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The Disruptive Mobility and the Future of our Neighbourhoods

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Building Better Homes, Towns and Cities National Science Challenge

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Abstract

This working paper provides a resource for urban designers, planners and policymakers in New Zealand concerning disruptive mobility and its potential impacts on our cities. Based on the literature review, the report aims to map future mobility in cities. Disruptive mobility may create a set of new opportunities and solutions to tackle the pervasive private car usage in our cities that relates to the following issues: safety, car ownership, parking demand, vehicle kilometres travelled, congestion and capacity, development patterns, infrastructure design, efficiency and carbon emissions, transportation equity, and the quality of the built environment.

This working paper endeavours to define a meaning for disruptive mobility and sheds light on its different dimensions, including automation and the electrification of cars, as well as shared mobility. To do so, it will first investigate the characteristics of the automation of cars as the first dimension of disruptive mobility. The electrification of cars will be considered as the second dimension of disruptive mobility; yet aligns with the automation. Then, it will review how the utilisation of smart technologies such as mobile Apps may significantly change our transportation from private car usage to shared mobility. This working paper will then investigate the potential positive and adverse impacts of disruptive mobility on urban form and the built environment in the future.

Table of Contents

1. Introduction

Different innovative and smart technologies are transforming our cities. Disruptive mobility, including automation, electrification and sharing mobility, is one of the most important innovative technologies that is shaping our cities, including the built environment and our everyday lives. Disruptive mobility that once featured in science-fiction movies and books is now becoming a reality on roads around the world, including New Zealand. While the potential impacts of disruptive mobility on cities, including urban form, design, planning, and development, seem significant, disruptive mobility and its impacts have not been well investigated and understood in urban planning and design. Through the existing literature, this working paper highlights how disruptive mobility potentially will reshape our cities and the built environment in New Zealand. It also reviews the opportunities and threats that the deployment of disruptive mobility may generate in the future.

There is a pervasive misperception that the electrification and automation of vehicles are two entirely separate technologies developing simultaneously. Automation and electrification are not interdependent trends; however, there are a number of notable synergies existing between these two emerging technologies (Underwood, Marshall, & Niles, 2014). This paper considers these two technologies as an integrated process. Thus, Electric Autonomous Vehicles (EAVs) will be the next generation of vehicles (Roemer, Jones, Marino, Hyland, & Southwood, 2017). The integration of both technologies is crucial to attaining a sustainable transport system in the future, since, as this paper shows, automation without electrification and shared mobility may adversely impact our environment.

EAVs will win widespread acceptance when they are shown to work efficiently and affordably (Skinner & Bidwell, 2016). This working paper will investigate how the new smart technology is fundamentally changing our ownership economy into a new form of the sharing economy. This paper argues that self-driving cars should not be investigated as a new technology separate from other social and economic trends and which will only change our transportation system in cities; rather, it should be considered as a component of a wider social, economic and technological transformation that is essentially changing our everyday lives based on a new smart technology (Barnes & Turkel, 2017, p. 4). This paper explains why the capacity of EAVs in combination with the smart economy will transform our travel behaviour based on a new form of smart shared mobility.

This working paper aims at mapping the key themes and subject of discussion for future research concerning mobility in cities. This paper supports the development of future research with more specific case studies and tests. For example, this working paper reviews the literature that suggests that Shared Electric Autonomous Vehicles (SEAVs) will reshape the built environment, particularly by decreasing the demand for parking. It shows how the new social, economic and technological changes provide new opportunities to reshape and reuse urban space for people instead of cars. SEAVs can assist in reclaiming invaluable land that is currently allocated for public parking, as well as for streets and urban centres. The reclaimed land can be used to provide urban services and amenities in places where a shortage of land is perceived as the main obstacle to generate high quality urban spaces.

2. Current transport context

> "A good transportation system minimizes unnecessary transportation." —
> Lewis Mumford - *Highway and the City* (1958)

Since the invention of the automobile in the late 19th century, the built environment has been transformed to facilitate the movement of cars (Zimbron-Alva, 2016). Wells (2013, p.144) names the last century, the "automobile century". He argues that steam engines facilitated the collective transportation by train and ships in the 19th century and in this context, "people's location relative to railroad lines profoundly shaped their everyday mobility options – particularly for travel over shorter distances" (Wells, 2013, p. 144). The invention of the automobile, particularly after the introduction of Ford's assembly line, dramatically altered urban transportation by facilitating individual commuting within and beyond cities. The pervasive usage of cars as the dominant mode of travel significantly transformed cities' built environments and their residents' everyday lives.

Fox (2016, p. 2) argues that "when we talk about urban sprawl, we talk about cars". However, suburbanisation initially emerged around railways. Cars have provided easy, fast, and affordable access to different parts of cities that mostly lack direct rail service, including outer suburbs. Using cars has generated a "new scale of local distance" within cities. They shorten the time of residents' commuting by putting residential neighbours, amenities and businesses fare from the city's Central Business Districts (CBD) (Wells, 2013). This new scale of local distance has justified further green development and land release beyond urban boundaries. "Cars made sprawl in its current form possible, and suburban development has ensured the continued dominance of the automobile through design centred nearly entirely around its needs. That design has taken a toll on both humans and the environment" (Fox, 2016, p. 2). The hegemony of cars in our cities has resulted in low-density urban development; a low quality built environment, highly consumptive development, particularly fertile land.

Cars also dominate our streets and public spaces (Gehl, 2013). Newman and Kenworthy (2015, p. 201) argued that

> the contemporary cities have been reshaped around the car, with major shifts in every conceivable aspect of city life as residents became more and more dependent on private motorized mobility. The non-motorized modes that had provided mobility in cities for about 8,000 years became more and more marginalized along with the public transit systems that had shaped cities for a hundred years before the car's dominance.

Following the hegemony of cars across the world, cities have not only adapted cars to the varied uses of urban spaces including streets, but by prioritising the movement of cars, they have removed all perceived obstacles to the movement of cars such as pedestrians. The prioritisation of cars in cities has eliminated public life from our urban spaces, including city centres and streets (National Association of City Transportation Officials, 2017).

Based on the new technological achievements in the second decade of the 21st century, there is an anticipation of the arrival of Autonomous Vehicles (AVs) in cities. AVs may provide a historic opportunity to reclaim our public spaces and life by correcting the mistakes of a century of urban planning and urban design (National Association of City Transportation Officials, 2017).

3. Driverless cars as an emerging technology

AVs or driverless cars are currently being tested in many countries around the world including New Zealand, and the expected timeline for commercial sales is shortening (Barnes & Turkel, 2017; Hörl, Ciari, & Axhausen, 2016). Several major companies, including Google, Audi, Nissan, Tesla and BMW, have announced their plans to offer their driverless cars in the global markets within the next decade.

> In a recent study done by IHS Automotive, more than 54 million self-driving cars will be on the road by 2035; by 2050, every car on the roads will be autonomous. The AV market is predicted to grow to $42 billion by 2025 and to reach $77 billion by 2035, with 25% AVs of all cars. (Noyman, Stibe, & Larson, 2017a, p. 2)

The public sector is attempting to facilitate the usage of AVs as an emerging technology that is potentially able to respond to current urban transportation problems (Simoudis, 2017). The US Department of Transportation has unveiled new policy guidance, anticipating widespread deployment of AVs in future (Zhang & Guhathakurta, 2017). The New Zealand Government also encourages the testing of AVs in New Zealand in order to facilitate our early adoption of this beneficial technology. To do so, the New Zealand Government (2014) and the New Zealand Transport Agency (2017) have provided the several plans and guidelines to companies which aim to test their driverless cars on New Zealand roads.

3.1. What is a ‘driverless car’?

AVs or driverless cars are receiving a great deal of media and academic attentions. AVs are alternatively signified as self-driving vehicles or driverless vehicles, and they are the new generation of equipped vehicles with smart technologies. These vehicles are able to drive themselves (SAE, 2016). This is made possible through the use of various sensors, transmitters, and computing-technologies. However, while the terms ‘automated vehicles’ and ‘autonomous vehicles’ are used interchangeably, these terms are not the same.

1) Automated vehicles are capable of driving themselves, yet they depend extensively on artificial hints in the environment. These external inputs are often referred to as Vehicle-to-Infrastructure (V2I) (Maitipe, Ibrahim, Hayee, & Kwon, 2012).
2) Autonomous vehicles are capable of handling uncertainty and compensate for system failure without external intervention (Antsaklis, Passino, & Wang, 1989).

Although the term 'autonomous vehicle' is frequently used, as of yet no vehicle exists that fulfils the criteria of a fully autonomous vehicle. The V2I technologies are widely being installed to support automated vehicles. Washburn (2014) argues that V2I technologies will be installed in AVs until full autonomous vehicles can be used safely. Therefore, this working paper considers autonomous vehicles and automated vehicles on a spectrum, rather than two binary technologies.

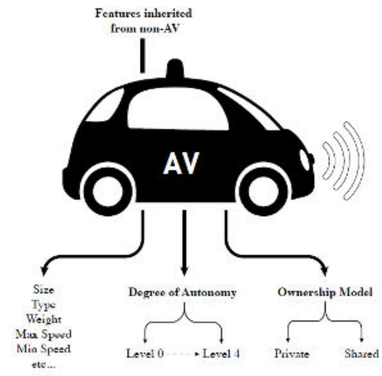
3.2. A brief history of driverless cars

The story of AVs and their potential benefits begins nearly a century ago. The earliest documented case of AVs dates back to the 1920s (Weber, 2014). After a century, this technology has materialised. It is anticipated that AVs will profoundly transform society, cities, and built environments. Some researchers predict that cities should expect AVs on their roads by 2025 (Azmat, Kummer, Trigueiro, Gennaro, & Moser, 2018), while others suggest that vehicles will reach full-autonomy before this time (Martinez & Viegas, 2017). Original Equipment Manufacturers (OEMs)[1] also believe that AVs will become available to consumers globally in the coming decade (Simoudis, 2017).

