Papers

Charting a path for cities in the Second Machine Age with or without the car: A focus on the human experience

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Abstract Two major components of technological change, innovations in transport and the automation of human labour, have been shaping and will continue to shape the built environment in the years to come. The coming decades are expected to see a steady increase in automation across all industries. Cities and regions will experience a transition from today's experimentation with semi-autonomous vehicles towards a future of fully autonomous vehicles. The Second Machine Age, a period of history centred on the automation of human cognitive functions, will transform cities by automating many aspects of daily life that generate the traffic patterns we experience today. How are urban areas to adapt to change with such far-reaching potential? Cities will first need to understand the impacts of this transformation and should respond by redoubling efforts to improve the human experience on multiple fronts. There will be an urgent need to build equitable environments and also creatively reuse infrastructure. Many urban areas may ultimately shift the focus away from transport as a defining feature of place.

Keywords: *autonomous vehicles, driverless cars, artificial intelligence, automation, technology, transport*

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INTRODUCTION

Technology has a long track record of reshaping the built environment. Throughout the course of the 20th century, innovations in transport technology aligned with the mechanisation of human labour have dramatically altered the American landscape. The car, powered by cheap fuel and public policy, helped to transform American cities into dispersed and often sprawling urban areas. From the turn of the 20th century to the 1930s, the usage of city streets changed from places mixed with pedestrians, vendors and horse-drawn vehicles to a zone dominated by the car. Car ownership skyrocketed and cities sprawled, many to encompass over two to three thousand square miles.[1] Today our urban areas are defined by interconnected networks of highways that feed both suburb and city with a steady flow of people and goods. The car is

now a critical force of urban design, as evidenced by the prevalence of car parks and structures and the wide roads that feed modern development.

In addition to transport technology, the mechanisation of labour has also played a role in the transformation of place. During the 20th century and continuing into the 21st, rural communities have been hollowed out by a process driven in part by the mechanisation of agriculture. From the middle of the 20th century to the late 1980s, agricultural production in France more than doubled, over a shrinking surface area powered by a workforce only three-quarters its former strength — with similar changes also occurring in America.[2] Population in rural areas has declined while jobs and people have moved to urban centres.[3] This movement has been facilitated by steady declines in the price of transportation. Transportation costs for manufactured goods declined by 90 per cent over the course of the 20th century.[4]

Just as technological innovations and mechanisation reshaped rural America, many futurists predict that automation through artificial intelligence and advances in robotics (the 'Second Machine Age'[5]) will transform urban areas throughout the coming decades of the 21st century. Predicting the future is notoriously difficult; many possible paths can be envisaged, since technological innovations are deeply intertwined with complex economic and social systems. One innovation by itself might effect change in one way, but combined with another innovation the future outcome may be very different.

Two key drivers of urban and rural change in the 20th century, transport innovation and the mechanisation of human labour, are poised to accelerate in the 21st century, in step with the accelerating growth of information technology. In light of the impact that transport and mechanisation have had in the past, the exponential rise of autonomous vehicles, artificial intelligence and robotics is likely to have a significant combined impact on our urban areas.

A future transformed by technology, automation and fully autonomous vehicles could be one where the car is not a focal point of urban design as it is today. This shift may take decades, and in the short term, the mixture of autonomous vehicles and driver-assisted cars may result in increased traffic. Real efficiencies in traffic may not be realised until the 2040s to 2060s when fully autonomous vehicles are fully adopted.[6] Additionally, the automation of human labour and knowledge work through artificial intelligence, along with new communication technologies, may reduce the need for people to move long distances on a frequent basis. With current technological trends offering up a variety of alternative futures requiring periods of transition, how are cities to chart a path forward to plan for the potential of disruptive change to the built environment? The most promising answer resides in the importance of creating places and designing infrastructure that puts people first and accounts for negative externalities.

Driverless cars are one component of a future that will be increasingly automated through artificial intelligence and robotics. This automation has the potential to provide many benefits such as reducing pollution, accidents and the cost of transportation.[7] The technology also has the potential for unintended outcomes. The rush towards an autonomous future will create tremendous wealth but also leave many behind. Even today, democracies around the world are experiencing shifting political and economic realities directed by those removed from the benefits of an increasingly automated and interconnected global society. Futuristic new transport technologies under development such as drones, autonomous vehicles and the Hyperloop will require new infrastructure.

