

The product of the aforementioned issues is evidenced by the ability of big data to exert power over the way humans make choices. The current era of information is defined by the use of big data. These new techniques are rooted in research concerning artificial intelligence and expert systems that have sought to produce machine learning that can computationally and automatically mine and detect patterns, build predictive models, and optimize outcomes (Kitchin 2014). With each different algorithm reaching alternate conclusions, the need for hundreds of algorithms to act upon the same data set is necessary. These algorithms are narrow in their attention and search for specific patterns but are solely inwardly focused and pay no heed to the implications of the outcomes. Autonomy deals with the unintentional outcomes that are created by the use of algorithms to define human behaviour. This was originally described as the "Statisticon" (Neidich 2013), but is more simply referred to as the "filter bubble" by Berardi. The filter bubble reduces future events into probability and predictability by pre-empting future behaviour through the analysis of previous actions, thus removing the possibility of choice. In the context of this framework, it is this pressure of the filter bubble that becomes visible within the space and time of the AV. Difficulty arises when trying to explore the presence of the filter bubble elsewhere, yet within the AV, the predetermined boundaries of time spent within the vehicle, are already in existence. This window into a transition space is a novel approach to viewing changing time-use dynamics. Large amounts of data allow the machine to adapt to the human environment and the necessity of the filter bubble to interpret this data induces living beings to comply with the narrowed expected responses provided by the machine (Berardi 2019). This bio-technical relationship leads to the modification of social structures in a manner determined by autonomous actors. With the predetermined physical boundary of finite space and time within the AV, an appropriate location for research into this impact of technology on choice arises.

Autonomy deals with the embodiment of societally structured failings through forms such as psychological and economic depression and relates their existence to the lack of choice and potential that is passively enforced by current tech-control structures. With subjugation through positive association individuals act on themselves to interiorize power dynamics and then interpret this choice as freedom (Han 2017). This disconnect between techno-linguistic automations and general human intellect is at the core of autonomist theory. With the economisation of time and the inception of MAAS converging within the space of the AV

the lens of time can highlight the social structures that determine such value. Time structures are what primarily perform the necessary translation of systemic requirements into individual action orientations. Because even in a post-traditional society they endow action with normatively binding force, largely stable expectations and an orienting frame that is experienced as if it were a natural fact (Rosa 2017). Progress in technology will continue to accelerate and have significant impacts upon the way humans function in society. Autonomy addresses this speed in relation to the inertia it creates within political governance. The inability for legislation to keep up with technological change creates issues surrounding the direction in which society develops and where that direction comes from. This inertia is also a focus of theories of Social Acceleration put forward by Hartmut Rosa. The way in which the replication of already existing social structure dynamics can be seen to operate on a new window of time and space is well suited to the setting of the AV as the journey taken by an individual creates a finite window for study.

While the presentation of this framework is specific and simplified so as to apply directly to the change of time-use that occurs within an AV, it emphasises the forces that are at play in pre-emptively determining how this time could be used and what drives the choice people make. The intention is for the same framework to be applicable in viewing how time is used in a world where the boundaries between spaces of labour no longer apply to physical space. The urban environment is tied directly to cyberspace and as this facilitates further dissolution of barriers to where labour does and does not take place, the lens of time is an effective tool to use in viewing the increased commodification of life.

4 Discussion

Using a theoretical framework informed primarily by theories of autonomy and social acceleration as a tool, the promises of AV manufacturers can be evaluated and put into perspective under current societal structures. The number of lives that the use of AVs alone would save, for example, is enough to warrant their implementation. However, it is necessary to critically assess the unforeseen social negatives of the implementation of such technologies. The perceived benefits of artificial intelligence, in this case AVs, are warped by the socio-economic structure within which both humans and AVs exist (Cugurullo 2020). Marx refers to this relationship between social interactions and capital, stating that "capital by its nature drives beyond every spatial barrier, the creation of the physical conditions of exchange—of the means of communication and transport—the annihilation of space by time" (Marx and Nicolaus 1981). This continued expansion into the realm of social time is the key focus of this discussion. While AVs do indeed have the potential to create free time that once was occupied in completing another task, the AV does not have the power to determine how that time is used. This discussion will focus on the creation of free time and how it is presented to the consumer, as well as the power dynamics that determine the ways in which that time is consumed. The theoretical framework provides a lens through which the space of the AV can be seen as a space in which the direct transition of time from an occupied state to a commodified state is occurring before our eyes. With this in mind the case of the AV is a novel contemporary example which can highlight the time-use dynamics that exist in the wider social sphere by beginning within an already defined space. By engaging with this space and time of the AV, it can become a stepping stone to viewing the contrast in belief surrounding time-use dynamics in everyday life.