[1] Original Equipment Manufacturers are major companies whose goods are used as components in the products of another company, which then sell the finished item to users. In the automobile industry, 14 OEMs are the original producers of vehicle components (Simoudis, 2017).

3.3. Different characteristics of Autonomous Vehicles (AVs)

Automation of Vehicles will create an entirely new mode of transportation within the next decade (Skinner & Bidwell, 2016). This new mode is named 'smart transportation'. However, smart transportation is not limited to the deployment of AVs; it also includes the expansion of smart infrastructure and smart economy.

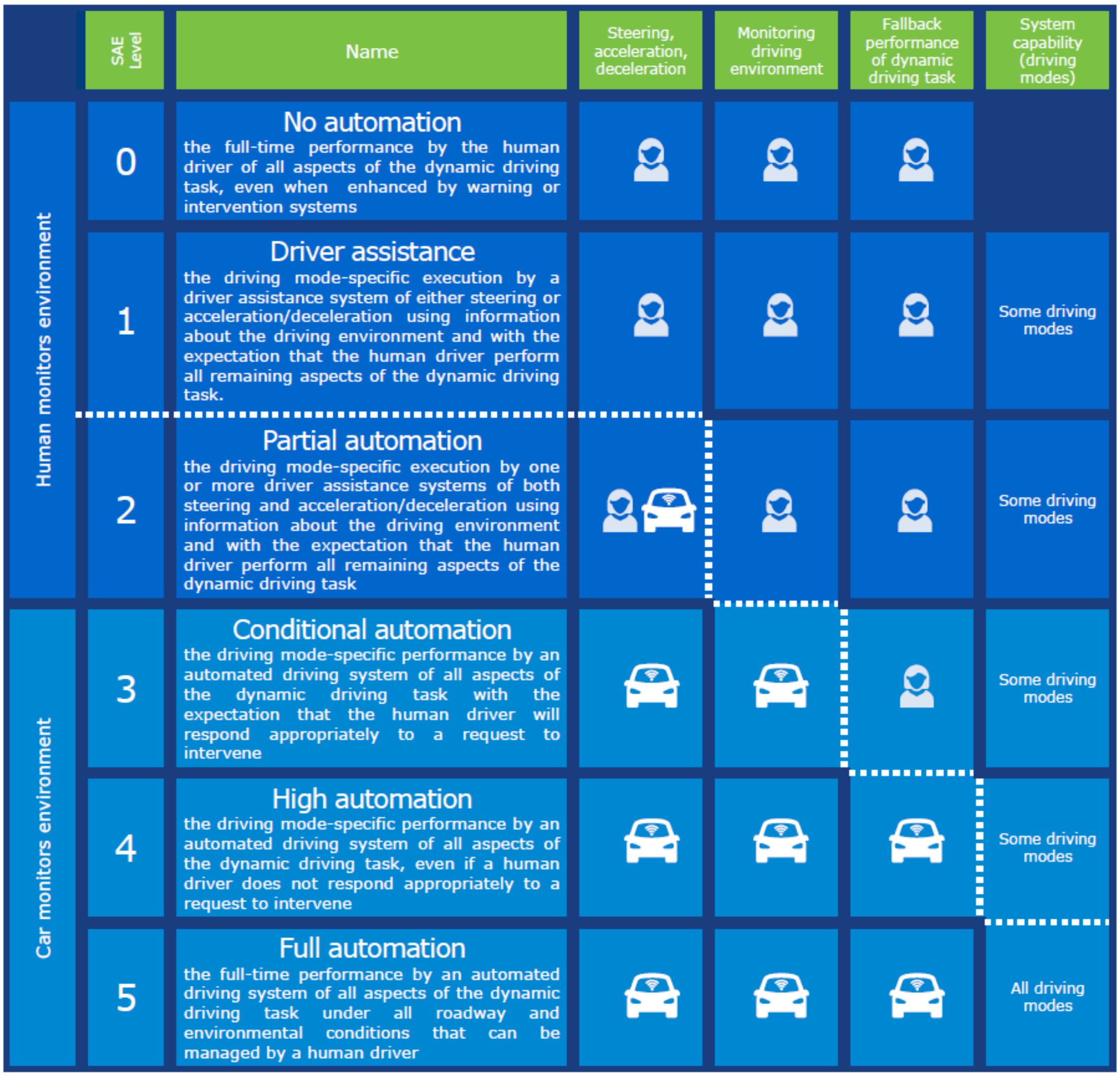


AVs can be categorised based on their different characteristics. However, some of these characteristics, such as their features, sizes, and types, are inherited from the current non-AVs. Some other characteristics of AVs are embedded in smart technology such as the level of automation and smart economy.

Autonomous vehicles also vary in size; that is, autonomous technologies can be applied to cars, light vans, trucks, and heavy freight (Skinner & Bidwell, 2016). To narrow down the area of this working paper, the impacts of small size autonomous vehicles (cars) that can be used by families for their everyday commuting in cities will be investigated.

3.4. Level of car automation

There are different levels of car automation resulting in different types of AVs on the road. The capabilities of autonomous technologies have been generally categorised into five separate stages which decrease the responsibility of the driver, with the final stage of 'full-autonomy' (See table 1). Full-autonomy is defined as "the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver" (SAE, 2016, p. 2).



	SAE Level	Name	Steering, acceleration, deceleration	Monitoring driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human monitors environment	0	**No automation** the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems				
Human monitors environment	1	**Driver assistance** the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.				Some driving modes
Human monitors environment	2	**Partial automation** the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task				Some driving modes
Car monitors environment	3	**Conditional automation** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene				Some driving modes
Car monitors environment	4	**High automation** the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene				Some driving modes
Car monitors environment	5	**Full automation** the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver				All driving modes

Table 1: the different steps of car automation (SAE, 2014)

Each step towards car automation requires significant improvements in autonomous technology to decrease the level of drivers' responsibility gradually. The automated driving system is the last step. The different levels of car automation will be gradually developed, tested, and marketed over the next decade. This process will provide an opportunity for urban planners, urban designers, and policy makers to prepare cities to embrace this new technology (Anderson et al., 2014).

However, it is not likely to be until 2030 that full-autonomy will be widely used. The different AV levels will be adopted and pervasively used in our cities by 2025 (Clausen, 2017). The predicted user ratio matches the existing model of individual car ownership, which has been developed based on the number of cars sold in the market. However, to more accurately measure the adoption rate of AVs, researchers suggest new methods that consider socioeconomic transformation and smart technological achievements in the assessment. The following are two suggested methods to study the adoption rate:

1) Proportion of AVs on the road,
2) Proportion of vehicle kilometres driven (VKT) by AVs.

Due to the emerging sharing economy[2] that will potentially change pervasive car-ownership, these methods can be used to evaluate the AVs adoption in the future. Based on the adoption ratio, Bansal and Kockelman (2016) estimate that up to 87% of vehicles in the United States will be AVs by 2045. Arbib and Seba (2017) estimate that by 2027, 95% of passenger vehicle kilometres travelled (VKT) in the US will use AVs.

Many studies have argued that AVs will make vehicle commuting more convenient that may increase in total vehicle travel. The implementation of specific demand management strategies, such as higher road user fees, will be necearry to manage the demand. For example, Trommer et al. (2016) estimate that AVs are likely to increase total vehicle travel by 3 to 9% by 2035. However, other researchers believe that the emerging smart economy will boost smart shared mobility using AVs that will result in decreasing total vehicle travel (see table 2).

Increases Vehicle Travel	Reduces Vehicle Travel
• Due to more convenient and productive travel, passengers can rest and work in their AVs thus reducing travel time costs and encouraging people to use vehicle travel and travel longer distances. • AVs provide convenient vehicle travel to non-drivers such as people too young, old, disabled, impaired, or otherwise lacking a driver's license.	• More convenient shared vehicles will allow households to reduce total vehicle ownership and use. • Increase in vehicle ownership and operating costs will further reduce private vehicle ownership. • Self-driving transit vehicles will improve transit services.

[2] Sharing economy is comprehensively defined in section 4

• AV taxis will travel more for empty backhauls. • Due to more convenient and productive travel, automobile-dependent locations will become more attractive, which may accelerate urban sprawl in future. • By reducing traffic congestion and vehicle operating costs, AVs will add to vehicle travel.	• Reduced pedestrian risks and parking demands will make urban living more attractive. • Reduce some vehicle travel, such as cruising for parking spaces.

Table 2 – The positive and negative impacts of AVs (Litman, 2017)

3.5. AV as a disruptive technology

AVs, like any other technologies, generate new opportunities and also challenge our cities. The "future is not guaranteed and history shows we could easily end up with the opposite. Traffic and emissions could skyrocket, 'robo-routes'[3] – walls of autonomous vehicles with few gaps, could divide communities, people could be relegated to inconvenient and unpleasant pedestrian bridges, and high-priced, inequitable mobility could supplant transit" (National Association of City Transportation Officials, 2017). Automation technology represents a potentially disruptive, yet beneficial, change to our urban transportation system. This new technology has the potential to influence vehicle safety significantly, congestion, and travel behaviour. However, researchers have mostly investigated automation transportation, including AVs, and its potential benefits in general and its capacities to solve our urban problems in particular.

Like any other invention in history, AVs may create new problems and challenges in the future if they are used without an initial preparation (see table 3).

[3] Autonomous mobile robots need good models of their environment, sensors, and actuators to navigate reliably and efficiently.

