Emerging transport technologies: Assessing impacts and implications for the City of Melbourne

Prepared for the City of Melbourne
by the Institute for Sensible Transport

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Institute for Sensible Transport
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Acknowledgements

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Executive Summary

The transport sector is currently undergoing its most rapid transformation in decades. Disruptive transport technologies, such as App based ride sourcing platforms, innovations in car sharing, real time public transport information and autonomous vehicles, are set to change travel behaviour in our cities over the next 5 – 10 years. The city of Melbourne, as the economic, cultural and transport hub of Victoria, is at the centre of these innovations.

This report represents the first known exercise by a government in Australia to directly explore the impacts and opportunities presented by the rapidly advancing field known as the *disruptive transport* sector*.* This report describes the types of emerging transport technologies currently available, as well as significant trends and future possibilities. This provides the foundation for exploring the impacts and policy actions the City of Melbourne can take to harness the opportunities presented by emerging transport technologies, in order to support Council's strategic directions.

The emerging transport technologies examined in this report have been guided by Council Action 6.3.9. and include:

- Car sharing, including new trends in one-way car sharing and peer-2-peer options.
- Ride sourcing applications (e.g. Uber).
- Car parking market place and revenue collection innovations.
- Multi-modal journey planning applications and smartphone payment options for transport services of all modes.
- Autonomous (driverless) vehicles and shared mobility compatibility.

The core aims and principles of the City of Melbourne have been carefully considered in the impacts and suggestions outlined below, with a view to strengthening the City of Melbourne's strategic position to meet the needs of a growing city.

The potential impacts of emerging transport technologies on the City of Melbourne include:

- Greater use of ride sourcing services, with a substantial increase upon the introduction of autonomous vehicles (i.e. 'robo-taxis').
- Rising demand for car sharing in the short to medium term.
- Significantly lower demand for car parking in the medium to long term (5 – 20 years).
- Greater demand for electric vehicle charging.
- Potential increase in congestion in the absence of additional congestion management measures.
- Reduction of road traffic crashes in the long term (15 – 20 years) upon the widespread reduction in use of conventional (human driven) cars.

In order to best position the City of Melbourne to benefit from the opportunities created by emerging transport technologies, the following suggestions are offered for consideration:

Policy reform

- Introduce car-parking reform, including real time information and dynamic pricing.

Investigate electric vehicle charging provision for new buildings. Planning reform

- Investigate planning mechanisms for newly constructed multi-deck car parking structures to be adaptable for new uses in the future.

Third party engagement

- Continue to Embrace open data policies and open Application Programming Interfaces (APIs) to allow 3rd Party App development to enhance travel information platforms. Encourage the State Government to take similar actions.
- Engage with Public Transport Victoria to investigate smartphone options to integrate multi-modal journey planning (i.e. beyond public transport), including the use of a smartphone to *‘tap and go’* for paying for public transport.
- Create dialogue with established and emerging members of the car sharing industry to facilitate one-way car sharing and investigate opportunities to grow peer-2-peer car sharing.
- Engage with Public Transport Victoria regarding bike sharing performance improvements, including its fee structure and payment integration with MYKI, its expansion and research on best practice bike sharing experience applicable to Melbourne.

Ongoing research

- Conduct research to monitor changes in demand for car sharing services among municipality residents and businesses.
- Investigate new technologies capable of efficiently contributing to the last mile freight task, including electric cargo bikes, drones and other mechanisms. Consider establishing a dialogue with the Civil Aviation Safety Authority and others regarding controlled trials of drone use for small parcel delivery.
- Work with transport modelling software providers to ensure their models are able to include future scenarios of shared mobility and autonomous vehicles.

Government agreement

- Request a position on the Victorian Government’s *Taxi and Hire Car Ministerial Forum*, to press for data sharing agreements and a code of conduct that supports the City of Melbourne’s strategic position.
- Investigate road user charging options, costs and benefits and lead a dialogue with other Melbourne local governments exploring this as a congestion management tool.

Other informal CoM initiative

- Take a leadership position on the development of an innovation lab, to act as a living laboratory for urban innovation, of all types (e.g. built form, green space, digital enterprise), with disruptive mobility as one theme. The focus of such an innovation lab should be to develop creative ways to blend technology and design to enhance urban productivity and liveability outcomes. This represents an opportunity to operationalise and join together many of the individual suggestions made in this report and comes at a time when innovation has emerged as central to the Federal Government’s agenda.

This report demonstrates that emerging transport technologies are set to have a profoundly transformative effect on cities, transport behaviour and urban life. For the City of Melbourne, these technologies offer the opportunity to support the strategic directions of Council, potentially helping to create a greener, more prosperous city that better manages the demands of a growing city with the need to maintain and enhance liveability. These desirable outcomes are unlikely to occur without the creation of the right set of policy signals, however. The City of Melbourne, as the cultural and economic centre of Victoria, is ideally positioned to take a leadership role that embraces new transport technologies and influences government to create the connected, creative, eco-city that it aspires to be.

1. Background

Contemporary society has entered a period of transport innovation beyond anything experienced in living memory. Apps that are able to summon rides at the tap of a screen, solar powered or battery operated cars that can drive themselves, GPS connected public bikes; these were once fanciful or even unimaginable ideas that have, in one form or another, arrived in our cities, all at various stages of development and adoption.

These developments have been a challenge for regulators and incumbent industries. Regulators have experienced varying degrees of difficulty in managing the burgeoning ride sourcing sector (e.g. Uber). Autonomous vehicles too are set to create any number of complex legal, ethical and transport challenges for public policy makers and the automotive sector itself.

This sharp increase in technologically driven transport innovation comes during a period in which decades-long transport trends are beginning to change. Vehicle ownership rates and even the proportion of young people with a driver's license, once a rite of passage, are beginning to decline. Since 2004, per capita vehicle kilometres travelled has also begun to decline. This is happening not just in Australia, but is recognised as a trend in a number of developed countries (Goodwin & Van Dender, 2013).

This report by the Institute for Sensible Transport has been commissioned by the City of Melbourne. The objective of this project is to inform Council regarding the current and future landscape with regard to emerging transport technologies, discuss the likely impacts on Council, and suggest actions that could be taken by Council to capture outcomes supporting Council's strategic position.

1.1. Relevance to the City of Melbourne

The confluence of changing travel patterns, particularly in urban areas, with the enormous growth in the availability of mobile, internet connectivity, has led to the emergence of what is now known as the *disruptive transport sector*[1]. The City of Melbourne has a role in developing and maintaining an active interest in this rapidly evolving sector, for several important, intertwined reasons. Firstly, the city of Melbourne is the hub of the Melbourne transport system. In 2014 some 854,000 people entered the municipality on a typical weekday and this is expected to rise to over 1.2 million by 2030 (City of Melbourne, 2014). Based on 2009 data, 46% of City of Melbourne arrivals are by public transport, 47% by private car, 4% on bike and 3% on foot (City of Melbourne, 2012, citing VISTA, 2009 data). Once in the municipality, only 15% of trips are by car and a much larger share of trips are conducted on foot (66%). Disruptive technology has the potential to alter travel patterns and mode choice. It is therefore in the interest of the City of Melbourne and the community it serves to stay abreast of the latest developments in this rapidly changing sector.

Strategically, much of what is offered via disruptive transport technologies (DTT) complement the policy context outlined in the City of Melbourne Transport Strategy (City of Melbourne, 2012). In particular, the opportunity provided by DTT to facilitate *access* rather than *ownership* of vehicles directly support the following statement (City of Melbourne, 2012, p. 51):

> Driving is expensive and it is getting dearer. The purchase, insurance and maintenance of the vehicles and fuelling them (oil and electricity) will continue to grow as a major business and household cost. This will likely drive a shift to more economic patterns of

[1] Whilst *disruptive* is a term often used to describe technological innovation in transport (e.g. Uber) it commonly fails to meet the strict definition of *disruptive innovation* according to Professor Clayton Christensen, who coined the term. This will be discussed in Section 4.

> driving, such as priority access for delivery and service vehicles, smaller lighter vehicles and car sharing.