Transport infrastructure with the sole focus on automated transport will have negative impacts on pedestrians and disadvantaged individuals. The negative impacts of new transport systems could end up mirroring the 'destruction of entire communities' and dislocation of disadvantaged populations caused by the construction of the US Interstate Highway system in the mid-20th century.[8]

ALTERNATIVE FUTURES: THE CASE FOR THE DIMINISHED IMPORTANCE OF PERSONAL MOBILITY

Is it possible to envisage a transport system with fewer cars on the road than there are today? It seems at first like a counterintuitive thought. Many cities in the United States have experienced significant periods of growth that coincided with the adoption of the car. That growth also meant more cars on the road throughout much of the 20th century. Figure 1 shows the growth of vehicle miles driven in the United States yet also documents the subsequent 'peak' of vehicle miles travelled (VMT) in June 2005.

To accommodate increasingly crowded roads and the demand to reach cheaper land on the fringes of urban areas, the United States built an average of around 9,500 miles of public roads per year since 1923.[10] These roadways connected growing suburbs with central business districts, shuttling workers to and from workplaces to modern, cost-efficient housing. The relationship between centres of employment and residential communities is still strong today, but is ripe for disruptive change. In the current decade, commuting to work constitutes approximately 28 per cent of all person vehicle miles travelled (VMT) and 39 per

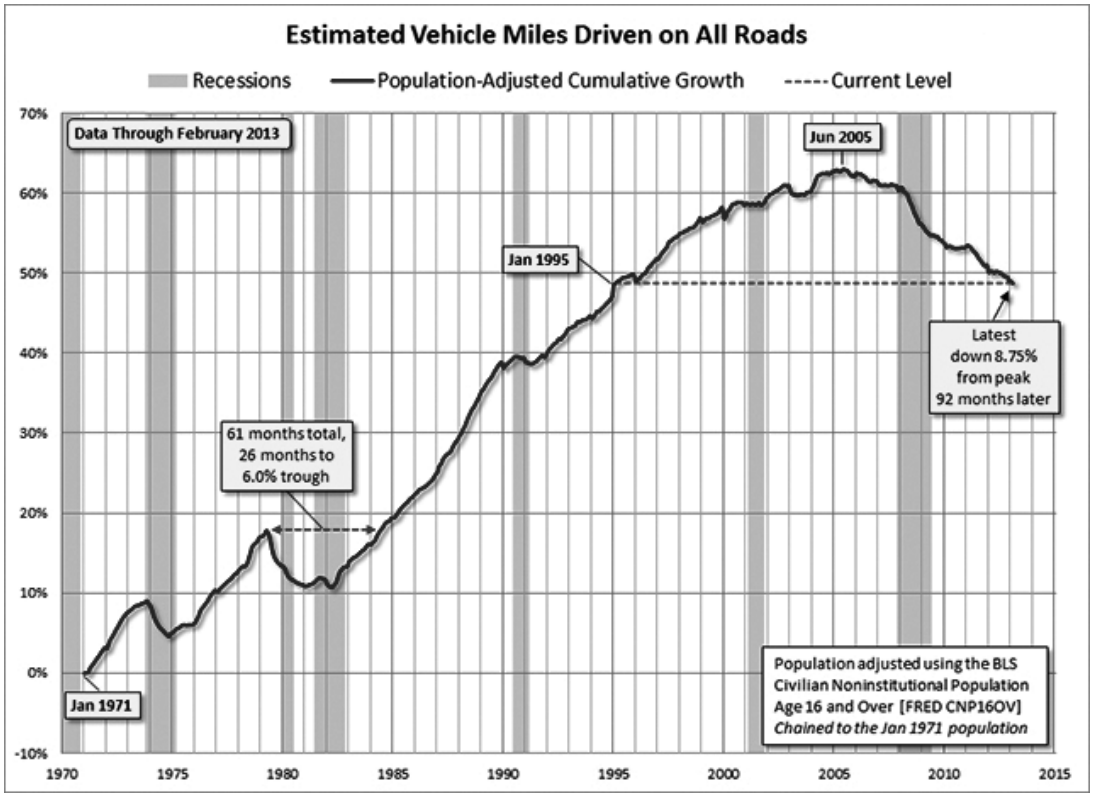

Figure 1: Estimated vehicle miles driven on all roads[9]

cent of all transit person miles of travel.[11] Will this relationship carry forward in the 21st century, as it has in the previous one?