Challenges
• Increasing costs: the deployment of AVs requires further automation equipment, services, and maintenance, and new smart infrastructure. • Increasing risks: the usage of AVs may create new risks, such as system failures that can be less safe under certain conditions. • Security and Privacy: there are some concerns about the misuse of AVs. They can be used for criminal and terrorist activities such as bomb delivery. They are vulnerable to information abuse (hacking), and their features such as GPS tracking and data sharing may raise privacy concerns. • Increased vehicle travel: with increasing travel convenience and affordability, AVs will increase vehicle travel in our cities. • Increased external costs: increasing vehicle travel will increase external costs such as parking, crashes and air pollution. • Expanding economic equity: the pervasive use of AVs may expand the existing socio-economic inequality in our cities. Economically disadvantaged groups may not be able to afford the expense of AVs. • Reduced employment and business activity: AVs will eliminate some jobs such as taxi drivers from the labour market. • Misplaced planning emphasis: the over-emphasis on the AVs' capacities as solutions for urban transportation may discourage urban decision makers from implementing more cost-effective transport solutions such as the improving walking, cycling infrastructure, public transport, and other demand management strategies.

Table 3 – The challenges of AVs (Litman, 2017)

AVs promise many benefits such as improved safety, reduced congestion, and lower stress for car occupants, among others. Yet, authorities that include central and local governments will need to adapt existing rules and regulations or provide new regulative tools to ensure the full compatibility of AVs with the public’s expectations regarding safety, conveyance, legal responsibility, and privacy (ITF, 2015).

This paper investigates the most important benefits of AVs that may persuade authorities, including central and local governments, to deploy AVs in the future (see table 4).

Benefits
• Reduced driver stress: AVs will reduce the stress of driving that allows passengers to rest and work while travelling. • Reduced driver costs: AVs will reduce travel costs by reducing the need for drivers for taxis and commercial transport. • Mobility for non-drivers: AVs will provide independent mobility for non-drivers such as senior residents, disabled people, and young children. • Increased safety: AVs may reduce accident risks by omitting the human factor. • Increased road capacity: AVs will increase the capacity of the existing roads and streets by allowing platooning (vehicle groups traveling close together), narrowing lanes, reducing intersection stops, and reducing congestion. • More efficient parking: AVs will drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs. • Increase fuel efficiency and reduce pollution: AVs will increase fuel efficiency and reduce pollution emissions since most AVs will be electric vehicles. • Supports shared mobility: AVs in combination with the smart economy will facilitate car-sharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings for people.

Table 4 – The benefits of AVs (Litman, 2017)

4. Sharing economy

Around 80 years ago, Joseph Schumpeter, one of the most influential economists of the 20th century, predicted that competition from “the new commodity, the new technology, the new source of supply, the new type of organization” would be more relevant than perfect competition. He described this as competition which “strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives” (Schumpeter, 2002, p. 3). His prediction has certainly come true due to smart technologies.

Many researchers have used different terms to conceptualize this phenomenon, such as the gig economy, the platform economy, the access economy, and collaborative consumption (Chandler, 2016). However, a PeW Research Centre survey revealed that 73% of participants in the US were unfamiliar with the term ‘sharing economy’ although 72% had used a shared and on-demand online services (Smith, 2016, p. 1).

The underlying premise of the sharing economy is that an individual only pays for access to goods or services for a duration when required (Sanchez, 2016). Bardhi and Eckhardt (2012, p. 881) argue that ownership is no longer the ultimate expression of consumer desire. However, this approach leads to an access-based economy rather an economy of sharing. Sharing implies joint ownership of an asset, whereas access indicates no transfer of ownership, just simple access to the asset (Richardson, 2015; Sanchez, 2016).

The sharing economy is defined in several ways due to the very different business models that a sharing economy comprises (Codagnone & Martens, 2016). The term ‘sharing’ is misleading because it does not signify the economic drivers and capital gains that are the fundamental elements of these business models. Thus, other confusing terms, such as collaborative consumption, peer-to-peer businesses, or the access economy, are often used to describe the sharing economy (Bardhi & Eckhardt, 2012).

Regardless of the ambiguity surrounding the term ‘sharing economy’, its business models are increasingly used around the world. The sharing economy and its business models allow individuals, groups, communities, and companies to make money from their underutilized assets such as their cars (Frenken & Schor, 2017). The sharing economy provides a platform in which physical assets can be shared as services in the market. Currently, different services are provided based on the sharing economy and its models such as in hospitality and dining, mobility and transportation, labour, delivery, short-term loans, and retail and consumer goods (Yaraghi & Ravi, 2017). In 2014, Hawksworth and Vaughan (2014), researchers at PwC analysed 10 different industry sectors and estimated that over the next six years, the five major sharing economy sectors – peer-to-peer lending, online staffing, peer-to-peer accommodation, car sharing, and music and video streaming – would generate more than 50% of total global revenue, up from their current share of the market at only 5 %.

4.1. Characteristics of the sharing economy

The characteristics of the sharing economy should be considered as a component of economic interactions. Supply and demand are immediately in contact through an online sharing platform. Based on the sharing economy, the supply side, including companies, communities, and individuals, can directly offer their services and products in the market with the underlying aim of benefiting from their underutilized assets (Sundararajan, 2016). Thus, one of the main characteristics of sharing economy models is the better utilization of existing assets including, but not limited to, physical assets, human skills, and finance.

From the demand side, the sharing economy reduces transaction costs and opportunity costs that attract potential users or consumers who may need the offered services and products, want to pay less for the service, and do not want to own the asset (Heinrichs, 2013). The sharing economy reduces the transaction costs inherent in other economic systems by providing a direct connection between the service supplier and the consumer through online platforms.

4.2. From the sharing economy to shared mobility

The reutilization of unused value is the core of the sharing economy and it business models. Unused value refers to the time to which products, services, and skills lay idle. This idle time is generally perceived as a wasted value that the sharing economy endeavours to reutilize based on its business models (Atcheson & Green, 2012). For example, the average car is unused 90% of the time (Eagle & Dahl, 2015). This idle time of wasted value is a significant opportunity to address the mobility problem in our cities. Over the last decade, several online sharing platforms have been developed around the world to facilitate shared mobility such as car-sharing, car-renting, and car-pooling.

An online sharing platform mostly works as a multi-sided open market, where individuals, communities, and firms can join the market from both the demand and supply side of the platform. This definition of the sharing economy as an economic activity more closely includes its different business models. The sharing economy's business models mostly provide the right of access to the required goods, skills, and services that remain in the ownership of another subject (Cohen & Kietzmann, 2014). Therefore, these economic transactions do not include property ownership per se; rather, they provide access to a good, skill, or service for a limited time. In this context, using the concept of access instead of the transferal of ownership may assist in better defining the characteristics of the sharing phenomenon, without losing its essential economic dimension (Gori, Parcu, & Stasi, 2015).

The different business models can be arranged based on the sharing economy:

- Individuals offering services through their own assets: a person offers his/her assets and skills in the market as a short-term service to other people, communities, and companies such as Yourdrive, and MyCarYyourRrental.
- Private companies offering their services: private firms offer their assets and spaces in the market and rent them for short periods. Often these assets are not required or are underutilized during a particular time. Some private companies share their assets frequently based on a pre-defined contract. Examples are the different car-sharing services, such as Car2Go or City Hop.

- Peer-to-peer marketplaces: these sharing platforms assist companies, communities, or individuals to sell their goods, services, and skills to other companies, communities, or individuals.
- Peer-to-peer labour services: these sharing platforms allow potential workers to offer their workforce and skills for a specific task in the labour market for a short time. A good example is Uber drivers.

5. EAVs and shared mobility

Both the promise of EAVs and the gradual shift to the sharing economy open the pathway to shared mobility. In many ways, this transformation has already started.

5.1. Traditional car ownership

Around a billion cars are driven on the roads of the world (Golub & Johnson, 2017). Over the past century, Fordism has provided an opportunity for a large number of people to own private cars. The widespread car ownership has reshaped our everyday lives. Car ownership has facilitated people's movements, and also expanded their access to residences, work, and recreation in the cities. Meanwhile, pervasive car ownership has significantly affected the physical environment of the cities through the allocation of a large amount of urban land to meet the insatiable requirements of car mobility, such as streets, roads, highways, parking spaces, and petrol stations (Dong, 2018; Newman & Kenworthy, 2015).

However, more recently, private car ownership has gone down for the first time in history, particularly in the US (Noyman et al., 2017a). Newman and Kenworthy (2015) argue that declining car ownership will eventually lead to the end of automobile dependence. They recognise several factors involved in this decline in car ownership, including the increasing price of fuel, increasing traffic congestion, the improvement of public transport, and the densification of cities. In addition, disruptive mobility, including the automation of vehicles, the electrification of vehicles, and MaaS will gradually change people's travel mode choice, and subsequently, reduce pre-existing car dependence in cities. However, while there is a common expectation that car ownership and car dependency will continue to decline in the coming year, transport planners remain primarily focused on addressing urban mobility issues based on old solutions or proposing incremental changes to existing infrastructure (Noyman, Stibe, & Larson, 2017b).

5.2. Traditional shared mobility

Shared mobility refers to the shared use of a mode of transport (Ronald et al., 2017). It includes the shared use of a vehicle or bicycle that enables users to have short-term access to transportation modes on an 'as-needed' basis (Shaheen, Cohen, & Zohdy, 2016; Stocker & Shaheen, 2017). There are different models of shared mobility services such as car-sharing, bike-sharing, scooter-sharing, ride-sharing, car-renting, and on-demand mobility services (Stocker & Shaheen, 2017). Shared mobility services have been growing rapidly around the world. In 2014, there were over 4.8 million carsharing members worldwide and over 100 000 vehicles, a 65% and 55% increase, respectively, from two years prior (Shaheen, 2016). On-demand mobility services, like Lyft and Uber, are also growing at a rapid pace. In 2016, Uber claimed that more than 50 million riders worldwide had taken more than 2 billion rides since its founding in 2009 (Meyer & Beiker, 2018). Shared mobility may generate several positive outcomes, namely, improving the utilisation of a vehicle, lowering the number of vehicles that need to be produced, decreasing single occupant vehicles on the roads, and possibly reducing the total number of vehicles on the streets and roads (Fagnant & Kockelman, 2014).