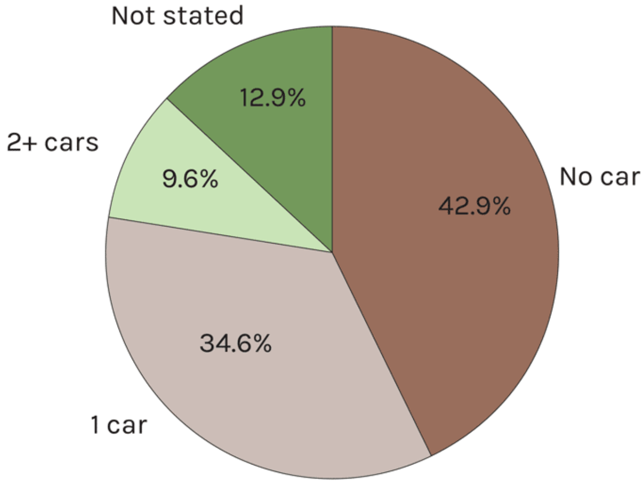
The City of Melbourne's policy direction acknowledges the physical limitations and inherent inefficiencies in providing for private car users, often at the cost of other, more efficient uses, as captured below (City of Melbourne, 2012, p. 52):

> The most convenient form of city parking is on-street parking. The stock of on-street parking has been falling however, as road space is re-allocated for higher efficiency road uses such as wider pedestrian paths, bicycle lanes and bicycle parking and better tram stops. This trend will continue as city activity intensifies and expands, and so will the demand for car parking spaces.

Disruptive transport innovation cuts across each of the above transport modes and it is therefore crucial that the City of Melbourne understands the ways in which DTT can be used to foster desirable outcomes, consistent with the City of Melbourne Transport Strategy (City of Melbourne, 2012).

Moreover, the municipality is the centre of the *knowledge economy*, and the agglomeration economics that attract the knowledge sector to the city supports many DTT (e.g. car share). Disruptive transport technologies are also of great relevance to the city of Melbourne given that it has the lowest car ownership and usage levels in Victoria. As shown in Figure 1.1, the city of Melbourne already has a high proportion of apartment dwellers without a car, or with only one car, and it is these households that provide the most fertile market for the adoption of DTT.

Figure 1.1 Car ownership among apartment dwellers in the city of Melbourne



Source: Dr Elizabeth Taylor, Centre for Urban Research, RMIT, based on Census (2011) data

Finally, as a municipality with ambitious transport, liveability and climate change targets, it is crucial the City of Melbourne is in a position to leverage the potential offered by emerging DTT. Doing so will help maximise opportunities to support the strategic directions of the City of Melbourne.

2. Aims

The aim of this project is to deliver on Council Plan Action 6.3.9: ‘Investigate the role we [City of Melbourne] have in relation to emerging technologies and trends associated with transport such as online apps for taxis, cars and parking’.

Specifically, this report aims to:

1. Describe disruptive innovation and the current state of emerging technologies and trends in transport, and this influence it may have on travel behaviour
2. Describe the potential impacts emerging transport technologies may have on the municipality
3. Identify what actions the City of Melbourne can take in light of these insights to continue to support their strategic objectives.

3. Methodology

The following provides a brief overview of the methodological approach used to meet the aims identified in Section 2. A more detailed explanation is provided in Appendix A.

1. Literature review: An analysis of the available literature related to emerging transport technologies was undertaken, encompassing both peer reviewed journals and industry publications.
2. Interviews: interviews were conducted with leading international and Australian experts in transport innovation and technology.
3. Case studies: a case study has been compiled, as an example of a city that has embraced emerging transport technologies.
4. Workshops: Internal workshop was conducted with staff at the City of Melbourne to explore the potential impacts of and responses to emerging transport technologies.

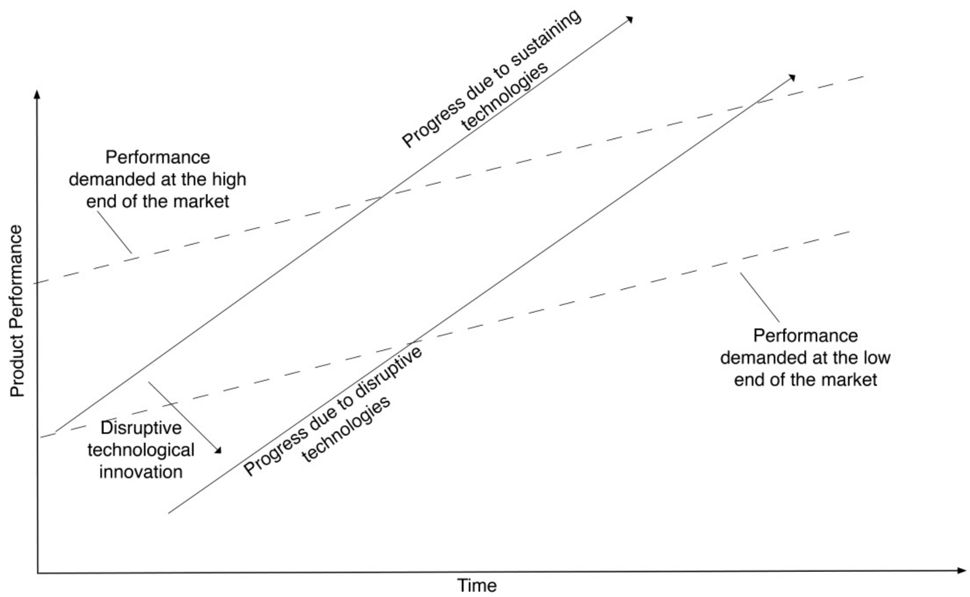
4. Emerging technologies in transport

4.1. What is disruptive transport innovation?

Professor Clayton Christensen of the Harvard Business School coined the term disruptive innovation (Christensen, 1997). Christensen defines disruptive innovation as an *'innovation that creates a new market and value network that will eventually disrupt an already existing market and replace an existing product'* (Christensen, 2015).

Relative to their more established competitors, *disruptive technologies* are generally cheaper, smaller and offer higher levels of convenience (Christensen, 1997). One reason incumbent industries fail to be attracted to disruptive innovation is that they generally hold lower margins than current products or services. Moreover, their introduction very often occurs in insignificant, emerging markets. Finally, for incumbent firms, their most profitable customers do not generally ask for the service or product initially offered by the disruptive technology (Christensen, 1997). According to Christensen, the early adopters of the disruptive technology are frequently the least profitable customers in a market. Although many disruptive technologies *underperform* compared to established products in the short term, overtime, they begin to meet the performance required at the high end of the market. This relationship is shown in Figure 4.1 below.

Figure 4.1 Disruptive innovation versus sustaining technologies



Source: Adapted from Christensen (1997)

4.1.1. What is, and is not '*disruptive innovation'*?

Christensen's work, published in 1997, predates the era of mobile internet connectivity that acts as the basis for much of the DTT that is the focus of this report. It is important to note that many of the innovations that are taking place in transport (e.g. App based ride sourcing, electric vehicles, autonomous vehicles) do not, according to Clayton Christensen, strictly meet his definition of *disruptive innovation*. Christensen has argued that *disruptive innovation* has been widely misinterpreted and applied to any situation in which an industry is disrupted. In this section, we will use the example of *Uber* to illustrate what is and what is not a *disruptive innovation*. We do not wish to imply however that Uber is necessarily less or more important than any other DTT detailed in this report, but rather it simply provides a pertinent example in which to illustrate the theory of *disruptive innovation.*

In a recent article published in the *Harvard Business Review,* Christensen, Raynor, & McDonald (2015) note that *Uber* in its current form, which is very frequently held up as a *disruptive technology* in fact, at least according to the authors, falls outside Christensen's original definition. One of the reasons why *Uber* does not meet the formal criteria to be classed as *disruptive innovation* is because it began as a *more convenient* alternative to a traditional taxi (disrupters usually begin as less convenient) and because, at least according to Christensen et al. (2015), *Uber* customers previously used traditional taxis. An important criterion for a disruptive innovation is that it creates a *new* market for a product or service. However, Christensen et al. do acknowledge that *Uber* represents a grey area and there are interpretations in which such technology could be seen as meeting the classical definition. Indeed Christensen has come under criticism recently for failing to modernise his theory to be able to grasp the fact that disrupters are emerging not from just other companies within the same sector, but completely different industries, with *Uber* and *Tesla* being cited as examples (e.g. see Wadhwa, 2015)

While there is some debate as to whether *Uber* strictly meets the criteria of a *disruptive innovator* for the traditional taxi industry, *UberBlack*[2], according to Christensen et al. (2015) does meet the criteria in relation to the limousine industry. This is because *UberBlack* provides a cheaper limousine-like service, and people use this service who were not previously regular limousine customers. Moreover, *UberBlack* does not provide advanced booking (i.e. less convenient), which the established limousine industry does. One could argue however that the same situation applies to *UberX (low cost option)*, in the sense that it too does not provide advanced booking but traditional taxis do.