AV manufacturers have no power over their claims that their product will be used as a space for "leisure and relaxation". Instead, they are simply providing a new space; their unique selling point is that the consumer will have time that was once occupied completing the task of driving to do with as they choose. The manufacturers do not determine how the passenger uses their time. The implication by manufacturers that the space will be used for leisure is tied to their need to create profit from selling as many of their products as possible. The creation of new time drives capitalist structures to expand into the new frontier and gain a quantifiable value from that time. With the inception of this newly available time comes a space that can be filled by the new market of the passenger economy. Such a newly formed physical space acts as an ideal location for the current subjugation through saturation (Han 2017) to take place. The acceleration of the pace of life can be contextualised within the AV as the user determines how they choose to use their time, leaning ever more toward labour. The passenger economy is the contemporary example of the Marxian concept that capital drives beyond every spatial barrier. As technology completes a formerly human task, the time once spent on that task becomes valuable. This time is now subject to the actions of postmodern capitalism, to influence actions on a pre-reflexive level, incentivising people to actively choose to spend their time working (Han 2017). While there is indeed a potential for this to become free time, it does not necessarily manifest in that way. If labour politics was once premised on the idea of placing limits on work—reducing hours, resisting speed up, guarding rights and benefits—in today's industrial settings the challenge is to adopt this politics to an environment that fails to recognise work as laborious (Wajcman and Dodd 2017). This promise of creating free time is more quantifiable when considering a city as opposed to an individual. The time savings AVs can bring in terms of traffic flow and congestion are more frequently referenced in the media and

academic research. This wider view of time savings is more tangible for an urban environment, yet, it again fails to recognise the human-centric nature of time.

Finally, the focus is placed upon the impact of external factors on the choice of how time is used within an AV. This insidious choice control is epitomised by Andrew Ure, who refers to "the training of human beings to renounce their desultory habits of work and to identify themselves with the unvarying regularity of the complex automation" (Ure 2006). Here, Ure refers to the point at which the evolution of automation will come to entirely consume the human realm until every moment is used as work time, yet the human believes the opposite is the case. The belief that automation makes us more free, when in fact it makes us less free in terms of time, is one that can be seen more clearly when applying the theoretical framework to the specific case of the AV. In a seminar Foucault (Martin 1988) mentions ideas of "technologies of power which determine the conduct of individuals and submit them to certain ends or domination" this can also be seen in Berardi's discussion of the effects of the filter bubble. This reduction of possibility into predictability through probability causes the time within an AV to be used not as free time but as work time. When humans choose to use their time in such a way that ensures it is not free time, their decision is being directly influenced by a social structure that places emphasis on productivity above all else. In the technologically driven world of today, the immaterial and non-physical forms of production are what determine the course of capitalism (Han 2017). The manipulation of choice due to socio-economic structure results in the potentially beneficial impacts of AVs manifesting themselves as negatives. In the case of the AV, the newly available space and time becomes a window of value made ripe for consumption while further disconnecting the individual from the products of their labour. The implementation of AVs has a huge potential to make the world a better and safer place, but when the current socio-economic system has the overt power to determine how time is used, we will become even less free as innovation continues.

With the undoubted continuing development of AV technology, it is of paramount importance that we critically examine the social implications of such technologies. The areas of contention arise more clearly when viewed through the wider lens of the social sciences. By viewing the contrasts between the promises of manufacturers and how time use really manifests itself, the human issues of AV implementation can be explored. With the specific case of the AV in mind, when discussing the implications this technology will have, the AV exists as a novel space to facilitate continued commodification of time. The value created by the implementation of the AV comes not from the cost of usage paid by the user, but in the value of the labour and data created within the space the AV provides. The accompanying theoretical framework provides a tool to engage specifically with the commodification of time within the AV, yet it can be a translatable tool to view the myriad ways that labour dynamics are changing as they operate more in the realm of cyberspace. The disconnection of labour from a physical space allows for labour to blend with every hour of the day, creating difficulty in knowing, where it begins and where it ends. We need to pay attention to the human issues that are accelerating due to AV use, such as the dissolution of borders between what is work and what is not, as well as the difficulties arising from the communications breakdown and lack of value alignment between autonomous and human actors. The benefits AVs provide for city-wide time and individual time are at odds with each other. This area of study will only grow in importance.