5.3. Current state of shared mobility models

This section reviews the existing business models of shared mobility that are used by the major shared mobility providers. These business models have been developed based on the sharing economy business models. Stocker and Shaheen (2017) investigated the different shared modes that can be encompassed under each shared business model. The three most common shared business models include 1) Business-to-Consumer Service Models, 2) Peer-to-Peer Service Models, and 3) For-Hire Service Models.

This following section will investigate how these shared business models impact on the shared mobility modes.

1) Business-to-Consumer (B2C) service models:

The Business-to-Consumer (B2C) service model is one of the most common business models used by on-demand mobility service providers. The mobility service providers are companies that typically own a fleet of vehicles (Stocker & Shaheen, 2017). They provide mobility service for their consumers to access their vehicles through membership and/or the predefined usage fees (Shaheen et al., 2016). B2C shared mobility service models may include shared modes: 1) car-sharing, and 2) microtransit.

Car-sharing: There are different definitions for car-sharing. Car-sharing is a term used to refer to the short-term use of a vehicle. Car-sharing allows consumers the benefits of a private vehicle while discharging them the costs of purchase and maintenance. Users can access vehicles owned by car-sharing companies as part of a shared fleet on an on-demand basis (Shaheen et al., 2016). Also, users can hire a car from individuals who rent their cars in unused time. Several online sharing platforms have been developed that assist both suppliers and users by offering their cars in the on-demand mobility market.

Business-to-consumer (B2C) car-sharing service models include roundtrip and one-way car-sharing. Accordingly, service users can purchase the mobility service based on an initial or yearly membership fee, and predefined usage fees such as the distance (kilometre or mile), or time (hours), or a combination of both distance and time (Shaheen et al., 2016). In roundtrip car-sharing, the vehicle must be returned to the original location, while in one-way car-sharing, the car can be parked anywhere within a designated service area, allowing point-to-point trip making. The roundtrip business model generally relies on both membership fees and fees per kilometre and hours driven. Typically, petrol and insurance costs are included in the pricing scheme. One-way or point-to-point car-sharing is a relatively recent type of car-sharing, emerging more prominently since 2012 (Shaheen & Cohen 2012).

The OEMs are exploring the capacity of B2C as business models to participate in the mobility market beyond their traditional roles as major car producers. They plan to provide a mobility service based on car sharing and B2C business models, in addition to their roles selling the vehicles (Clausen, 2017). The B2C business models will assist the OEMs to benefit from renting their cars while providing mobility service for the consumers who cannot afford to purchase a vehicle (Simoudis, 2017).

5.4. Microtransit or Mobility as a Service (MaaS)

Microtransit services can be defined as a mobility service in which a vehicle may route deviate to serve on-demand requests, point deviate to visit pre-defined stops in paths defined by requests in real-time, or serve unscheduled stops along a predefined route (Stocker & Shaheen, 2017). Microtransit services may offer a fixed route, a fixed schedule like traditional public transport, or a flexible route with on-demand scheduling.

2) Peer-to-Peer (P2P) service models:

In P2P service models, companies provide a platform and resources needed for the exchange and control transactions among individual owners and consumers. P2P service models differ from B2C models because the company usually does not own any of the assets, such as vehicles, being shared under a P2P model. This section reviews four personal vehicle sharing ownership models: 1) Fractional ownership; 2) Hybrid P2P- traditional car-sharing; 3) P2P car-sharing; and 4) P2P marketplace.

A- Fractional ownership

In the fractional ownership model, multiple individuals lease a vehicle owned by a third party. Each of these individuals takes on a portion of the expenses for access to the shared service. This could be facilitated through a dealership and a partnership with a car-sharing operator, where the car is purchased and managed by the car-sharing operator. This provides the individuals with access to vehicles that they might otherwise be unable to afford (e.g., higher-end models), and can also offer additional income sharing when the vehicle is rented to non-owners. An example of this model is Audi Unite, which launched in Stockholm, Sweden in 2014 and offers multi-party leases between two to five individuals.

B- Hybrid P2P-traditional car-sharing

Similar to roundtrip car-sharing, individuals access vehicles by joining a company that owns its car fleet, which also includes privately-owned vehicles. Insurance is typically covered by the company during the period of rental of both company-owned and peer-owned vehicles.

Members access vehicles through either a direct key exchange or operator-installed technology that allows remote vehicle access (Stocker & Shaheen, 2017).

C- <u>P2P car-sharing</u>

This model of car-sharing assists private vehicles owners to make their vehicles available for shared use by an individual or member of a P2P car-sharing company. The P2P car-sharing company typically provides insurance during the rental. The operator generally keeps a portion of the rental amount in return for facilitating the transaction and providing third-party insurance (Stocker & Shaheen, 2017).

D- <u>P2P marketplace</u>

The P2P marketplace enables direct exchanges between individuals online. Terms are usually decided among parties entering a transaction, and disputes are subject to private resolution. This model is different from P2P car-sharing since transactions are made between parties instead of managed by a third-party provider which offers insurance coverage and technology assistance as part of their service (Stocker & Shaheen, 2017).

E- <u>For-hire service models</u>

For-hire services involve a customer or passenger hiring a driver on an as-needed basis for transportation services. For-hire vehicle services can be pre-arranged by reservation or booked on-demand through street-hail, phone dispatch, or e-Hail via a smartphone or other Internet-enabled device (Stocker & Shaheen, 2017). Shared mobility options that employ a for-hire service model include: 1) Ridesourcing, 2) Taxis/E-Hail, and 3) Courier Network Services (CNS).

F- <u>Ridesourcing</u>

Ridesourcing services provide both pre-arranged and on-demand transportation services for compensation by connecting drivers of personal vehicles with passengers. The ride-sourcing service was initially developed in the US in 2012, and then expanded swiftly around the world (Lyft and Sidecar). Ridesourcing has developed based on an online platform. The requests for the mobility service (trips) can be booked or ordered via smartphone and the Internet. Mobile applications are used for booking, payment, and driver/passenger ratings (Stocker & Shaheen, 2017). These services typically charge a combination of base fare, a rate per minute, and a rate per kilometre, which may change based on the type of vehicle, service, location, and time of day.

G- Ride-splitting

Ride-splitting enables riders to share rides and split the cost of Ridesourcing through riding with someone traveling a similar route. These shared services typically charge less than regular ride-sourcing offerings and allow for dynamic changing of routes as passengers request pickups in real time (Stocker & Shaheen, 2017).

H- Taxis/E-Hail

Taxis are a type of for-hire service in which a driver gives a ride to one or multiple passengers. Taxi services can be pre-arranged or on-demand. In the US, taxis are typically regulated by local authorities, which set rates using a metered fare including an initial charge and a per mile or time rate. Taxis are reserved through street hailing, phone dispatch, or through e-Hail services provided by the taxi company or a third-party platform. E-Hail services, which have become more popular since their advent in late-2014, are platforms that allow Internet-enabled and smartphone hailing of taxis (Stocker & Shaheen, 2017).

I- Courier Network Services (CNS)

Courier Network Service is for-hire goods delivery services that works based on an online platform (website and/or smartphone application). The CNS assists drivers to use their personal vehicles for goods pickup and subsequent delivery to a customer. The service charges a delivery fee based on the cost of the goods delivered. Most CNS work based on P2P models and consider their couriers as independent contractors. Some CNS classify their couriers as part-time employees (Zillman, 2015).

The promise of EAVs and the gradual shift towards on-demand mobility services are leading to a deep paradigm shift in the way cities accommodate mobility (Noyman et al., 2017). The next section will explore how the automation of vehicles has transformed shared urban mobility.

5.5. The Shared Electric Automated Vehicles (SEAVs) as a solution for the future

There have been recent developments in the usage of shared mobility in combination with partial or conditional autonomous vehicles (AVs). However, the companies involved have mostly utilized SEAVs Levels 2 and 3 of the automation in their pilot projects because of the technological limitations. There is a common expectation that the level of automation of shared automated mobility will improve through technological achievements and addressing the practical obstacles of the widespread usage of EAVs in the cities.

Most SEAV projects involve a driver or a monitor of the automated system, or only provide certain automated functions within a controlled operating environment. Some pilot projects have used ride-sourcing services and automated vehicles. For example, Uber tested an AV service open to frequent UberX customers in Pittsburgh in 2016 (Stocker & Shaheen, 2018). However, an engineer was required to control the SEAVs and the system constantly. In 2016, two companies, nuTonomy and Grab, jointly provide an AV ride-sourcing service in Singapore (Slowik & Kamakaté, 2017). These SEAV pilot projects assist the companies to examine automation technologies in practice. Following the pilot test and then addressing the practical problems, issues, and concerns, there is an expectation that these companies will expand their AV ride-sourcing services based on owning or leasing a portion of their vehicle fleet instead of relying on personal vehicles owned by the drivers themselves.

There have been several automated shuttle service pilots around the world, including New Zealand. Most automated shuttles are in their first testing phase. These shuttles generally operate in a low-speed setting. For example, the French company EasyMile has provided its EZ10 electric automated shuttle in over 10 pilots around the world including multiple locations throughout Europe, in addition to the US, Singapore, Dubai, and Japan (Stocker & Shaheen, 2017). However, all automated shuttles pilots require an engineer to monitor the whole system. HMI is an Australia and New Zealand-based company that has recently developed an automated shuttle named “Ohmio” to be tested in Sydney, Melbourne, and Christchurch. These shuttles work at a low-speed and can carry 15 passengers (HMI, 2018).