There are two key trends that may disrupt traditional relationships between suburb and city, commuter and work that have shaped urban form for the last century. These trends are the automation of knowledge work through artificial intelligence (augmented by innovations in communication technology) and the rise of autonomous vehicles, a technology that integrates artificial intelligence into the mechanisation of labour (robotics). By itself, autonomous vehicle technology could possibly increase the number of vehicles on roads by reducing barriers to entry, which is why traffic may increase in the short run. Barriers such as vehicle ownership and the ability to drive could be removed with the advent of fully autonomous vehicles. Yet when examined within the context of future technological advances such as artificial intelligence and communication technology, there is the potential for a reduction in overall demand for distance travel.

Artificial intelligence: Artificial general intelligence (AGI), whereby machines can fully replicate all aspects of human cognition, is still in the realm of science fiction. The artificial intelligence (AI) advances of today centre around the rapid progress in the creation of algorithms and computer systems that can simulate narrow aspects of human cognition. AI is the theory and development of computer systems able to perform tasks that normally require human intelligence. The forefront of today's artificial intelligence technologies, as outlined by Deloitte University Press, are 'cognitive technologies' such as machine learning, natural language processing, speech recognition, computer vision and other algorithms that are becoming increasingly 'better at performing specific tasks that only humans used to be able to do'.[12]

It is forecast that around half or more of today's jobs could be automated in 10–20 years through advances in computerisation and artificial intelligence algorithms.[13] Researchers have documented the decline of jobs involving routine through being replaced by sophisticated algorithms. MIT researchers Andrew McAffee and Erik Brynjolfsson aren't convinced that new technologies will create more jobs than they destroy.[14] McAffee and Brynjolfsson believe that the automation of knowledge work and mechanisation of labour are allowing the economy to essentially do more with less. This is part of what they term the 'Second Machine Age', where work that was once the sole product of human strength and ingenuity is increasingly supplanted by algorithms and robots.

The transition of the photography industry is often cited as an example of how digitisation and automation can reduce the need for human labour. The transition from film media to digital disrupted traditional supply chains, shrinking demand for human labour by eliminating the physical distribution process. At its peak, Kodak employed nearly 145,300 people along with a large distribution network employing many more people. Today's digital photography is often conducted through smartphones, where photography is just one component of these multifaceted devices. Consumers no longer develop film or rely on supply chains to provide film for their next holiday. Instead, consumers can instantly post and edit photographs online using applications like Instagram and Facebook. The companies behind these apps can now capitalise on the efficiencies of digital distribution over digital networks. Instagram had a team of 13 employees when it was sold to Facebook for $1b.[15] Figure 2 shows how productivity