The taxi industry is highly regulated and Christensen et al. (2015) describe how this regulation has hampered innovation, which created fertile ground for *Uber*. This is pertinent to the Melbourne context:

> Uber's strong performance therefore warrants explanation. According to disruption theory, Uber is an outlier, and we do not have a universal way to account for such atypical outcomes. In Uber's case, we believe that the regulated nature of the taxi business is a large part of the answer. Market entry and prices are closely controlled in many jurisdictions. Consequently, taxi companies have rarely innovated. Individual drivers have few ways to innovate, except to defect to Uber. So Uber is in a unique situation relative to taxis: It can offer better quality and the competition will find it hard to respond, at least in the short term.

In summary, it has become common for a broad range of transport technologies (i.e. App-based ride sourcing, electric vehicles etc.) to be labelled *disruptive innovation* but very often do not meet the definition according to the originator of the term. However, to best meet the aims of this report, a broader definition of disruptive innovation will be used, which includes ride sourcing services (e.g. Uber), autonomous vehicles, shared transport, app based multimodal journey planners, dynamic car pricing technology and peer-2-peer car parking technology platforms.

Therefore the term 'disruptive' in a wider sense and 'emerging' can be used interchangeably throughout this report, unless specifically defined.

[2] The UberBlack service includes more luxurious vehicles and drivers must hold Driver's Accreditation, a Policy of Commercial Insurance and a Metropolitan Hire Car Licence.

4.1.2. Disruptive transport technologies (DTT)

As highlighted in previous section, DTT are beginning to impact across a wide variety of transport modes. This section offers a description of the main types of DTT, either currently offered within Melbourne, or expected to be available within the near future (next 2 – 5 years).

4.2. Car sharing

Car sharing can be seen as consisting of three distinct offerings, each of which hold characteristics of *disruptive technology*, highlighted in the previous section. A brief description of the different car sharing models is provided below.

4.2.1. By-the-day rental

The first has been around for just about as long as the car itself, rental *by-the-day* (e.g. Hertz, Budget, and Avis). This category has now evolved, such that rather than just accessing a car in full day increments, cars can now be accessed *by-the-hour*. This is becoming a very dynamic part of the market. At first these 'clubs' operated distinct from traditional car rental companies, and although many still do, there is an industry shift (e.g. Hertz) to enter the *by-the-hour* market.

4.2.2. By-the-hour car sharing

Car sharing services first became available in Australia in 2002. Launched initially as *Newtown CarShare* in Sydney, the service was rebranded *GoGet* and introduced in Melbourne in 2004. *Flexicar* launched in Melbourne in 2004, originally named *Flo Carshare*. Flexicar was purchased by Hertz Australia in 2010. *Green Share Car* was established in 2010 and currently has over 3,500 members, and over 130 locations in which vehicles can be rented.

Melbourne currently has an active *by-the-hour* car sharing market, with *GoGet, Flexicar* and *Greensharecar* currently operating within the city of Melbourne. *GoGet* had no Victorian members in 2011, but now have over 10,000. Flexicar membership has been growing steadily since 2005, with a sharper annual increase starting in 2012. As of December 2015 there were over 8,000 Victorian *Flexicar* members and over 250 cars.

Some car manufacturers are also entering the *by-the-hour* market due to an appreciation that changing consumer preferences are valuing *access* over *ownership*. A new Start Up, *DriveNow* owned by BMW, offers premium end vehicles in cities across Germany, as well as London and San Francisco.

Box 1 provides a distillation of some of the key findings that emerged from a City of Melbourne commissioned report into car sharing conducted in 2015 (City of Melbourne, 2015b).

In 2015, the City of Melbourne commissioned a consultant report on car share, which recommend that 'Council facilitate growth in the car share fleet operating in the city from 245 to approximately 2,000 vehicles by 2021' (City of Melbourne, 2015b, p. 1). The report contained estimates that one car share vehicle replaces about nine privately owned vehicles and car share members in the city of Melbourne drive half the distance of non-car share members. The authors assume that each car share vehicle supports around 20 members, with each vehicle reducing the distance travelled by car by 40,000 kilometres per year (City of Melbourne, 2015b). To date there are estimated to be around 5,500 residents of the city of Melbourne with car share membership, and this is estimated to have reduced the number of vehicles by 2,000, compared to no car share options (City of Melbourne, 2015b). The report estimates that current car share operations in the city of Melbourne deliver a public and private benefit of $3.4 for each $1 invested. According to the report, a car share vehicle is used 20 times per month, for an average of 6 hours per booking, with almost three-quarters of bookings involving less than one hour's driving time (City of Melbourne, 2015b). The implication of this latter finding is that car share vehicles are parked for much of their cycle.

Box 1: Recent analysis of car sharing in the municipality

Source: City of Melbourne (2015b)

4.2.3. One way car sharing

An offshoot of the *by-the-hour* car sharing offer is *one-way* usage, in which the user is no longer required to return the car to its original pick up location (Shaheen, Chan, & Micheaux, 2015), and can by *by-the-minute* rather than per hour. The benefits to the user are significant when one considers that, as introduced in Box 1, the typical *by-the-hour* car sharing rental lasts six hours, but involves less than an hour of actual driving (City of Melbourne, 2015b). The ubiquity of the smartphone coupled with the fact that one way is usually cheaper than returning the vehicle to the same location has made it very popular in the markets in which it is offered. In a survey of the current one-way car sharing market, Shaheen at el. (2015) note that there are now 18 operators providing one way car sharing, across 10 countries. There are two main methods by which one way car sharing operates; *free-floating* and *station based* (Shaheen, Chan, & Micheaux, 2015). Users of a free-floating system are able to leave the car anywhere within a defined 'geo-catchment', while station based systems require their user to park in designated parking bays.

In their engagement with industry, Shaheen et al. (2015) note that most operators considered expansion to be contingent on the degree to which the model can be integrated with public transport and electric vehicle charging facilities. In relation to public transport, this includes both the strategic location of designated parking bays, as well as access by public transport smartcard.

The Daimler Chrysler owned *Car2Go* is a leader in the one-way car rental market, currently operating in a number of European and North American markets. The Institute for Sensible Transport understands most Australian car sharing companies are actively exploring opportunities to offer *one-way* to their members. Initial discussions suggest a *station-based* approach is likely to be adopted.

The final subcomponent of the car sharing market is *peer-2-peer*. This can be thought of as *AirBNB* for cars. At least one company currently facilitates *peer-2-peer* car sharing in Australia (*CarNextDoor*), but it is yet to reach the scale of North American and European equivalents (e.g. *Turo*[3] and *SnappCar*). Given the fact that cars are used less in the city of Melbourne than any other municipality in Victoria, there is significant potential to grow the peer-2-peer market. The trend for developing digital platforms

[3] Formerly known as *Relay Rides*.

to enable the shared use of resources suggests that Melbourne will see a growth in *peer-2-peer* car sharing platforms. This may include the expansion of current operators, as well as the emergence of new enterprises.

Underpinning each of these car sharing subcategories are some economic and usage fundamentals. Cars can be costly to buy and maintain, yet for some 95% of their life, they sit unused (Shoup, 2005). It is this surplus capacity that helps make car sharing attractive to a growing number of people. As part of this project, the Institute for Sensible Transport will assess options available to the City of Melbourne for facilitating outcomes supportive of their strategic objectives.