Although several companies have announced their intention to test SEAVs based on a fully automated fleet, and public agencies are investigating the implementation of potential strategies and policies to regulating these services, SEAVs based on full automation have not yet been deployed. For example, Lyft co-founder John Zimmer (2016), in his article titled, “The Third Transportation Revolution”, predicts that most Lyft rides will take place in fully automated vehicles by 2021, and private car ownership will be reduced significantly in major US cities over the next 10 years. In 2016, Tesla Motors announced that all its new vehicles would be equipped with fully self-driving hardware. The company intends to develop its shared fleet named ‘Tesla Network’ in the future. This business model allows the Tesla owners to offer their EAVs on a shared network when they are not using their vehicles. However, the owners will be only be permitted to use their vehicles in the Tesla Network’ rather than in other ride-resourcing companies. Other major automakers such as Ford, GM, Fiat Chrysler, BMW, Daimler, and Volvo have prepared a strategic plan to become mobility providers as well as auto manufacturers in the future (Stocker & Shaheen, 2018). This new function of major car makers may assist in reinforcing the car sharing trend; however, it also may limit the development of an extensive car sharing network if these companies use Tesla’s model that limits the vehicle owner to use the companies’ sharing network.

The different scenarios of shared automated mobility can be projected onto the different combinations of future vehicle ownership scenarios and the shared business models. There are three vehicle ownership scenarios: business-owned EAVs; individually-owned EAVs; and hybrid business/individually-owned EAVs. It is important to determine what entities or individuals will own and manage the SEAV network operations, and more importantly to define the relationship with the vehicle owners. These entities as SEAV network operators will generally manage fleet-level operations such as developing booking systems, defining routes, establishing methods of payment, defining areas of operations, collecting and controlling user data, marketing, mitigating conflict, and providing insurance (Stocker & Shaheen, 2017). However, these functions and responsibilities can be partially or fully transferred to the vehicle owner(s) or another entity based on the utilized business model, and the different types of agreements. Regardless of the differences and the diversity of the shared automated vehicles, capital gain is the core of all these business models in which the vehicle owners and SAVs network operators will receive a portion of the user fees in return for their assets and services.

Stocker and Shaheen (2017) reviewed a set of potential ownership-operation combinations of SEAVs:

- <u>B2C with single owner-operator:</u> This business model involves the same company owning and operating a SEAV fleet, including the vehicles and the operating system. These B2C car-sharing operators, such as Zipcar or car2go, both own and operate a SEAV fleet.

- <u>B2C with different entities owning and operating:</u> Some entities may have network operations experience but own no or few vehicles, and some may own vehicles yet have no in-house operations expertise. It is possible that a business model may emerge where two (or more) companies partner to provide SAV services.

- <u>P2P with third-party operator:</u> In this model, individual car owners put their vehicles on a SEAV network when they are not using their AVs or when they have extra seats in their vehicle during a trip. A third-party manages the SAV network in exchange for this service. It takes a predefined percentage of the fee from the vehicle owner, the user, or both. The proposed Tesla Network will work under this business model.

- <u>P2P with decentralized operations:</u> This business model is based on individually owned vehicles. The operational system is not controlled by a third party; instead, it works based on individual owners' decisions and agreed-upon operating procedures. Several advantages are expected through using this business model such as increasing data privacy, much lower commission for users and owners, and increasing control for the vehicle owners. However, the utilization of this business model may generate some disadvantages including, but not limited to, regulatory uncertainty, insurance and liability issues, and network optimisation.

- Hybrid ownership with same entity operating: An entity owns a portion of the SEAVs in its fleet. It adds individually owned EAVs into its shared SEAVs fleet when individuals make their vehicles available for sharing on the network. The main advantage of this business model is its flexibility which helps it to meet peak demand when the entity's fleet cannot sufficiently respond to the demands, or the company cannot provide a service in geographic areas where the entity-owned vehicles cannot provide ample coverage.

- Hybrid ownership with third-party operator: Based on this business model, the operator is a third-party that does not own a SEAV fleet. The third party provides a shared online network of vehicles that can use both individually owned and entity-owned AVs in its fleet. Most network operators prefer to use individually owned AVs in their fleets until an additional demand requires them to pull another entity's vehicles into their network.

The implementation of Shared Electric Autonomous Vehicles (SEAVs) with its different business models depends on social, cultural, financial, demographic, and institutional factors. A recent study by MIT estimated that a fleet of 300,000 autonomous shared vehicles could serve the entire population of Singapore (6 million people) within 15-minutes waiting time during peak hours Spieser et al. (2014).

6. The potential of disruptive mobility to transform future neighbourhoods

Over the last century, around one billion cars have been produced. It is estimated that 1.2 billion cars are currently used around the world, and it is expected that the number of cars will increase to 2 billion by 2035 (Noyman et al., 2017a). After a century of urban sprawl and suburbanization, "it is evident that the surrender to the car, its industry and marketing efforts is pivotal in the impetus behind the design of cites" (Noyman, Stibe, & Larson, 2016, p. 5). Sheller and Urry (2000, p. 738) address the misconception of the car in urban studies, arguing that,

> [C]ars have been conceived of either as a neutral technology, permitting social patterns of life that would happen anyway, or as a fiendish interloper that destroyed earlier patterns of urban life. Urban studies have omitted to consider how the car reconfigures urban life, involving … distinct ways of dwelling, travelling and socializing in, and through, an auto-mobilized time-space.

Over the last century, this neutralization and subsequent prioritization of cars in plans and urban design projects have resulted in a pervasively car dependent urban form including suburbanization, low density, and urban sprawl.

Urban scholars have extensively considered the relationships between modern types of mobility and their impacts on cities. They have developed several concepts and terms such as 'car-culture', 'car-dependent urban planning', and 'car-architecture' to describe the role of cars in the transformation of urban form, the design of cities and neighbourhoods, and even the architecture of buildings. Noyman et al. (2017a, p. 3) argue that "the car gutted buildings and streets, shuffled land-use and redefined the design of landscapes".

The prioritization of cars in urban planning and design has adversely reshaped residents' travel behaviours as well as the physical environment. Cars are the often the only adequate and feasible transport mode for most people living in the suburbs due to a lack of safe, convenient, and affordable transport alternative modes (Newman & Kenworthy, 2015). Skinner and Bidwell, (2016) maintain that the prevalence of car dependency has transformed the built environment; for example, front gardens are increasingly paved over to park multiple cars. Drivers seeking to avoid congested main collecting roads have increasingly used local suburban connector roads and streets, particularly during peak hours. As a result of widespread car dependency, pedestrian and child safety, noise, air quality, and traffic speeds are a growing cause for concern in cities and particularly in neighbourhoods.

Lewis Mumford, a famous urban scholar, argued that "forget the damned motor car and build cities for lovers and friends" (Jackson, 1985, p. 75). As previously explained, although the implementation of disruptive mobility seems promising in addressing some of our urban issues such as traffic congestion, noise, air pollution, and safety, these potential benefits of automation are not guaranteed. Urban planning and design must proactively lead disruptive mobility to prioritize people-centric design in order to maximize the benefits and mitigate the adverse impacts of the usage of this technology (National Association of City Transportation Officials, 2017)

The widespread usage of disruptive mobility may assist in improving the quality of living in neighbourhoods. First, SEAVs would result in more efficient usage of road networks due to the system-wide control over route choice. Second, SEAVs would direct traffic out of residential areas, except where they form an essential element of the trip (Skinner & Bidwell, 2016). Third, the provision of SEAVs as a mobility service to a neighbourhood would offer appropriately sized vehicles within minutes with significantly lower costs than running a car, and thus would decrease car ownership dramatically.

The increasing interest in mobility services does not totally exclude private car ownership and its usage in neighbourhoods in favour of SEAVs in the near-term future; the replacement of private cars with SEAVs will be a transition process. For example, households will initially use SEAVs instead of owning a second car. By building trust and familiarity with mobility services, a shift is expected towards greater use of SEAVs for everyday trips to and from home in the neighbourhood. However, it may be that some residents purchase and use their own EAVs in the future. Declining car ownership in neighbourhoods will gradually transform the built environment and urban form (National Association of City Transportation Officials, 2017).

The widespread shift to SEAVs is part of the unprecedented attempt to achieve sustainable transportation. City leaders, transport planners, and urban designers have increasingly promoted, experimented and implemented different sustainable modes of transportation such as biking, walking, and public transport to improve the quality of life in their cities. The implementation of the SEAVs should complete this progress (National Association of City Transportation Officials, 2017). Accordingly, SEAVs should be used and developed as a component of a sustainable transport system in the future. However, some have perceived SEAVs as a potential threat to attaining sustainable transportation goals that include safety, equity, public health, and environment protection. There is general concern over the large number of unknowns in the future. As explained previously, most of these concerns will be addressed through technological developments as well as the implementation of the required regulations (National Association of City Transportation Officials, 2017). The deployment of SEAVs will potentially provide some benefits for our neighbourhoods:

A- <u>Safety:</u>

- Setting speed limits for the SEAVs will increase walking, cycling, and other activities
- Setting speed limits for SEAVs will increase safety for children, elderly, and disabled residents
- SEAVs will be programmed to prioritize people and their movements
- Real time data collection from SEAVs will assist to identify hazardous locations and redesign them to improve safety

B- <u>New transport planning:</u>

- Updating existing traffic and transport models to cater to SEAVs as well as reducing the need for roadways
- Reallocating existing roads to SAVs and residents' active and transit movements
- Redesigning the streets and pavements to be shared by SAVs and the residents

C- Design for a lower number of vehicles:

- Reducing parking minimums in zoning codes to reflect lower parking needs in the neighbourhood
- Supporting the SAVs by allocating space for charging stations and employing an occupancy-based congestion price
- Supporting and developing infrastructure for public transit and active modes in the neighbourhood

This working paper attempts to provide a base for policies and an aspirational framework for the deployment of SEAVs. The policies and plans will lead future cities in the autonomous era. However, with the lack of such plans and policies, transportation network companies and technology companies will play the main role in reshaping urban transportation in the future. Their technical and financial rationale and knowledge may neglect residents and their needs in the cities. Therefore, the large usage of SEAVs could generate new urban issues in the future. SEAVs "can support cities as they work toward streets that prioritise pedestrians, dedicate more space to better bicycle infrastructure, and allow for reliable transit service – but only with smart, thoughtful, intentional policies". (National Association of City Transportation Officials, 2017, p. 16)

6.1. The SAVs will potentially transform the metropolitan and town centres

The widespread uptake of SEAVs will create an opportunity to reinvigorate city and town centres. By using the capacity of SEAVs, urban designers and planners will be able to make the metropolitan/town centres greener, cleaner, and more liveable places (Skinner & Bidwell, 2016).