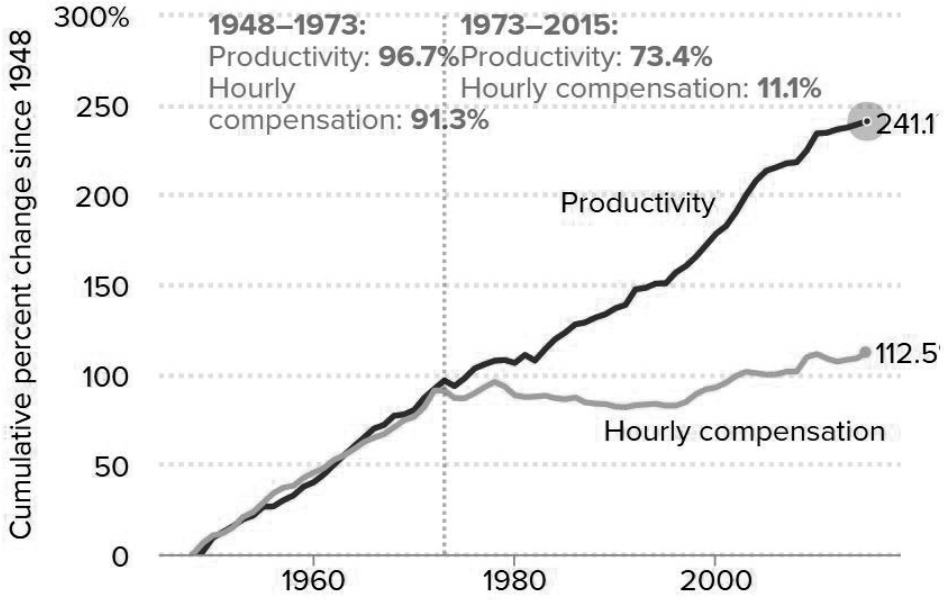

Figure 2: Disconnect between productivity and a typical worker's compensation, 1948–2015[16]

continues to rise but compensation for human labour has stagnated since around 1980, as demonstrated by this chart from the Economic Policy Institute.

Digital technologies have the potential to exacerbate the dissonance between productivity and employment. As more routine cognitive work is automated, there could be increased demand for the services of people with high-functioning skills, people that can utilise technology to complete routine work but can also think comprehensively about how to generate solutions to complex problems while managing human interaction.[17] Artificial intelligence advances are already changing the economics of employment, and future impacts could be even more dramatic than they are today. Just as mechanisation altered the rural landscape of American in the 19th and 20th centuries, the Second Machine Age has the potential to transform urban and rural areas in the future.

If technology does indeed create fewer jobs than it destroys, traditional commuting patterns will decline. With or without the potential reduction of the future workforce, new communication technologies such as virtual reality and the mobile computer could reduce the need for remaining workers to commute to their jobs. Additionally, fewer jobs could mean that there is less of an incentive to spend money to own, or even rent, a car. The ease and effectiveness of future communication technologies may mean that it's more cost-efficient and just as effective to commute virtually rather than physically.

The rise of autonomous vehicles: Autonomous vehicles could provide efficiencies to the transport system, reducing the amount of space needed for roadways and parking. Additionally, the technology has the potential to provide a new personal mobility business model, encouraging a pay-as-you-go transport system. Figure 3 shows how varying levels of vehicle autonomy might reduce costs associated with transport.

Car ownership is expensive, and estimates point to cars sitting idle for

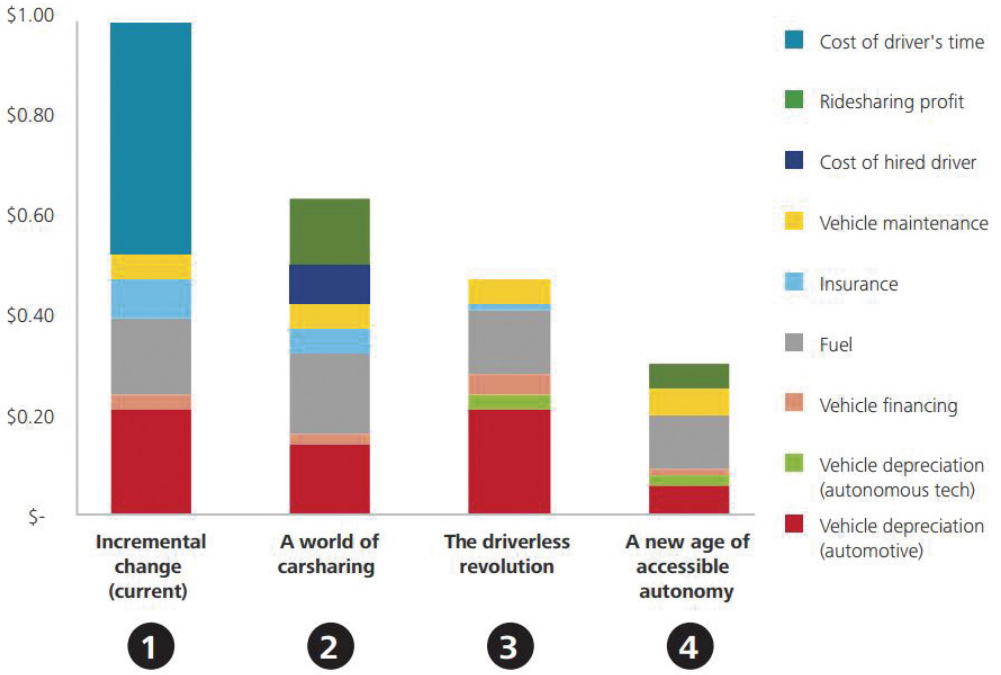

Figure 3: Cost per mile breakdown for future states of autonomous vehicles[18]