4.3. Ride sourcing services

Routinely described in the media as 'ride sharing', services such as *UberX* are not 'shared transport', as the driver is making a trip purely to transport the passenger. A more accurate term for this type of service is *ride sourcing* (Rayle et al., 2014), in which an App is used to connect a driver with a paying passenger. The distinction is important because ride sharing suggests that the driver has a destination complementary to the paying passenger, when in fact, the driver is making the trip for the sole purpose of transporting the passenger.

The rise of *Uber*, and its equivalents rely on the ubiquity of the Smartphone and its GPS capabilities to connect drivers with passengers. Whilst not seeking to suggest *Uber* as the only service provider in this space, they are the largest and a brief description of their activities is instructive in the understanding of how these technologies may impact on the city of Melbourne.

Uber has been operating in Australia since 2012 and its cheaper version *UberX* has been in operation in Melbourne since 2014. The key difference between *Uber* and *UberX* is that *Uber* drivers are required to have a licence to operate a taxi or hire car. *UberX* has come under scrutiny from State regulators for not adhering to their existing taxi and hire car policies. *UberX* drivers must still show they have comprehensive car insurance, pass a police check and have a good driving record. In the months since this report was commissioned, the ACT, NSW and WA have allowed *UberX* to operate within their jurisdictions.

The Institute for Sensible Transport communicated with *Uber Technologies* as part of this report and although not all the requested data was made available, what has been provided is included in a separate, confidential version of this report (for the City of Melbourne).

4.3.1. Understanding the impacts of ride sourcing: what we need to know

Among the most important questions for local government is whether the emergence of ride sourcing services will lead to a change in travel patterns. As previously identified, even before the rise of app-based ride sourcing, millennials[4] rate of car ownership and driver's license rates had lowered from previous generations (Delbosc & Currie, 2013). Now, with a more convenient method of accessing vehicles, it has been suggested that future generations have less need for their own vehicles than previous generations. Indeed, recent market research found 22% of people who have used *Uber* in the last six months say *Uber's* availability acted to delay the purchase of a new car (Newberg, 2015).

An assessment of the current evidence reveals that there are more questions than answers regarding the impacts of ride sourcing. Many of the most crucial questions required to understand the impact of ride sourcing are yet to be sufficiently understood. To what degree does a platform like Uber cannibalise traditional taxi services and to what extent are their users substituting from public transport, or other modes (including the private car)? How has the availability of *Uber* in Melbourne

[4] Millennials are defined as being born between 1980 and the mid-2000s.

influenced private car ownership decisions? What impacts do ride sourcing services have on congestion, physical activity (if they were to substitute for active modes) and emissions? These are all important questions from a public policy perspective, yet little data exists within the public realm. This raises a point identified by most of the expert interviewees during discussions held as part of this project (see Section 6). The data that is required to answer these and other questions are held by the ride sourcing platform operators, or at the very least, could be relatively easily obtained by them. Currently, there is little in the way of regulation requiring these companies to provide the detailed information on trip patterns a public authority requires to understand their impacts. It was the view of the expert interviewees that in exchange for using public infrastructure (roads), ride-sourcing companies should be required to provide detailed data on travel patterns to relevant agencies. Notwithstanding these limitations, Uber Technologies have cooperated with the Institute for Sensible Transport via the sharing of some of the data requested for this project.

4.3.2. Uber usage within the municipality and links to public transport

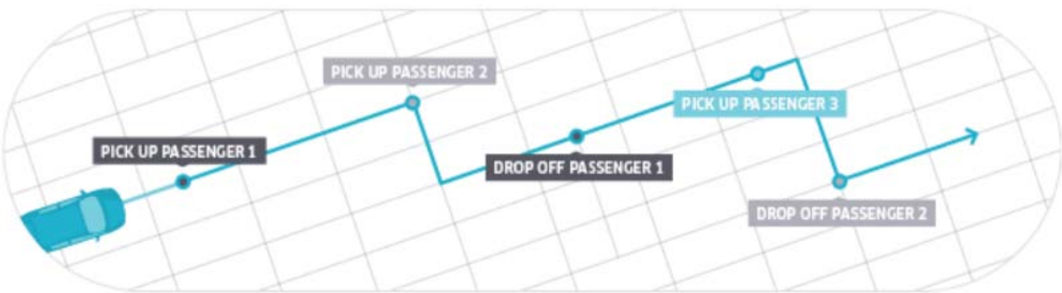
The City of Melbourne is one of the major areas for Uber pick ups and drop offs in Victoria. Additional data provided by Uber for this report has been removed due to Commercial in Confidence. Nate Silver, a Bayesian statistician has suggested that *Uber's* best growth strategy would be to work to integrate their service with public transport, as this offers the best balance between reduced journey time and price (Silver & Fischer-Baum, 2015).

Few people predicted the speed with which *Uber* has disrupted the Australian transport industry (primarily taxis) and regulators are now beginning to consider methods by which they can be brought under a form of regulation. The Australian Capital Territory is the first authority in Australia to begin regulating Uber (Belot, 2015). It would appear that the stance initially taken by state government agencies (fines and court actions) is beginning to soften. Although it is difficult to make predictions with any certainty, it would seem a form of regulation rather than outright ban is the most likely outcome from the reviews currently underway.

4.3.3. Shared ride sourcing services

A recent development within the ride sourcing sector has been the emergence of shared options, in which passengers can elect to share their ride with someone with a compatible route, in return for a substantial fare discount. The *Uber* service of this type is known as *UberPool,* with their US rival, *Lyft* calling their service *LyftLine*. Both services have been running in San Francisco since 2014 and reportedly now return more revenue to each company than their non-shared services (unverified by independent third parties). These services are in effect a *disruptive innovation* of the initial *Uber* and *Lyft* service and meet the criteria initially established by Professor Christensen. A visual description of how the service works can be seen in Figure 4.2.

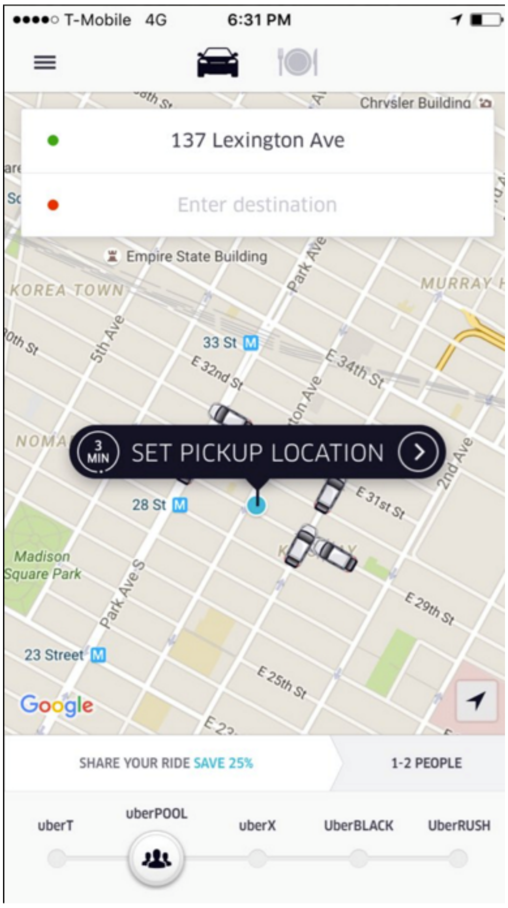
Figure 4.2 UberPool – the 'perpetual ride'



Source: Uber Technologies (2015)

To access *UberPool*, users indicate via their App that they are willing to ride with another party, as shown in Figure 4.3.