The land allocated to public parking in the metropolitan/town centres is significant (Litman, 2014). SEAVs will not need parking in the same way as conventional private vehicles do, and the level of car ownership will reduce significantly. The allocated land for public parking can be reclaimed for other activities in the cities, particularly in metropolitan/town centres. Skinner and Bidwell (2016) investigated the capacity of SEAVs to claim parking land in the cities. They argue that there are 6.5 hectares (16 acres) of parking for every 40.5 hectares (100 acres) of land in the urbanized area of Los-Angeles which is more than double the 2.8 hectares (7 acres) of parking coverage in 1950. The central area of London has approximately 16% parking coverage that includes around 6.8 million parking spaces. Based on an average parking lot size, this means that around 8,000 hectares (19,700 acres) of central London is used for parking. Skinner and Bidwell (2016) generalized the figures of 15% to 30% parking coverage as typical of New York, Paris, Vienna, Boston, and Hong Kong.

Skinner and Bidwell (2016) argue that the implementation of SAVs could provide between 15% and 20% additional developable land compared with a typical central urban layout due to the removal of parking spaces as well as the amendment of roads and streets. The development of SEAV zones within the existing metropolitan centres would create at least 15% additional land area for more valuable uses (Skinner & Bidwell, 2016). Depending on size and location, this reclaimed land could be potentially used for residential and mixed land uses, as well as extra land for quality green, urban amenities and quality public spaces.

Reclaiming land in the metropolitan/town centres may persuade private developers to invest in the establishment of SEAVs as it would provide more efficient use of land for business activities instead of car parking in ground level space, and perhaps above or below, depending on the parking situation (Skinner & Bidwell, 2016). For example, an estimation shows that the establishment of a SEAV zone with a 100 hectare development in the heart of London would gain more than £1.25 billion directly in additional land value increase. The introduction of SAV zones could, therefore, become a significant factor in future development viability appraisals (Skinner & Bidwell, 2016). The deployment of SEAVs in Auckland would also assists in reclaiming land currently allocated for parking in the CBD and other metropolitan areas. This reclaimed land could be used as a tool to boost the economy in the future.

Developers and land-owners may make significant gains through the replacement of car-oriented development with SEAVs-based development. Land owners and developers may perceive the reclamation of 15-20% additional land for further development in the centres as a new source of revenue and/or construction cost savings. This is especially relevant to those who wish to achieve a long-run interest in their sites, for example through a Private Rented Sector (PRS) model. It seems feasible that access to SEAVs will become part of the package available to future residents. The economic drivers may persuade the private sector to invest and collaborate with the public sector to maximize the benefits of the deployment of SEAVs in the metropolitan/town centres (Skinner & Bidwell, 2016).

Developers and land owners may be attracted to invest in centres that are not currently viable due to poor transport access but which may become far more accessible with the introduction of SEAVs. Some newer metropolitan/town centre developments are designed, planned, and delivered based on Transit Oriented Development that has no or lower car parking spaces. These new developments are close to a station offering fast, frequent, public transport services (Newman, 2015). The establishment of SEAV zones should be a component of this larger integrated transport strategy to be delivered equitably across far larger areas including several neighbourhoods, giving everyone a high-quality transport solution at their front door (Skinner & Bidwell, 2016).

The expansion of SEAVS zones would increase the amount of residential land in the centres by removing parking spaces, thus making make future developments considerably more viable and affordable (Skinner & Bidwell, 2016). DCLG's data (2015) identifies that post-development residential land value uplifts of £1-4 million per hectare are typical of much of the UK. In New Zealand, the Auckland's metropolitan/town centres are mostly planned for high densification and mixed land use development. Land reclamation through SAVs in these centres would reinforce the process of high densification and mixed land use in the future. The introduction of SAVs, therefore, opens up the potential for hundreds of thousands of new homes in our existing city centres.

There is a pervasive expectation that demand for mass movement along main routes between centres will remain high in future, particularly during the peak hours. The utilization of individual AVs will not provide sufficient efficiency or cost gains to converge these routes. SEAVs will provide a door-to-door mobility service with a first or last kilometre travel option to and from mass transit interchanges. To be sure SEAVs minimize car dependency in neighbourhoods, MaaS should cover journeys where there is no public transport provided, or where levels of demand do not support an economically viable service. This model will assist to provide Mobility as a Service in outer Auckland's neighbourhoods in which the traditional public transportation system is both inefficient and costly because of the low density. Disruptive mobility can be offered from a series of 'mini-hubs' throughout the SEAV zone such as a neighbourhood. Currently, three SEAV minibuses are being tested and operated testing in Christchurch (HMI, 2018). These mini-buses will supply a mobility service on demand to any home or business in the neighbourhood. A data-rich integrated transport network will help to make central stations highly efficient, integrated interchange points between SEAVs and rail, ferry, or bus services. This smart transport system will reduce waiting times for travellers using public transport (Skinner & Bidwell, 2016).

The utilization of SEAVs will improve safety, efficiency, and air quality in the city centres. Drivers who search for parking spaces generate around 30-45% of city centre traffic (Skinner & Bidwell, 2016). SEAVs will offer additional place-making benefits and congestion relief. Unnecessary parking can be eliminated from city centres, and the reclaimed land can be reused, re-planned, and redesigned for other required land uses. Some of this land can be used for pedestrian and cycle enhancements, small-scale retail and commercial improvements, and better open spaces. SEAVs will result in a lower number of AVs and cars in circulation than today's car-based patterns. Several research projects have revealed that private cars are stationary 96% of the time (James, 2017) and SEAVs would be in use for a far greater proportion of time (Skinner & Bidwell, 2016).

6.2. Disruptive Mobility and the Future Streets

In the autonomous age, streets will not be used for the movement of vehicles only; rather, they will be part of the public space that can be used for social activities. To prepare for this, the current streets should be redesigned to prioritize pedestrians, cyclists, and transit riders, against SEAV movement. That means the existing design codes and standards should be fundamentally revised to address the new requirements of the autonomous era.

The US National Association of City Transportation Officials (2017, p. 2) published a blueprint for Autonomous Urbanism "to serve as a foundational and aspirational human-oriented vision for the city – a statement and visualization of core principles in an uncertain future shaped by technology. For the private sector, the Blueprint is intended to communicate the urban vision that cities are working toward and the importance of partnership to achieve this vision." The blueprint suggests that the future street should provide smaller and fewer lanes for SEAVs in order to mitigate conflicts and provide crossing distances for pedestrians, and to provide space for the expansion of cycle networks on neighbourhoods streets. The restriction of speed would drastically reduce the number of vehicles including the SEAVs. However, travel times would not increase; rather, the greater capacity of active travel modes, the expansion of transit modes, the lower traffic congestion, and smoother intersection movement at low speeds would decrease travel time. This future street would offer a higher quality environment for everyone using it. In short, the utilization of SEAVs will assist us to revitalize our streets as places for socio-economic and political activities rather than car movements.

Over the last century, cars have occupied our streets, neighbourhoods, and cities (Newman, 2015). For many residents who live in inner or outer neighbourhoods, car ownership is often the only option to commute in car-dependent cities due to a lack of safe, convenient, and affordable transport alternatives (Banister, 2011). Skinner and Bidwell (2016) argue that private cars are mostly parked at homes for 96% of the time whether on or off the street. Alessandrini (2015) maintains that minor improvements and transformations of the physical environment will improve the performance of SEAVs significantly. For example, existing on-street parking could impede the capacity of SEAVs to work efficiently by forcing them to drive at lower speeds than necessary, thus worsening existing congestion. According to Alessandrini (2105), existing on-street parking could decrease the speed of SEAVs to approximately 12km/h, even though the speed restriction is 40km/h in most neighbourhoods. To attract residents to use SEAVs, they should work at higher speeds. Transport planners and urban designers should remove road-side parking spaces to facilitate the movement of SEAVs. The reduction of on-street parking spaces would allow SEAVs to work at higher speeds and thus reduce the travel time.

A- Greener Streets

The reduction of on-street parking spaces would generate an opportunity to expand green spaces in the streets. Skinner and Bidwell (2016, p. 15) point out that "around 80% of the UK's suburban housing stock has some form of front garden space, of which around a third have been paved to become a parking space". They argue that between 2005 and 2015, around half of the front gardens in London were transformed into parking spaces, increasing front gardens without plants five times. The utilization of SEAVs, able to move without a driver on board, opens up options to reclaim on-street parking and to convert many residential off-street parking spaces back into gardens and vegetation. The reclaiming of on-street parking would improve the quality of the streetscape, and air quality, and provide safe spaces for leisure and social activities (Heath et al., 2006).

B - Less flooding

The expansion of green space would benefit biodiversity and rainwater runoff, as well as reducing pressure on the sewerage and storm water collecting systems. For example, if half of the UK's paved suburban front gardens were reclaimed, this would stop or significantly slow up to 2,400 litres/second of rainfall entering the system and causing flooding (Skinner & Bidwell, 2016).