5 Conclusion

This piece seeks to contribute a tool in the form of a theoretical framework that aids in highlighting the continued commodification of time that takes place as labour moves more prominently into digital format and takes place in cyberspace. While this tool is, in this piece, specifically directed at the space and time made available by the AV, it is translatable to contemporary labour dynamics. The AV is a defined space and time, whereas other areas in which this same commodification of time take place are more difficult to define. With the internet accessible at any second, the significance of defining, where labour begins and ends is of paramount importance. While the AV is a specific case in which this dissolution of barriers between labour and non-labour can be shown, the same dissolution is taking place in all aspects of labour that exist in cyberspace. Contemporary neoliberal structure encourages the consumption of time through incentivising the individual to make this choice, where labour as value creation in a digital world is enforced via positive association. This subjugation of time via encouraged participation (Han 2017) is a defining factor in viewing the use of time within an AV and how labour is changing in the digital age. The implications of AVs come to the fore when considering the future of humans and society. By accepting their functional benefits for a more connected and safer urban environment without question, we take the risk of being oblivious to future social issues their use will create. This need for interdisciplinary study is emphasised well by Iyad Rahwan—"the consequential choices that we make regarding the integration of AI agents into human lives must be made with some understanding of the eventual societal implications of these choices" (Rahwan et al. 2019: 483).

This paper has sought to actively engage with the contemporary example of AVs and time use. By acknowledging that AVs do have the potential to create free time, but

that they do not determine how that time is used, the issues around the economic consumption of time can be addressed. The belief that we are more free due to AVs stems from the way their manufacturers promote and market their use; however, manufacturers have no concern for their product once it enters the social environment. This fails to recognise the socio-economic conditions within which AVs will operate. The commodification of data has led to non-transparent marketplaces that utilize human belief and trust to continue to generate continuous growth. The reduction of the barriers between work and life becomes a method for creating a continuous process of production within which each human is an oblivious piece.

This conclusion expands to incorporate aspects related to choice determination. AVs become a prime environment for viewing the potential implications of the filter bubble and its interaction with newly available free time. The AV itself has no impact on the way in which the time spent within it is used, yet its existence serves a valuable purpose of allowing this new time to be quantified and exploited. The societal conditions within which the human and the AV both operate show that the requirement for time use to create value is impacted by the reduction of possible choice to predictable choice. If this free time spent within an AV does not manifest itself as free time, then we may believe that we are more free when we are indeed less free in terms of time. Through this lens, we see that beliefs related to freedom can be skewed to adopt goals that serve a wider economic function that is not financially or socially beneficial to the individual. This is an area that has been neglected in research to this point. Before these AVs are in widespread use, it is of paramount importance to critically examine the complex problems they create for humans within an urban environment and how they will continue to perpetuate already existing consumption dynamics. Such problems are created by an over-reliance on engineering to provide solutions to human problems without engaging with the systemic factors that are constantly operating on the individual. By viewing the same issues through the lens of the social sciences, a more proactive and rounded approach can be taken. The changing dynamics of labour and time use are a complex issue, and it is imperative that it is explored thoroughly to address the potential negative social outcomes of AVs before these negatives become a reality.

While AV technology is progressing quickly, it is only a small part of a far larger group of novel technologies. The creation of level 5 automation will send shockwaves throughout the world, but these innovations are minor compared to the prospect of future breakthroughs in AI research, such as artificial general intelligence and superintelligence (Yigitcanlar and Cugurullo 2020). The issues that impact society stem from disconnects in the communication between humans and machines. These shortcomings will be amplified by an order of magnitude in the context of artificial general intelligence and superintelligence. Before prospects become realities, the chaotic and unstructured network of human life needs to be urgently explored in relation to AI and AVs by combining the machine and human fields. In viewing this relationship through the lens of time, a novel contrast can be drawn between the finite nature of lived human time and the need for infinite frontiers in the current technological world.