around 95 per cent of the day.[19] A transport system that is fully autonomous and that operates around a rental or 'sharing' business model would allow for greater efficiency in land use. Today it is increasingly easy and affordable to simply rent a car service rather than own a car. Future advances in autonomous vehicle technology may make renting a car, and taking public transport, more affordable and safer than it is today. Autonomous vehicles and mass transit could circulate through a transport network almost continuously, picking up and dropping off people as needed. When demand for autonomous vehicles falls during any one period of time, vehicles could store themselves at various sites strategically distributed throughout a city.

These trends point to a possible future that includes fewer cars used for commuting to places of employment and trips associated with daily life. Statistics already show that driving to work is down about four percentage points from 2006 to 2013 among urban 25 to 29-year-olds.[20] As automation increases, it is possible that the need to use a car will decrease as various purposes for travel will become superseded by automated processes. This 'taxonomy of travel' consists of a variety of tasks involving transportation, many which have the potential to be automated in the future, with or without human occupants.

A future of widespread automation will raise philosophical, economic and social questions that will need to be addressed by policies and also the design of the built environment. An automated future with declining car traffic and car ownership has the potential to create a built environment that excludes some people while liberating and benefitting others. How might cities, which have defined humanity for millennia, respond to an economic system that is increasingly automated? How can the design of cities celebrate humanity while creating an environment that enables the people to jointly interact with an automated world? Cities have

been the platform for idea exchange and collaboration for millennia and must flexibly adapt to respond to an economic system that is increasingly automated. Cities of the future might actually take cues from medieval European cities of the past, re-creating streets that are for pedestrians first and for transport second.[21]

RECOMMENDATIONS — WITH OR WITHOUT THE CAR

When one considers autonomous vehicles, artificial intelligence and other technological innovations, it is easy to envisage a sleek, futuristic world of large, whirring infrastructure. In a world that is increasingly automated, however, it will be more important than ever to create places that embrace and celebrate what it means to be human. Benchmark examples of human-scale walkable urbanism are visible all over the word, such as the city blocks of Washington, DC, active public spaces like Bryant Park in Manhattan, and many of the medieval streets in European cities that author Allan B. Jacobs references in his book 'Great Streets'.

Our physical environment operates concurrently with a growing digital world. The digital world, which has already been under development for several decades, increasingly mirrors our physical world through its social networks, economic systems and three-dimensional representation of real and imagined places. The future traffic of economic exchange likely lies in this world, leaving our physical world to become increasingly ordered by automation and digital technologies — yet our cities can still be defined as places built for people rather than automated systems. In the 20th century new transport technologies transformed much of the way we live and work, despite at times creating environments that were devoid of life and presented barriers to pedestrian movement.

It may take decades for the effects of autonomous vehicles and artificial intelligence to be realised on the built environment. In light of the complexities of planning for alternative futures and the transitional periods in between, cities can — through design and public policy — focus on a broad commitment to improving the human condition at all levels. Humanity can potentially benefit greatly from an automated future, yet there is also the chance that automation could wreck cities by putting efficient automation before people. Cities must be at the forefront of flexible regulations that prioritise people first. In the Second Machine Age, cities can maintain relevance in a driverless future by focusing on what they do best: celebrating humanity and bringing us back to the reality of the physical world in a visceral and irreplaceable manner.

There are four areas where urban planning efforts can be focused to encourage a meaningful human environment:

1. Cities should human-scale urbanism by promoting the development and sustaining of pedestrian-focused environments.
2. Technology can enable smarter cities, but technology and automation should be as much as possible 'behind the scenes', with people as the priority.
3. Cities should be places that are inclusive and affordable to all people.
4. Cities should operate as sustainable systems that exist in symbiosis with the environment.