C - Safer Streets

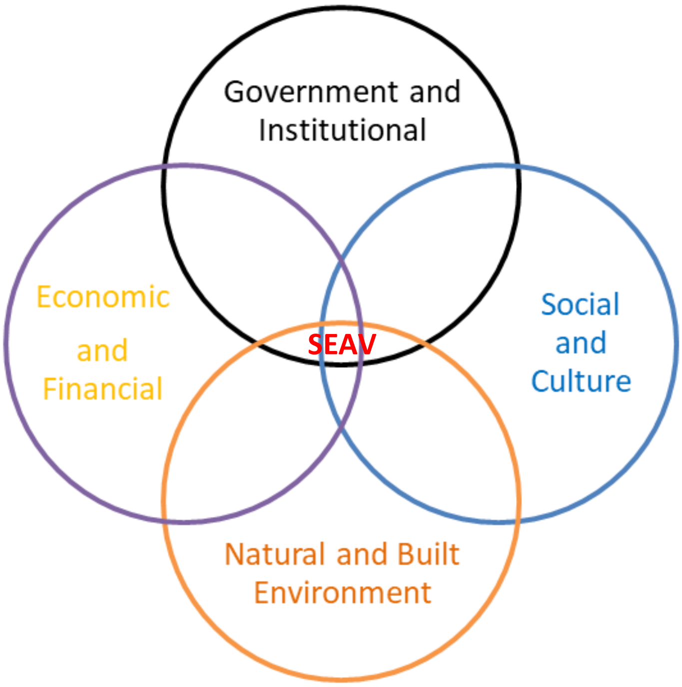
The total social cost of vehicle injury crashes in New Zealand in 2016 was NZ$4.17 billion (Ministry of Transport, 2018). Not surprisingly, urban accidents tend to involve more pedestrians and cyclists than other road types. The introduction of SEAVs may reduce the accident numbers (Skinner & Bidwell, 2016). SEAVs would be aware of bicycles as moving objects. Thus cyclists' safety would be higher than it is today. In addition, future smart bicycles would be linked into the wider network system, offering even greater safety improvements. Pedestrians would be better protected as the speed of SEAVs would be adjusted to take proper account of people crossing roads. One of the key changes that would make neighbourhood streets significantly safer than in the existing urban areas is that SEAVs would put people at the top of the hierarchy, rather than vehicles. Thus, the deployment of SEAVs would create pedestrianized streets without the need to compromise on accessibility (Skinner & Bidwell, 2016).

E - No major investment

SEAVs are able to be used on existing streets without major investment and transformation of streets. SEAVs are vehicle-mounted rather than on the roadside. The road network, as a fundamental element of the urban transport and streetscape, would remain in place. The deployment of SEAVs does require an upfront investment to change exiting streets and other related transport infrastructure. However, the streets and other infrastructure would be gradually upgraded as a process that depends on the progress of SEAVs and increasing Mobility as a Service (MaaS). The implementation of policies such as road pricing would provide an adequate financial resource to update urban streets.

7. Further research areas

The integration of automation, electric vehicles, and on-demand mobility service will create one of the fastest, deepest, and most consequential disruptions of urban transportation in history. Arbib and Seba (2017) predict that by 2030, 95% of US passenger miles travelled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals. This disruption will impact various aspects of our cities, including the following:



7.1. SEAVs and sustainable transportation

There is a general perception that the utilization of AVs will contribute positively to shape sustainable transportation in the future (Arbib & Seba, 2017; Fagnant & Kockelman, 2014; Martinez & Viegas, 2017). However, AVs are not environmentally sustainable by default, despite having inherent properties to allow for better environmental performance relative to conventional vehicles. Sivak and Schoettle (2015) estimated that the deployment of AVs might increase total vehicle trips by up to 11%. To attain sustainable transportation, planners, urban designers, and policymakers will play a significant role in fully realizing the contributions of

AVs to sustainable mobility through making arrangements at neighbourhood, regional, and national levels through ,for example, protocols, regulations, policies, plans, and design codes (Clausen, 2017; Lang et al., 2016). At the city level, an ‘active urban management’ including urban design and planning should be utilized to ensure AVs contribute to sustainable urban mobility in future.

There are two primary factors that could result in AVs contributing to sustainable urban mobility. The first is AVs’ capacities to be electric vehicles (EVs). The second is providing a shared mobility platform for on-demand mobility service provision, or Mobility as a Service (MaaS) (Fulton, Mason, & Meroux, 2017). The pervasive usage of AVs in combination with electrification of vehicles could lead us to omit CO2 emission, and the expansion of shared mobility could significantly reduce the overall number of vehicles in our cities (Fagnant & Kockelman, 2015).

7.1. A- Electrification and Automation of Vehicles (EAVs)

There is a common mistake that electric vehicles (EV) and autonomous vehicles (AVs) are two entirely separate technologies developing simultaneously. Automation and electrification are not interdependent trends; rather, there are synergies that exist between these two emerging technologies (Marshall & Niles, 2014). Therefore, Roemer et al. (2017) argue that autonomous electric vehicles (AEVs) will be the next generation of vehicles in our cities.

Globally, the transport-sector generates 24% of all CO2 emissions from fossil fuel combustion (International Energy Agency, 2017), and it produces 15% of total greenhouse gas (GHG) emissions (World Resources Institute, 2018). While the electrification of autonomous vehicles will not fully omit CO2 emissions, it may mitigate air pollution significantly in our cities, which is crucial to improving the quality of life.

The private sector also has engaged in the electrification and automation of vehicles. For example, the main aim of Elon Musk, Tesla's CEO, is “to create something that will have a profound effect as the impetus behind his automobile company” (Zimbron-Alva, 2016, p. 8). Tesla has endeavoured to eliminate fossil fuels from transportation by developing its first compelling electric vehicle. In addition, Tesla is attempting to produce a fully autonomous vehicle. Musk stated that "Tesla is the leader in electric cars, and we'll also be the leader in autonomous cars, it's going to be the default thing" (Zimbron-Alva, 2016, p. 9). Tesla believes that their autonomous electric vehicle (AEV) will fundamentally transform transportation. Tesla is addressing the problem of sustainability with a unique solution – marketing AEVs.

7.1. B- Mobility as a Service (MaaS)

There is a pervasive belief that AVs will accelerate and expand the growth of mobility as a service (MaaS). Mobility as a service is one of the main disruptions occurring in the transport sector (Burrows, Bradburn, & Cohen, 2015). MaaS is embedded in new socio-economic systems such as the sharing and collaborative economy, in which access to mobility and on-demand services over car-ownership is transforming transportation. MaaS includes mobility service providers (MSPs) and an on-demand mobility service (ODMS) (Fagnant & Kockelman, 2014; Simoudis, 2017).

B-1- Towards a pay-as-you-go transport system

The automation of the majority of vehicles will generate a new opportunity to move to a pay-as-you-go system as an on-demand mobility service. A pay-as-you-go transport system is a shared use platform based on a network 'booking system'. It provides an opportunity for its users to confirm an AV journey from A to B at a specific time with a required AV. The platform can initially estimate and then fix the cost of a journey according to various variables such as time of day, anticipated congestion, distance travelled, type of AV, and the priority to be assigned to the vehicle. This platform also allows those who are willing to use a shared AV, book further in advance or are flexible over the choice of route to make a trip at a lower cost than those who request their own AV for immediate use. The platform is compatible with existing public transport systems such as bus, trains, and ferries (Skinner & Bidwell, 2016). While shared autonomous vehicles cannot generate sustainable transportation as a separate transport mechanism, they should be integrated into the existing urban transport system. Chapter 4 will extensively explain the different dimensions of the smart economy, shared mobility, and on-demand mobility service.

B-2- Time

Once high numbers of shared AVs become common on city streets, the wait-times for mobility are expected to drastically decrease (Burns et al., 2013; Viegas et al., 2016). Waist-time is perceived as one of the main barriers of using public transport. On-demand mobility will address this issue.

B-3- Vehicle kilometres travelled

The widespread adoption of AVs will impact on vehicle kilometres travelled (VKT) (Fagnant & Kockelman, 2014; Schaller Consulting, 2017; Viegas et al., 2016; Wadud et al., 2016). The main objective of sustainable urban mobility plans is to reduce VKT significantly. Despite the increasing integration of AVs into sustainable urban mobility plans, the deployment of AVs may lead to a sharp rise in VKT (Fagnant & Kockelman, 2014; Wadud et al., 2016), creating a phenomenon referred to as 'induced demand' (Milakis et al., 2015). The integration of AVs contradicts the objective of sustainable urban mobility as AVs will provide higher rates of accessibility and a lower cost of travelling.

Several other factors will contribute to the overall vehicle kilometres travelling (VKT) of AVs in the future. These factors include, but are not limited to, the growth in MSPs, the degree to which ridesharing can be incentivized, the level of private AV ownership, and the type of traveller the mode of transport attracts (Clausen, 2017).

7.2. SEAVs and safety

The World Health Organization (2015) estimates that each year over 1.2 million deaths result from traffic accidents worldwide. One of the most promising benefits of AVs is safety (Anderson et al., 2014; Litman, 2014; Meyer & Beiker, 2018). Crashes and injury rates are expected to improve because AVs do not include the risk of distracted drivers. Depending on the level of automation, automation may avoid 10% to 90% of vehicle accidents and crashes (Fagnant & Kockelman, 2015). Skinner and Bidwell (2016, p. 7) argue that, The widespread introduction of AVs could reduce both the number and severity of road accidents substantially.… With 1775 reported road fatalities in the UK in 2014, and 195,000 casualties of all severities, road accidents cost the UK upwards of £10 billion each year.… There is an expectation that driverless and autonomous systems will deliver a near-zero harm solution for everyone, including pedestrians and cyclists as well as those inside the vehicles.

In contrast, some believe that the deployment of AVs will not improve safety on our roads and streets. Tennant, Howard, Franks, Bauer, and Stares (2016, p. 2), from the London School of Economics (LSE) and Goodyear, conducted four focus groups and an extensive questionnaire-based survey to "understand the level of 'openness' people have towards AVs and, conversely, the situations in which people hope to avoid engaging with these vehicles". The study found that 60% of participants did not know enough about AVs. Furthermore, 73% of respondents feared the system could malfunction. Kyriakidis, Happee, and de Winter (2015) conducted a questionnaire-based survey to investigate potential users' acceptance, concerns, and willingness to purchase partial, high, and full AVs. The survey was conducted in 109 countries and included 5,000 respondents. The survey revealed that the participants' main concern in buying AVs focused on issues related to safety, legality, software hacking, and misuse. Since automation is a process that includes different steps to become a full AV, AVs and their associated technologies will be fully checked and examined to address users' concerns before offering them on the market.