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Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

Acheampong R, Cugurullo F, Gueriau M, Dusparic I (2021) Can autonomous vehicles enable sustainable mobility in future cities? Insights and policy challenges from user preferences over different urban transport options. Cities 112:103134

Adorno T, Bernstein J (2000) The culture industry, 2nd edn. Routledge, London, pp 162–170

Berardi F (2003) What is the meaning of autonomy today?. [online] transversal texts. Available at: https://transversal.at/transversal/1203/berardi-aka-bifo/en. Accessed 15 May 2020

Berardi F (2019) Futurability. Verso, London

Berardi F, Smith J, Cadel F, Mecchia G (2009) The soul at work. Semiotext(e), Los Angeles

Bertoncello M, Wee D (2015) Ten ways autonomous driving could redefine the automotive world. [online] www.McKinsey.com. Accessed 14 Jan 2022

Chen J, Sun P (2020) Temporal arbitrage, fragmented rush, and opportunistic behaviors: the labor politics of time in the platform economy. New Media Soc 22(9):1561–1579

Cohen T, Stilgoe J, Stares S, Akyelken N, Cavoli C, Day J, Dickinson J, Fors V, Hopkins D, Lyons G, Marres N, Newman J, Reardon L, Sipe N, Tennant C, Wadud Z, Wigley E (2020) A constructive role for social science in the development of automated vehicles. Transp Res Interdiscip Perspect 6:100133

Crary J (2014) 24/7. Verso, New York

Cugurullo F (2020) Urban Artificial Intelligence: From Automation to Autonomy in the Smart City. Front Sustain Cities 2:38. https://doi.org/10.3389/frsc.2020.00038