CELEBRATE THE HUMAN SCALE

Pedestrian-only and multimodal zones: A recent article on 'Imagining the Driverless City' by the Urban Land Institute underscores that autonomous vehicles could be a boost to walkable

urbanism.[22] In light of research regarding an automated future, it is critical that autonomous vehicles enhance walkable urbanism as one aspect of celebrating human-scale environments. Autonomous vehicle traffic could be managed in ways that today's traffic cannot. Faculty at Carnegie Mellon University are envisaging urban environments that can transform into pedestrian-only streets based on the time of day without the need for bollards or other vehicular barriers.[23] Barcelona is creating pedestrian-only zones to reduce traffic congestion and conflicts and to reduce pollution/emissions in the city centre.[24] Many pedestrian-only zones created in American cities in the 1970s ended up failing, but as American cities densify their populations and mix uses, such zones could provide relief for urban residents.

Along with emphasising walkable urbanism, cities should promote multimodal travel on urban streets — integrating public transit, bicycles and other modes of transport with autonomous vehicles. Cities can look back to the active streetscapes of the 19th century, while using technology to promote pedestrian safety. Cities such as Stockholm and Amsterdam have been successful in bringing back bicycles into the urban fabric. In an automated future, we can use technology to make streets friendlier to pedestrians and cyclists. In its planning for the future, Stockholm is promoting a dense and mixed-use urban environment that reduces the need to travel, while also connecting districts with multimodal linkages.[25]

New uses for parking: Dr Kara Kockelman of the University of Texas at Austin estimates a loss of around 50 per cent of demand for parking spaces and the removal of seven out of eight cars on the road.[26] Surface parking in Houston's Central Business District makes up over 21 per cent of existing land use.[27] How might this land be re-envisaged in the future? Adding more parks to impermeable surfaces might help with stormwater runoff, urban ecology and human wellness, but might not be entirely feasible for privately owned land. Certainly though, new development in these parcels could be constructed to standards that promote ample permeable surfaces and green roofs. Along with surface parking, parking structures could also be reimagined for new uses. The Savannah College of Art and Design's Atlanta campus has explored the addition of micro housing units to above-ground parking garages in their SCADpad concept.[28] Before you retire for the evening in your micro-unit you might also want to grab a beer with friends on the parking structure's rooftop beer garden, such as Berlin's Klunkerkranich Roof Top Bar.

'Mixed-use' cartways: Fully autonomous vehicles might not only reduce the need for parking but also the size of our cartways — the space on roads occupied by vehicles. The University of Texas at Austin has simulated efficient traffic enabled by autonomous vehicles, which could mean less space is needed for cars.[29] These efficiencies, combined with the overall reduction in need for physical travel in the Second Machine Age, mean less traffic on the street.

Wide city streets could be narrowed, adding more space for landscape elements or even new buildings in some circumstances. In overbuilt cities like Detroit, green infrastructure or multi-use paths could take the place of some roadways and unused parcels of land. The city of Indianapolis has created a cultural trail, taking road right-of-way to create a robust pedestrian and bike route that connects major cultural destinations in the city.[30] For cartways over 100ft wide, it might be beneficial to investigate new active or passive uses. Depending on

widths, residential and retail uses could potentially share space with a diminished cartway in key locations in both urban and suburban areas. In dense cities like DC, oversized roadways may be used for additional development or retail, like Las Ramblas in Barcelona. Micro-units, or high-tech apartments with small footprints, might be good candidates for infill in cartways with excess space.

TECHNOLOGY 'BEHIND THE SCENES'

Highway construction in 20th-century American cities resulted in improving access to urban and rural areas but also caused destruction and division within existing communities. Potential efficiencies gained by autonomous vehicles should not repeat the mistakes of the past. Streets should not be realms devoted entirely to the constant flow of traffic, but should be flexible spaces that first and foremost encourage pedestrian activity with vehicular traffic as secondary. As noted above, technology also enables the flexibility of space, so that the balance of pedestrian or vehicular traffic could be managed depending on time of day or demand. In the end, technology — whether it be through smart city sensors or autonomous vehicles themselves — can work to provide safe spaces that put people first but also provide space for the efficient flow of vehicular traffic.