Figure 4.3 Selecting UberPool and other services, New York City



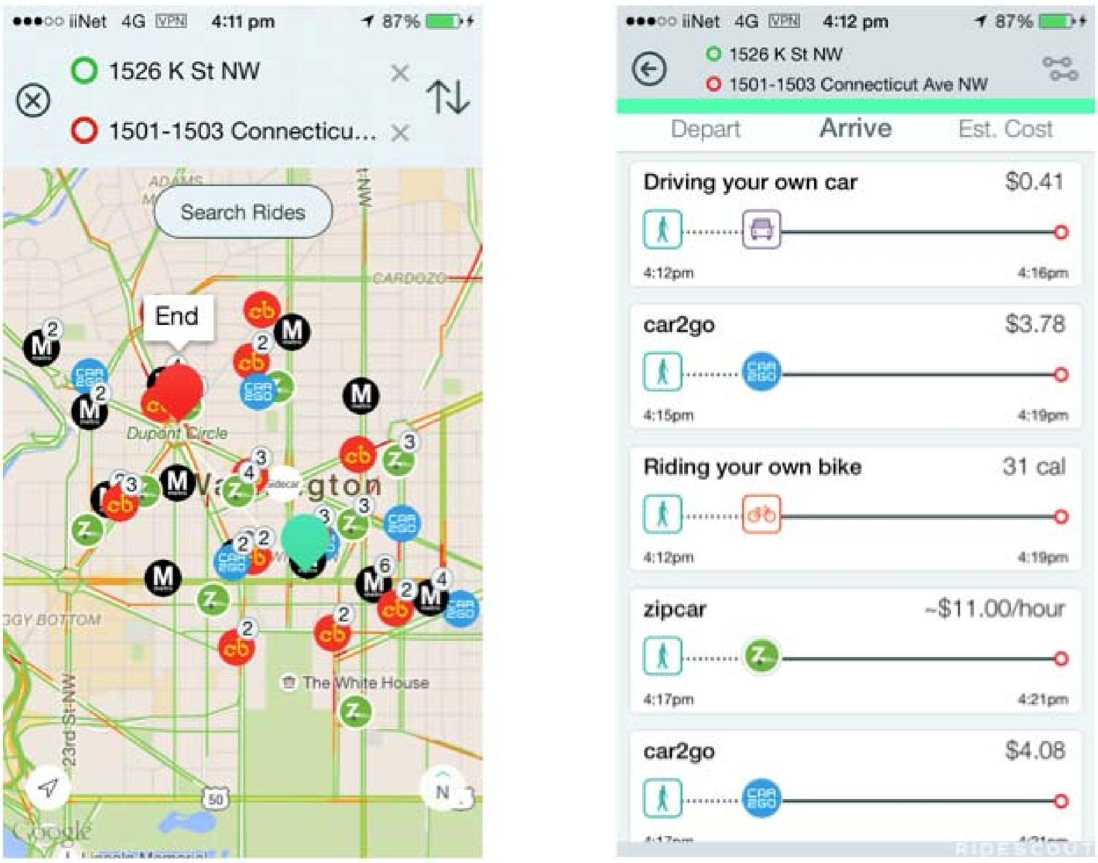
Finally, in some cities in North America and Israel, so-called *pop up transit* has emerged (e.g. Bridj), in the form of an on-demand bus service. In the past, on demand transport has very often failed, often due to staff (driver) costs (Enoch, 2015), although this may change as driverless vehicles become available. Even before commercial availability of driverless vehicles, the increased efficiencies that link riders with vehicles via GPS enabled smartphones may prove to bring the commercial viability of these services to a self-sustaining level (costs are met by revenue). *Bridj*, which run services in Boston and Washington, D.C. is a form of high quality shuttle (self-described as *'pop up transit'*), that enables users to request rides with their smartphone. The service can be requested days or minutes in advance and go to a pick up spot to meet the shuttle, which can be tracked in real time. Once on the shuttle, services are semi-express and passengers have access to Wi-Fi.

Whilst it is unlikely on demand public transport services such as those described above will compete with rail services to the city of Melbourne, there may be scope for the commercial sector to identify areas of outer Melbourne that suffer from low levels of quality public transport and meet a mobility need. If such services connect with rail lines, this may potentially have a beneficial impact on the city of Melbourne, in terms of reduced private cars travelling into inner Melbourne. Any operator seeking to provide such a service would need to comply with Victorian legislative requirements.

4.4. Multimodal, app based transport information

The ubiquity of the Smartphone has created the foundation for a wide variety of mobile applications focused on transport information. Many of these Apps share a common goal of enhancing transport mode decision making, which often equates to a more economical use of the private motor vehicle. Utilising GPS capabilities and API feeds from public transport providers, these Apps allow users to receive detailed, real time public transport information. Some Apps are even able to provide detailed, multimodal journey options, including estimated arrival time and price. A leader in this market is *RideScout*, which was recently acquired by Daimler Chrysler. As shown in the App screenshots in Figure 4.4, *RideScout* lists the available modes between an origin and destination, and shows estimated cost and journey time for each mode. Not listed in the right hand image in Figure 4.4 are the numerous other modes (including public transport and bike sharing) that were shown when scrolling the list of available options.

Figure 4.4 RideScout mobile App travel information, Washington, D.C.



These Apps enable users to make informed decisions based on current traffic conditions, utilising an optimised combination of different travel modes. Building on this one-platform, multimodal model, there appears to be a trend emerging for *in-App* ticket purchase, potentially eliminating the need for users to interact with traditional public transport ticketing (including smartcards). Portland, Oregon has been using *Mobile Tickets* since 2013 and have sold more than 5 million fares via the platform, with more than 230,000 downloads on the App. Portland was the first major US city to launch Smartphone ticketing. Recently, Chicago launched a Smartphone payment option (*Ventra Mobile App*), eliminating the need for paper tickets. Whilst the shift to Smartphone public transport payment is not strictly a *disruptive technology*, it does have the potential to make public transport use more convenient. In addition to not having to carry anything other than your mobile phone, these mobile tickets can also be used to send customised, location specific information to travellers. For instance, a public transport agency can use past travel history to notify users of service disruptions (potentially before the traveller has left their home or office), via the App, and thereby minimising the impact of cancellations or delays.

4.5. Peer-2-peer car parking platforms

As with many of the other innovations highlighted in this section, the widespread availability of Internet connected devices has enabled platforms to emerge that link people with a car park to those requiring one. *Parkhound* is one such platform, and operates around Australia, with over 3000 listed parking spaces. Those seeking a car park select the one that meets their requirements via Parkhound's platform and pay a set free to the owner. Although it is not entirely clear whether such a service has any impact on transport behaviour at the network level, it does, it would appear, assist in better utilising surplus car parking spaces.

4.6. Autonomous (driverless) vehicles

In the past 12 months several major companies have announced plans to offer commercially available driverless vehicles by 2020 (Bridges, 2015). In addition to traditional motor vehicle manufacturers, the technology giants Google and Apple have announced their commitment to developing a driverless vehicle, as has the high performance electric vehicle maker Tesla.

The emergence of commercially available autonomous vehicles in the near future is said to bring significant environmental, safety and economic benefits to society (Barclays, 2015). These benefits, it is argued, arise from significant improvements to road safety (some 93% of crashes today are due to human error)[5], improvements to road capacity, fuels savings from more efficient driving and subsequent lower emissions (Fagnant & Kockelman, 2015). Even if the distance travelled by autonomous vehicles doubles (which is predicted by most researchers), some estimate a reduction in crashes of 80% (Fagnant & Kockelman, 2015). The McKinsey Global Institute estimate the economic impact of driverless cars and trucks is within the range of $US200 billion and $US1.9 trillion by 2025 (McKinsey & Company, 2013). This estimate includes the freeing up of time that would otherwise be consumed by driving, safety improvements and reduced vehicle operating costs. It is the intention of this section to provide a brief overview of some of the pertinent issues for the city related to autonomous vehicles, given that this presents perhaps the most significant change in the automotive and transport sector since it began more than 120 years ago.

In a report on the future of autonomous vehicles it was noted (PwC, 2015, p. 21):

> According to the Economist, automobiles are among the most expensive investments people make, but they sit idle 96 percent of the time. Mobility-as-a-service reduces the number of cars and the congestion on the road, along with the number of parking spaces required for transportation. It will encourage cars that look different from the automobiles of 2015; it will challenge the way people think about cars in the first place.

This section examines the possible impacts of autonomous vehicles in relation to the core areas of interest to the City of Melbourne, namely; safety, changing ownership structures and use, congestion and parking.

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[5] According to a US report by the National Highway Traffic Safety Administration (Fagnant & Kockelman, 2015).