7.3. SEAVs and smart road pricing

"Taxes are usually considered an economic transfer from consumers to governments" (Litman, 2002, p. 10). Vehicle fuel taxes are special charges that can be considered as user fees that internalize external costs. Lindberg and Fridstrøm (2015) estimate that by 2020, the pervasive usage of EAVs will lead to a decrease of $800 billion in tax revenue currently gained from fossil fuel taxation. The deployment of new pricing mechanisms will be required to cover the costs of transportation including service, maintenance, and development of the transport system. A road pricing scheme is suggested as a potential solution. This scheme is designed to price Vehicle Kilometres Travelled (VKT) that can be measured and recorded by GPS.

Road pricing is not a new policy, but it is largely used for different purposes (Johansson & Mattsson, 2012). Road pricing is currently deployed to mitigate traffic congestion in Singapore, the US, and the UK, among others. Road pricing is generally used as an effective tool to decrease private car usage in some cities. For example, Blankert, Senior Advisor Traffic Management, Amsterdam, argues that "we thought of pricing the road to prevent empty cars. Now you pay a lot of parking, and it is the only way we discourage people from going with a car" (Clausen, 2017, p. 38). Road pricing is implemented to generate revenue as well as to improve environmental quality and safety (Johansson & Mattsson, 2012).

The implementation of road pricing also assists in mitigating threats that EAVs may create in future. For example, an issue could arise in the context of empty autonomous vehicles ("zombie cars") in cities (Fitt et al., 2018). Transport planners should implement policies to evacuate zero-occupant AVs from roads, particularly in peak rush hours. Road pricing may persuade private AV owners to find parking for their autonomous vehicles when they do not use them (Marinelli, 2018).

7.4. SEAVs and accessibility

The improvement in accessibility is another expected benefit of the widespread use of EAVs in the future. One of the main concerns of urban planners and transport planners is providing access for all residents to the existing opportunities of work, leisure, health care, and urban services (Meyer et al., 2017). Currently, a large number of residents, particularly disabled, elderly, and economically disadvantaged groups have limited or no access to urban facilities, services, and opportunities in the cities because of the hegemony of private cars in urban transportation (Duvarci & Yigitcanlar, 2007). One of the expected benefits of the pervasive deployment of EAVs is the inclusion of excluded groups such as disabled, elderly, or youth by providing door-to-door access at an affordable price (Meyer et al., 2017). However, there is a concern that the deployment of EAVs will increase the amount of urban congestion by increasing the demand for mobility, particularly from excluded groups.

7.5. SEAVs and feasibility

There is a common expectation that EAVs will become a highly attractive mode of urban transport due to their relatively low cost and high level of convenience (Bösch, Becker, Becker, & Axhausen, 2018; Meyer & Beiker, 2018). The widespread deployment of EAVs promises massive economic gains that can be attained across society, including by individuals, businesses, and governments.

For businesses, a multi-trillion-dollar market is expected to emerge from EAVs, due to improvements in productivity, reduction in accident costs, and fuel saving costs (Fagnant & Kockelman, 2015). There is an expectation of other booming markets, such as the entertainment market, due to the wide usage of EAVs in the future. For example, a new in-vehicle entertainment market for the 'connected consumer' will produce significant opportunities for new revenue streams. This in-vehicle experience will not only significantly improve the quality of travel, but it will generate new business and job opportunities (Bertoncello et al., 2016).

EAVs in combination with MaaS will reduce the price of mobility to a fraction of current urban transport costs (Keeney, 2017). For example, it is estimated that a middle-class family may save 10% of their annual household income in transportation costs by using MaaS instead of their private cars. By 2030, the pervasiveness of MaaS and EAVs "will assist American families to save an additional $1 trillion per year in total" (Arbib & Seba, 2017, p. 15).

The major OEMs such as Mercedes, Volvo, and GM are examining different business models to shift towards becoming Mobility Service Providers (MSPs) due to increasing demand for mobility services as well as the low operational costs of EAVs. As previously mentioned, the electrification of AVs will reduce operation and maintenance costs, and persuade organizations, communities, and firms to own and operate EAVs on a fleet-basis (Clausen, 2017).

Some studies have shown that there is a willingness to own and use full autonomous vehicles privately. A study by Daziano, Sarrias, and Leard (2017) found that most of their respondents would pay an additional $4,500 to own their own AV. Bansal and Kockelman's investigation in Texas (2016) found that respondents were generally eager to pay higher costs to purchase AVs. A limited group of OEMs have already offered a relatively feasible price for autonomous driving capabilities in the market. For example, Tesla Motors has recently announced that all their vehicles will be equipped with the hardware necessary for full autonomy, which can be enabled at an additional fee of $8,000. These persuasive offers may convince a large number of people to purchase and own EAVs instead of using a shared on-demand mobility service in future. The most realistic scenario in the future would be a combination of individually owned EAVs and shared EAVs in our cities.

Because of the lower operation cost of EAVs, there are some concerns about governments' future plans and policies such as reducing their expenditures on public transportation (Bösch, Becker, Becker, & Axhausen, 2017). This governmental policy shift will adversely impact sustainable urban transportation in general, because it will limit alternative sustainable transport modes.

7.6. SEAVs and Land use planning

Automobile and land use have been inherently intertwined since the very invention of the motorised vehicle (Thakur, Kinghorn, & Grace, 2016; Zhang & Guhathakurta, 2017). EAVs will change land use patterns to a level not seen since the mass production of cars around a century ago. There is a pervasive expectancy regarding the positive impacts of EAVs on land use, particularly in reversing current planning and urban design codes and regulations that mostly prioritize car movement (Anderson, 2014).

The transformation of transportation is perceived as excellent news for urban planning and designer since one of the main concerns of urban designers and planners has been the dominance of cars in our cities (Gehl, 2013). The development of automobile dependence in cities is a complex process, enacted over decades of land-use and infrastructure development linked to the prioritization of car movement in the cities (Newman & Kenworthy, 2015). Big thinkers on cities, such as Mumford (1986), Jacobs (1961), and Schneider (2003), have investigated these processes from different perspectives and argued that over the last century, major urban problems have been generated by planning and designing that have reshaped our cities around cars.

The widespread use of EAVs may provide a new opportunity to repurpose existing land use in our cities (Alessandrini, Campagna, Delle Site, Filippi, & Persia, 2015; Kondor, Zhang, Tachet, Santi, & Ratti, 2017). Many researchers believe that EAVs will deliver urban passengers directly to their destination. Therefore, on-street parking and public parking facilities will no longer be as necessary for our cities (Litman, 2014). Another expected benefit of the pervasive use of EAVs will be improvements in land utilization by increasing road capacities between 30 and 80%. In future, EAVs will be able to drive in closer proximities, accelerate and decelerate simultaneously, and bypass the need to come to a stop at intersections (Brownell, 2013; Childress et al., 2015; Friedrich, 2015). Coupled with the reduced need for parking lots, these spaces could be repurposed with urban infill.

There is a general perception that the utilization of AVs will contribute positively to shape sustainable transportation in the future (Arbib & Seba, 2017; Fagnant & Kockelman, 2014; Martinez & Viegas, 2017). However, AVs are not environmentally sustainable by default, despite having inherent properties to allow for better environmental performance relative to conventional vehicles. Sivak and Schoettle (2015) estimated that the deployment of AVs might increase total vehicle trips by up to 11%. To attain sustainable transportation, planners, urban designers, and policymakers will play a significant role in fully realizing the contributions of AVs to sustainable mobility through making arrangements at neighbourhood, regional, and national levels through ,for example, protocols, regulations, policies, plans, and design codes (Clausen, 2017; Lang et al., 2016). At the city level, an 'active urban management' including urban design and planning should be utilized to ensure AVs contribute to sustainable urban mobility in future.

There are two primary factors that could result in AVs contributing to sustainable urban mobility. The first is AVs' capacities to be electric vehicles (EVs). The second is providing a shared mobility platform for on-demand mobility service provision, or Mobility as a Service (MaaS) (Fulton, Mason, & Meroux, 2017). The pervasive usage of AVs in combination with electrification of vehicles could lead us to omit CO2 emission, and the expansion of shared mobility could significantly reduce the overall number of vehicles in our cities (Fagnant & Kockelman, 2015).

8. Conclusion

Disruptive mobility is significantly transforming the built environment, transportation, and everyday life. Disruptive mobility includes three intertwined technological trends: automation, electrification, and smart shared mobility. This report briefly explained why these trends should be considered together, particularly in order to shape sustainable transportation in the future. These technologies and their consequences were reviewed in this report.

This report argued that to attain sustainable transportation in the future, both national and local governments should provide adequate regulations, policies, and plans. The governments should facilitate the implementation of disruptive mobility as well as mitigate the adverse side effects of these technologies in the future.

However, most researchers mainly focus on one of these progressive mobility technologies. This working paper briefly explained why automation, electrification, and smart shared mobility should be considered as intertwined trends to generate an integrated picture of the disruptive mobility in future. If automation of vehicles will facilitate mobility in future, it might reinforce urban issues such as increasing the existing traffic congestion and further urban sprawl. However, the electrification of vehicles will improve the efficiency and affordability of transport system. It may increase the demands for mobility that consequently will result in more traffic congestion. Smart mobility as a solitary technology could not address the existing mobility issues such as air pollution, traffic congestion, and safety. This paper suggested that the integration of these emerging technologies as a disruptive mobility might assist to address some of the existing mobility issues.

This report showed that disruptive mobility is transforming our city centres as well as our urban streets. These transformations will potentially revitalize our neighbourhoods by reclaiming parking spaces, prioritizing people movements over cars, redirecting traffic to outer neighbourhoods, providing safe and secure streets, as well as greener streets. To materialize these potential outcomes, planners and urban designers should engage more in the process of decision-making. Also, the existing urban design codes and standards should be updated and revised to address the new requirements that are generated by disruptive mobility.

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