Cugurullo F (2021) Frankenstein Urbanism, Eco, Smart and Autonomous Cities, Artificial Intelligence and the End of the City. Routledge, Taylo and Francis Group, Abingdon
Dowling R, McGuirk P (2020) Autonomous vehicle experiments and the city. Urban Geogr 41:1–18
Duarte F, Ratti C (2018) The impact of autonomous vehicles on cities: a review. J Urban Technol 25(4):3–18
Elias A, Gill R, Scharff C (2017) Aesthetic labour. London: Palgrave Macmillan UK: Imprint: Palgrave Macmillan, pp 3–49
Fleming K, Singer M (2019) Energy implications of current travel and the adoption of automated vehicles. [online] Golden, Colorado: National Renewable Energy Laboratory, p.6. https://www.nrel.gov/docs/fy19osti/72675.pdfAccessed 14 Jan 2022
Friman M, Fujii S, Ettema D, Gärling T, Olsson L (2013) Psychometric analysis of the satisfaction with travel scale. Transp Res Part A 48:132–145
Gairola R, Roth M (2019) Cyber zones: digital spatialities and material realities across Asia. Asiascape 6(1–2):4–16
Gripsrud M, Hjorthol R (2012) Working on the train: from 'dead time' to productive and vital time. Transportation 39(5):941–956
Han B (2017) Psychopolitics: neoliberalism and new technologies of power. Verso Books, London, p 28
Harvey D (1990) Between space and time: reflections on the geographical imagination1. Ann Assoc Am Geogr 80(3):418–434
Hochschild A (1997) When work becomes home and home becomes work. Calif Manage Rev 39(4):79–97
Intel Newsroom (2017) Intel at SXSW: artificial intelligence will change lives | Intel Newsroom. [online] Available at: https://newsroom.intel.com/news/intel-sxsw-artificial-intelligence-will-change-lives/#gs.witwwu. Accessed 4 May 2020
Janelle D, Hodge D (2000) Information, place, and cyberspace. Springer Berlin Heidelberg, Berlin, pp 341–356
Julsrud T, Denstadli J (2017) Smartphones, travel time-use, and attitudes to public transport services. Insights from an explorative study of urban dwellers in two Norwegian cities. Int J Sustain Transport 11(8):602–610
Kitchin R (2014) Big data, new epistemologies and paradigm shifts. Big Data Soc 1(1):2
Krafcik J (2020) Waypoint—the official Waymo blog: Waymo is opening its fully driverless service to the general public in Phoenix. [online] Waypoint—the official Waymo blog. https://blog.waymo.com/2020/10/waymo-is-opening-its-fully-driverless.html. Accessed 14 Jan 2022
Lanctot R (2017) Accelerating the future: the economic impact of the emerging passenger economy. Autonomous Vehicle Service. [online] Strategy Analytics. Available at: https://newsroom.intel.com/newsroom/wp-content/uploads/sites/11/2017/05/passenger-economy.pdf. Accessed 4 May 2020
Lefebvre H (1992) Rhythmanalysis. Bloomsbury Academic, London, p 57
Litman T (2019) Autonomous vehicle implementation predictions: implications for transport planning. [online] Victoria Transport Policy Institute. Available at: https://www.vtpi.org/avip.pdf. Accessed 20 Apr 2020
Lyons G, Urry J (2005) Travel time use in the information age. Transp Res Part A 39(2–3):257–276
Marx K, Nicolaus M (1981) Grundrisse. foundations of the critique of political economy, 18th edn. Vintage Books, New York, p 526.
Martin L, Gutman H, Hutton P (1988) Technologies of the self: a seminar with Michel Foucault, 1st edn. The University of Massachusettes Press, Amherst
Metz D (2008) The myth of travel time saving. Transp Rev 28(3):321–336
Mobility C (2018) Coalition for future mobility expands membership advocating for autonomous vehicles legislation. [online] Prnewswire.com. Available at: https://www.prnewswire.com/news-releases/coalition-for-future-mobility-expands-membership-advocating-for-autonomous-vehicles-legislation-300606683.html. Accessed 24 Apr 2020
Neidich W, Blom I (2013) The psychopathologies of cognitive capitalism. Archive Books, Berlin
Rahwan I, Cebrian M, Obradovich N, Bongard J, Bonnefon J, Breazeal C, Crandall J, Christakis N, Couzin I, Jackson M, Jennings N, Kamar E, Kloumann I, Larochelle H, Lazer D, McElreath R, Mislove A, Parkes D, Pentland A, Roberts M, Shariff A, Tenenbaum J, Wellman M (2019) Machine behaviour. Nature 568(7753):477–486
Rosa H, Trejo-Mathys J (2017) Social acceleration. Columbia University Press, New York
Shapiro A (2017) Between autonomy and control: strategies of arbitrage in the "on-demand" economy. New Media Soc 20(8):2954–2971
Sheller M, Urry J (2000) The city and the car. Int J Urban Reg Res 24(4):737–757
Sivak M, Schoettle B (2015) Road safety with self-driving vehicles: general limitations and road sharing with conventional vehicles. [online] Ann Arbor, Michigan: The University of Michigan, Transportation Research Institute, p.6. https://deepblue.lib.umich.edu/handle/2027.42/111735. Accessed 14 Jan 2022
Stilgoe J (2017) Machine learning, social learning and the governance of self-driving cars. Soc Stud Sci 48(1):25–56
Taeihagh A, Lim H (2018) Governing autonomous vehicles: emerging responses for safety, liability, privacy, cybersecurity, and industry risks. Transp Rev 39(1):103–128
Taiebat M, Stolper S, Xu M (2019) Forecasting the impact of connected and automated vehicles on energy use: a microeconomic study of induced travel and energy rebound. Appl Energy 247:297–308
Thompson C (2019) The 3 biggest ways self-driving cars will improve our lives. [online] Business Insider. Available at: https://www.businessinsider.com/advantages-of-driverless-cars-2016-6?r=US&IR=T. Accessed 19 Mar 2020
Trommer S, Kolarova V, Fraedrich E, Kröger L, Kickhöfer B, Kuhnimhof T, Lenz B, Phleps P (2016) Autonomous driving: the impact of vehicle automation on mobility behaviour. [online] Institute for Mobility Research, p.10. https://www.researchgate.net/publication/312374304_Autonomous_Driving_- _The_Impact_of_Vehicle_Automation_on_Mobility_BehaviourAccessed 14 Jan 2022
Ure A (2006) The philosophy of manufactures, or, an exposition of the scientific, moral, and commercial economy of the factory system of Great Britain. Routledge, London, p 15
Volvo Cars (2022) 360c – A new way to travel | Volvo Cars. [online]. https://www.volvocars.com/intl/v/cars/conceptmodels/360c. Accessed 14 Jan 2022
Wajcman J, Dodd N (2017) The sociology of speed, 1st edn. Oxford University Press, Oxford, p 114
Wang B, Loo B (2018) Travel time use and its impact on high-speed-railway passengers' travel satisfaction in the e-society. Int J Sustain Transp 13(3):197–209
Watts L, Urry J (2008) Moving methods, travelling times. Environ Plan D Soc Space 26(5):860–874
Waymo (2018) Waymo—Waymo. [online] Available at: https://waymo.com/. Accessed 20 Aug 2019
Yigitcanlar T, Cugurullo F (2020) The sustainability of artificial intelligence: an urbanistic viewpoint from the lens of smart and sustainable cities. Sustainability 12(20):8548

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