4.6.1. Driverless vehicles and safety

Autonomous vehicles are the ultimate defensive driver (Bridges). Road safety is a major issue for the city of Melbourne. Autonomous vehicles present an opportunity to reduce road trauma in several important ways. Autonomous vehicles are better able to drive within the speed limit, have faster reaction time for braking in the presence of an obstacle"(e.g. pedestrian), eliminate distracted driving and impaired driving caused by alcohol or other drugs. The City of Melbourne has committed to reducing road injury and fatality. Currently, a person is killed or injured while walking in the city of Melbourne every two days, with 956 pedestrians killed or injured between 2006 – 2011. The municipality records the highest number of people killed and injured while walking of any local government area in Victoria (City of Melbourne, 2014).

It would appear that autonomous vehicles present an opportunity to increase road safety outcomes in the city. The City of Melbourne has also committed to reduce death and injury to people cycling within their municipality and for the same reasons identified previously, driverless vehicles may offer reduced levels of road trauma to people on bicycles. In addition to the factors offered in relation to pedestrians, it is possible the incidents of *dooring*[6] may reduce, as autonomous vehicles may include sensors capable of detecting cyclists in the path of an opened door and delay opening until the cyclist has passed. The issue of dooring was identified in *Action 22* of the *Transport Strategy 2012* (City of Melbourne, 2012).

It is however noted that the adoption of autonomous vehicles is still some years away, and will take decades to replace the current fleet of vehicles. The transition period, when the vehicle fleet is partly autonomous, sharing the road with 'conventional' vehicles, presents a range of road traffic safety issues. For the City of Melbourne context, a scenario that may result in a significant proportion of crashes is when an autonomous vehicle brakes rapidly to avoid collision with a pedestrian. The reaction time for the autonomous vehicle will be rapid, but should the car travelling behind the autonomous vehicle be driven by a human, the slower reaction times may result in a collision between these two vehicles. In a congested, heavily pedestrianised environment, this crash scenario may be relatively common. Crashes of this type may also damage the autonomous vehicle's rear sensors, preventing it from continuing. This is simply one example of new crash scenarios that are currently being investigated by ARRB and Austroads as it prepares for the introduction of autonomous vehicles on Australian roads (see project details provided as part of Appendix 3.

4.6.2. Changing vehicle ownership and mobility as a service

In the United States, a car is, on average, driven for 56 minutes (4%) of the day (Barclays, 2015) and there is little reason to suspect this would be substantially different within the city of Melbourne. Developments in autonomous vehicles have occurred in parallel with the growth of the *shared economy* and many scholarly and consultant reports are arriving at a similar conclusion – autonomous vehicles present an attractive opportunity to gain access to mobility without the financial burden of ownership (Barclays, 2015; Bridges, 2015; Fagnant & Kockelman, 2015; McKinsey & Company, 2013; PwC, 2015).

A recent report by Barclays suggests that by 2035, the majority of vehicles may be autonomous and that in such a scenario, car ownership is potentially reduced by 50%. The authors of this report (automotive industry analysts), suggest that one shared car could replace *at least* nine privately

[6] Dooring is the term used to describe the opening of a car door whilst parked into the path of an oncoming cyclist. It is illegal to open a door into traffic but accounts for a significant proportion of cyclist injury.

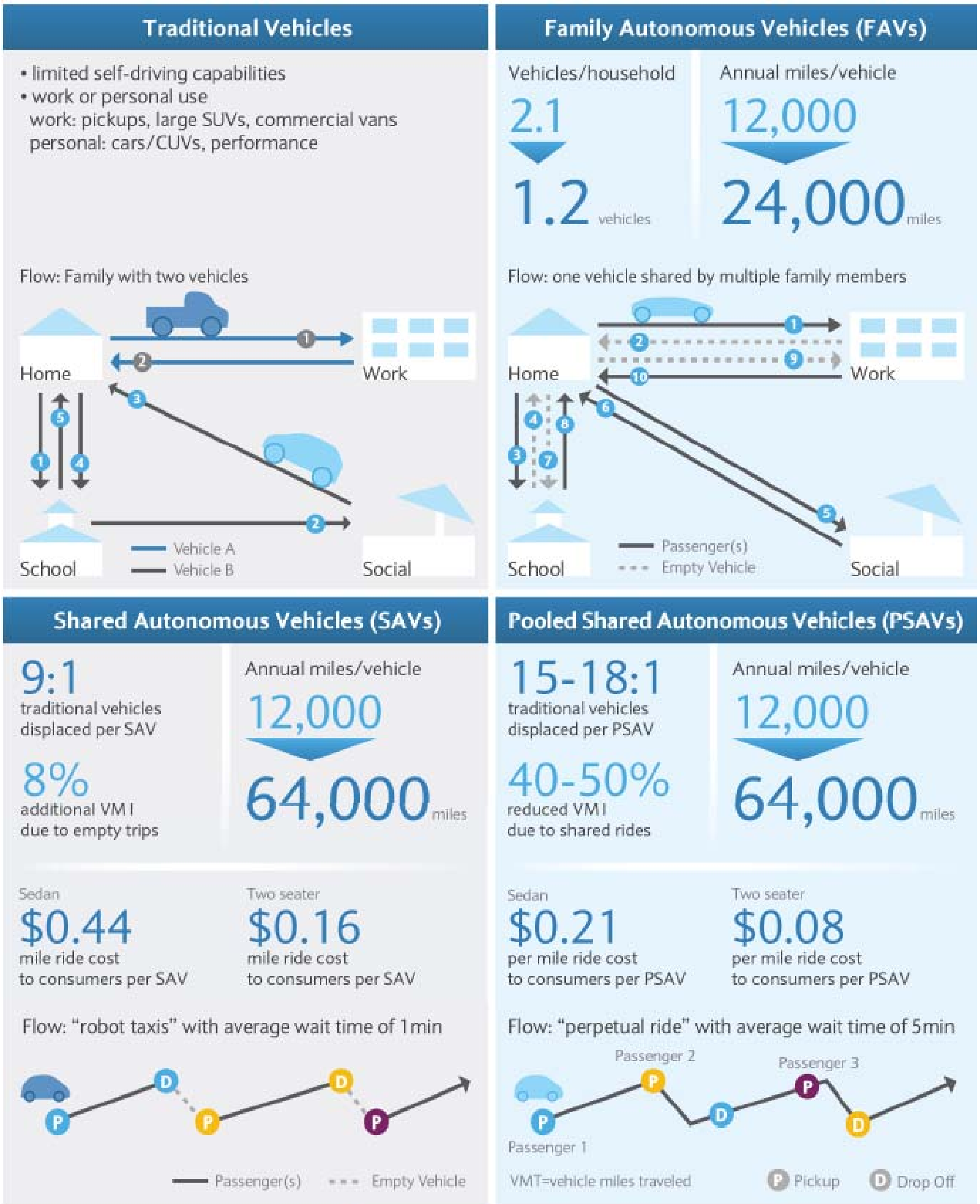
owned,[7] conventional vehicles (Barclays, 2015). In the report, it is theorised that driverless cars are likely to be divided into four categories:

1. Traditional vehicles: limited self-driving ability, used primarily for work, especially for tradesperson type industries. This category would also include those that specifically seek to have manual control of their vehicles or for reasons of 'status'. This category may account for around 25% of vehicles ultimately.
2. Family autonomous vehicles: essentially the same as a household vehicle of today in terms of usage, with the key difference being that it is driverless. There are significant negative consequences for network level congestion impacts should this category be the most prevalent form of driverless vehicle adopted. These consequence pathways are discussed in Section 9.2.5.7.
3. Shared autonomous vehicles: a vehicle used for ride sourcing (e.g., Uber, but without a driver), described in the Barclays report as a *robot taxi.*
4. Pooled shared autonomous vehicles: a slight variation of shared autonomous vehicles, with the difference being that they can take multiple independent passengers simultaneously, similar to *UberPool* or *LyftLine* (but without a driver), in exchange for a significant reduction in cost.

The four categories above are illustrated in Figure 4.5, with some indicative outline of costs and how they might function.