The Second Machine Age could result in a decrease of human-occupied traffic and an increase in fully autonomous traffic, shuttling goods around a city in vehicles with no human occupants. Autonomous traffic in the future could also include drone delivery, as currently envisaged by Amazon. In this case it would be important to ensure that fully autonomous traffic does not interfere with human activities within urban areas. Urban areas might consider zones for fully autonomous traffic that are separated from places that celebrate human interaction. This robotic network would need to feed into and connect seamlessly with human-centred places.

INCLUSIVE AND AFFORDABLE

The advent of the Second Machine Age has the potential to exacerbate inequality, as machines take on an increasing array of cognitive tasks that were once the purview of humanity. The design of communities as mixed-income places can help promote our common humanity and help mitigate the tendency to bifurcate society into an elite group and a large, disenfranchised population. Of course, design is not the only answer to solve the issue of inclusivity and income inequality — public policy will play an important role. The White House Executive Office of the President National Science and Technology Council Committee on Technology has released a report on preparing for a future of automation.[31] The report touches on the potential economic effects of automation and recognises that more work will need to be done in generating policies that promote equality and mitigate the negative effects of automation on the workforce. Countries such as the Netherlands are exploring programmes like Universal Basic Income that intend to replace traditional safety nets with a guaranteed income.[32]

Autonomous vehicles have the potential to reduce the cost of transport and free up land in urban areas for new uses, which could put downward pressure on the cost of land and housing. Although this would not be a positive development for homeowners in the future, it could mean a future with increased access to affordable housing. Aside from freeing up land in cities to be transformed from parking into housing, autonomous vehicles could also provide cost-effective access to low-density and undeveloped

suburban land. This might have the effect of exacerbating sprawl, but in the Second Machine Age there will be a premium on the types of human interaction that urban areas can provide. Cities should focus on providing access to affordable housing while continuing to develop walkable, pedestrian-focused communities in cities and suburbs.

SUSTAINABILITY AS A BASELINE

Something pervasive in this brave new world of automation should be a built environment that takes sustainability seriously. Future advances in renewable energy, combined with efficiencies provided by automation and artificial intelligence, have the potential to create urban environments that are less wasteful and destructive to the environment than today's cities. Cities should not just expect this to happen by itself and should promote walkable urbanism, renewable energy and green infrastructure. Creating sustainable cities that use less energy and turn infrastructure into green space can also support urban resiliency, which is critical as cities discuss how to adjust to climate change.

In a future where automation is pervasive, cities can be a haven for humanity; it is important therefore that they should be healthy places to live that can support growing populations. Today Beijing and Shanghai are enshrouded in smog and Paris is clouded by diesel emissions. Battery-powered autonomous vehicles could mitigate this problem, just as the creation of the car eliminated the problem of horse waste in urban areas in the 20th century.[33]

CONCLUSION

Driverless car technology has made leaps and bounds since DARPA's Grand Challenge in 2004. It's still unclear how many years it might take to have Level 4 autonomous vehicles as the dominant vehicle type within our transport system. Likewise, advances in artificial intelligence continue to make inroads on tasks that were once the domain of human cognition. The future is likely one that is increasingly automated by robotics and artificial intelligence. Trends point to a potential future with less vehicle traffic with human occupants, altering the traditional dynamics of how we envisage a city.

Despite clues presented by technological, demographic and economic trends, however, it's still unclear whether or not fully autonomous vehicles will arrive en masse in ten years or 40 years and whether automation and new technologies will reshape our urban areas in the same way that mechanisation transformed the world in the 19th century. Despite these uncertainties, cities can begin to prepare for a driverless future by celebrating what defines the greatest cities in the world: walkable urbanism, inclusivity and sustainability, all supported by technological advances.

Automation might blur Euclidean boundaries of segregated uses for living, working and playing, as economic and social activities continue to shift to digital landscapes. In such a future, cities can stay relevant by celebrating and encouraging the type of development that goes back centuries. In the Second Machine Age, cities can act as respites from a digital world that may be increasingly beyond the control of any one individual. The urbanism of the future should mirror our most cherished places of the past while integrating technology in a way that is unobtrusive and beneficial to people of all economic and social backgrounds.

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