[7] This is based on the scholarly work of Fagnant and Kockelman (2015; 2015) using a modelling approach for Austin, Texas.

Figure 4.5 Four types of future vehicles and estimated usage/costs



Source: Taken from Barclays (2015), based on the work of Fagnant, Kockelman, & Bansal (2015)

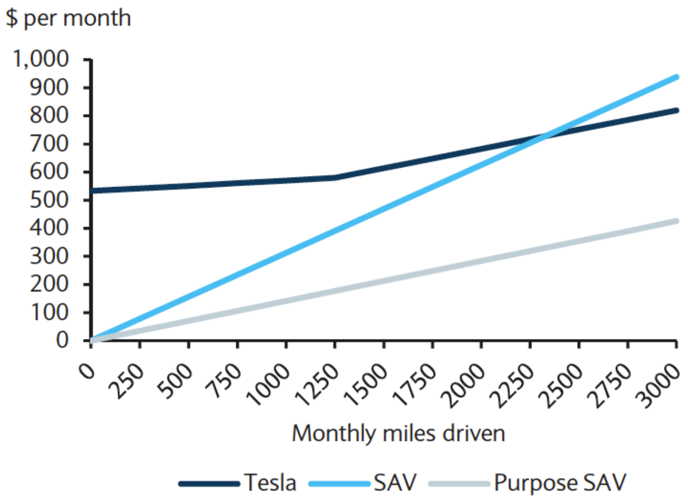
The top right quadrant in Figure 4.5 provides an illustration of how *family autonomous vehicles* might function, indicating that the total number of vehicles per household drops by half, whilst the distance travelled doubles. The two lower quadrants show how *shared* autonomous vehicles are likely to provide significant reductions in total vehicle numbers (each one replaces nine traditional vehicles), but 5.3 times greater annual mileage. The general pattern of less vehicles but more kilometres travelled in each vehicle is broadly consistent with the finding of other research (Adams, 2015).

In the modelled scenario from Austin, Texas, some 94% of all pick-ups involve a wait time of less than 5 minutes. The *pooled shared autonomous vehicle* is where the greatest efficiencies lie in terms of resource and usage charges. This usage type is estimated to replace between 15 – 18 traditional vehicles. This model is essentially a robot taxi that can take multiple, independent passengers, providing what is termed a '*perpetual ride'* (see lower half of bottom right quadrant for pick up/drop off pattern). This is essentially how *UberPool* and *LyftLine* operate today (conceptualised in Figure 4.5), with the only major difference being the presence of a driver.

The authors of the study that provided the basis for the estimates shown in Figure 4.5 note that their results were based on urban trip patterns and are not expected to be applicable to rural or outer suburban contexts in which trip distances are larger. Interestingly, this modelling found that almost 9% of vehicle kilometres travelled were with an *empty* vehicle (a subject that will be discussed in Section 4.6.3, reducing to 4.5% when the model introduced the possibility of ride-sharing (two or more independent people, pooling a ride).

One factor that may influence people's vehicle choice (i.e. of the four types identified above) will be the amount of travel they require. For those with high annual mileage rates, purchasing their own car may make more sense, from an economic standpoint. Barclays analysis suggests that for most people, based on U.S. driving patterns, a shared autonomous vehicle will be about twice as cheap than an even low cost Tesla (i.e. $US30,000 compared to more than $US75,000 in 2015). A pooled shared autonomous vehicle is estimated to be around four times as cheap as owning a Tesla. The relationship between cost and amount of driving is illustrated in Figure 4.6. This relationship is particularly relevant to the city of Melbourne, as residents travel less by car than all other municipalities in Victoria and considerably lower than the Greater Melbourne average (Australian Bureau of Statistics, 2012).

Figure 4.6 Monthly cost versus monthly miles driven



Source: Taken from Barclays (2015)

NB: SAV is Shared Autonomous Vehicle and Purpose SAV is a pooled vehicle.

4.6.3. Autonomous vehicles and congestion

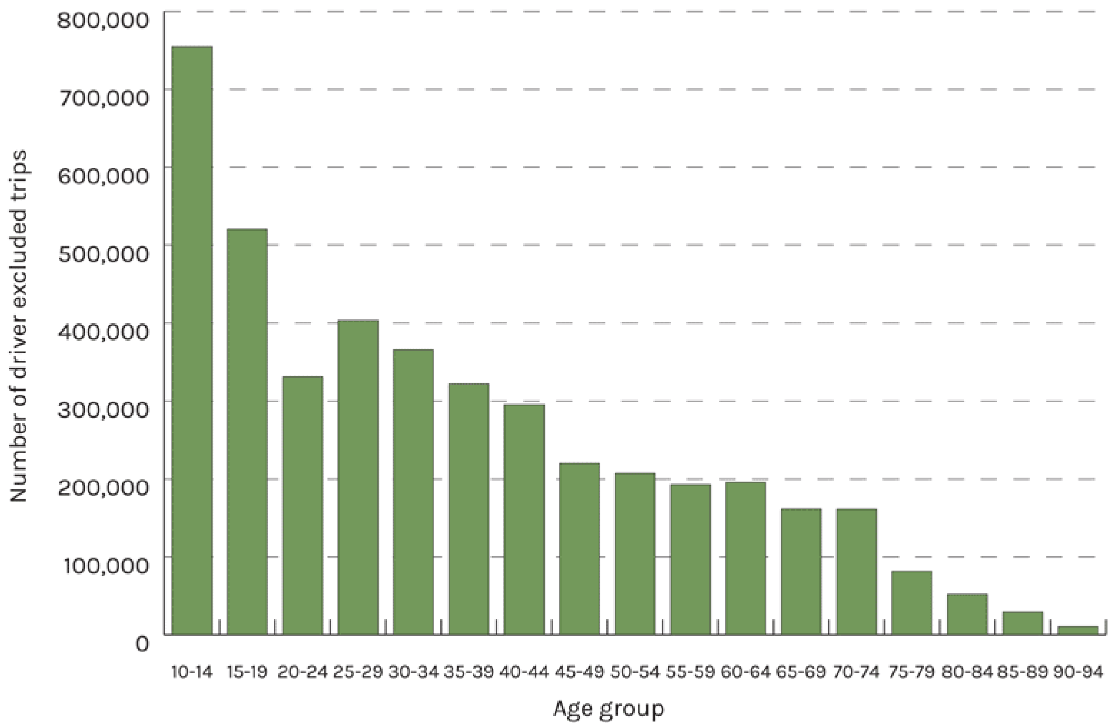
Congestion is considered a major issue for Australian cities, including Melbourne (Department of Infrastructure and Regional Development, 2015). One of the most pertinent, and as yet unresolved issues raised by the imminent introduction of autonomous vehicles is the impact they may have on congestion (Whiteman, 2015). The ability of driverless vehicles to drive closer together due to their reduced reaction time has led some people to argue that it will reduce congestion. At the other end of the spectrum, the greater accessibility of travel by automobile (e.g. those too young or old to drive currently), as well as the possibility of significant reductions in cost may result in VKT growth. It is currently too early to definitively know the precise impact autonomous vehicles will have on VKT or congestion (Whiteman, 2015) and this section is intended to introduce some of the emerging discussion points from the early work related to this important issue, with a particular focus on pertinent issues for the city of Melbourne.

Fagnant & Kockelman (2015), writing in the journal *Transportation Research Part A* suggest that autonomous vehicles, whilst bringing considerable benefit in terms of safety, convenience and reduced car parking requirements, may in fact *increase* congestion. The possibility of increasing congestion due to the availability of autonomous vehicles may occur via a number of pathways, as identified below:

- People who are too young or old to drive will be able to summon a ride. Some of these people may have been chauffeured previously, but some will be either making a trip they would not otherwise have made, or do so by autonomous vehicle rather than use another mode (e.g. public transport, bicycle).
- Pooled autonomous vehicles may be able to compete on price with public transport. Even if the cost is slightly higher than public transport, many non-CBD based trips may be substantially quicker than the same trip by public transport and this may result in a drop in public transport use.
- By not having to focus on driving, the rider avoids the 'time cost' of driving, which may increase their willingness to travel further or spend more time in congested traffic. This is supported by University College London risk analyst Professor John Adams (Adams, 2015), as well as each of the experts interviewed as part of this project (see Appendix B.)
- Cars may be able to drive without any occupants. Whilst this may reduce demand for car parking, it is likely to exacerbate congestion by increasing VKT. This is especially the case with those who choose to own their autonomous vehicle (as opposed to those accessing a fleet of vehicles). For instance, an owner may choose to travel in their autonomous vehicle from their home in a Melbourne suburb to their inner Melbourne workplace. Rather than parking their car near their workplace, the owner may simply send their car back to their home (empty), until it is time for them to travel home again, at which time it is summoned again, travelling from suburban Melbourne (empty) to the inner Melbourne workplace. Under this scenario, the VKT is doubled. Moreover, many autonomous vehicles will be electric, which incur about 20% of the running costs of an internal combustion engine (Bridges, 2015), potentially amplifying VKT growth. Should a situation such as this occur at a population level, the effect on the transport network may be dramatic, especially when this may occur at a time when Melbourne's population is closer to 7 million rather than its current size (4.5 million). Moreover, because the owner is not 'exposed' to the congestion when the vehicle is driving empty, they may be more willing to have the vehicle exposed to the high levels of congestion such a practice may cause – a cost which is imposed on other road users.

Figure 4.7 shows the number of trips made on an average weekday in the Melbourne Statistical District using a mode other than 'car as driver', broken down by age group. This provides an indication of the potential *latent demand* that might exist for a future autonomous vehicle service. Whilst some of these 'future trips' by driverless car may be replacing chauffeured journeys, a significant proportion may be replacing travel done by active or public transport. Moreover, it is plausible the introduction of an autonomous vehicle option will *induce* trips that would not have previously been made. In all, some 4.3 million trips take place on a typical weekday in Melbourne by those nominating a mode other than 'car as driver' (Department of Transport, 2009). These trips, coupled with those currently forgoing some journey that may take place due to autonomous vehicles represent new demand that may be unlocked by driverless cars.

Figure 4.7 Number of trips made by all modes other than 'car as driver' on an average weekday in Melbourne (MSD)



Source: VISTA 2009-10 (Department of Transport, 2009)

At peak times in particular, the congestion levels caused by the introduction of the autonomous vehicle, in the absence of demand management measures may exceed many of the other benefits associated with these vehicles. As a cautionary note, Professor Graham Currie and others identify that on demand, small scale motorised transport services are unlikely to be an effective replacement for heavy rail in the dense central core of the city during peak times, due to space efficiency reasons (Walker, 2015).

Several discussions have taken place as part of this project with scholars and practitioners on potential congestion impacts of autonomous vehicles. The central conclusion from these discussions is that the introduction of autonomous vehicles may require a form of *road user pricing* to be implemented. Without road user pricing, any potential benefits of driverless vehicles may be eroded by a significant increase in congestion, for the bullet pointed reasons offered earlier in this section. Moreover, as indicated previously, many of the driverless vehicles that will be introduced onto the road network will be electric, and whilst this has benefits in terms of urban air quality and climate change[8], it will also mean a reduction in the revenue collected by Treasury from fuel excise. In 2015-16, the Commonwealth Treasury expect to receive $19.26 billion in fuel excise (Treasury, 2013). Road user pricing is a way to both manage (reduce) congestion and recover some of the lost revenue from fuel excise reductions.

[8] If the electricity is generated from renewable, carbon free sources.

4.6.4. Autonomous vehicles and parking

One of the most direct outcomes from the anticipated introduction of autonomous vehicles is a change in car parking demand. Specifically, it is expected that autonomous vehicles will reduce the need and therefore the demand for car parking vehicles (Barclays, 2015; Bridges, 2015; Fagnant & Kockelman, 2015). Several pathways have been identified in which automation may change car parking.

Initially, a so-called *valet assist* will be provided by automakers in which the vehicle itself undertakes the necessary navigation to make it possible for the vehicle to park in an off street structure without the aid of an occupant. An example of this is expected to be offered by BMW (among others), called *Remote Valet Parking Assistant*, which uses a downloaded blueprint of the parking structure, to assist the car find a suitable park. When the car is required, the owner summons it from an Internet connected device (smartphone) and meets the car at the entrance of the parking structure. Whilst adding convenience for the user, the valet assistance described above is unlikely to have a dramatic impact on overall transport patterns, in terms of overall parking demand, mode choice or VKT. Fully autonomous vehicles however, capable of driving themselves on public roads are expected to have a much larger impact on parking demand. This can be expected to start taking place within 10 years.

The introduction of fully autonomous vehicles is of particular significance for the City of Melbourne, which receives substantial revenue from both on and off street parking. The scenario described in Section 4.6.3 in which an owner of an autonomous vehicle travels to central Melbourne and then avoids the cost of CBD car parking by sending their car to a remote car park (either back to the origin of the trip, or to a remote car parking facility) may have a profound impact on both parking revenue and congestion costs. The third way in which parking demand is expected to reduce due to driverless vehicles is related to the shared vehicle options discussed in Section 4.6.2. Under this scenario, the majority of car users are passengers of a car owned by a ride-sourcing company. This ‘robo-taxi’ is able to keep moving or travel to an area with surplus parking before being summoned by another user. Predicted growth in shared vehicles will reduce residential and commercial car parking demand, as well as on-street parking. From a local government perspective, there are clear implications for off street parking requirements. Moreover, there may be a reduction in revenue from parking fees and fines, with direct budgetary implications.

4.6.5. Summary

This section has highlighted a range of opportunities and challenges presented by the emergence of DTT. On balance, it appears this rapidly growing area holds considerable potential to enhance the mobility experience, but important challenges will need to be addressed to ensure these technologies do not impede the City of Melbourne in meeting its strategic goals – particularly in relation to sustainability, liveability or productivity.

It is worth noting, that whilst the technological capabilities enabling driverless mobility are moving at a rapid pace, consumer acceptance may take some time to adjust to the notion of driverless cars. Market research conducted by J.D. Power and Associates (2012) suggests that if autonomous vehicle costs were comparable to traditional vehicles, 37% would ‘definitely’ or ‘probably’ purchase such a vehicle when they renew their current car (cited in Fagnant & Kockelman, 2015). One interesting interpretation of this result is that two thirds of respondents would be unlikely to purchase an autonomous vehicle, even if it were the same price as a traditional vehicle. It is important to mention however that a significant problem with market research on autonomous vehicles is that they do not current exist as a consumer item. From a market perspective, *seeing* other people in an autonomous vehicle is an important requirement before people see it as an option themselves (Fishman, Washington, & Haworth, 2012). Finally, perhaps the notion of *ownership* of an autonomous vehicle is not the most pertinent question given the applicability of driverless technology increasing the attractiveness of *shared* mobility.

The city of Melbourne is in a unique position, as the economic, cultural and transport centre of Victoria to capitalise on the opportunities these technologies present. The next section presents the outcome of interviews with leading experts in the field, followed by a synthesis of findings from the workshop held as part this project with City of Melbourne staff.

5. Interviews with leaders in emerging transport technologies – summary of findings

A series of interviews were conducted with leading transport policy specialists as part of this project. Each telephone interview was conducted over a period of 30 – 60 minutes in September 2015 and interviewees were offered a brief description of the project and then asked to discuss the current developments within the field of DTT. Interviewees were also asked to explore what issues and opportunities they saw for local government, in terms of capturing the benefits associated with DTTs. A synthesis of the key discussion points of relevance to this project is provided below.

- The following people were interviewed:
- Professor Graham Currie, Monash University, Australia
- Professor Susan Shaheen, University of California, Berkeley
- Kristen Handberg, Connected Mobility – New Energy, AGL
- Professor Koen Franken, Utrecht University, The Netherlands
- Timothy Papandreou, Director, Office of Innovation, San Francisco Municipal Transportation Agency, San Francisco

The detailed material, based on the conducted interviews is attached to this report. Below only summaries of that material are presented, grouped around emerging technologies:

5.1. Car sharing

Much of Professor Shaheen's research has involved car sharing in San Francisco, including the requirements car sharing companies have for curbside car parking. Professor Shaheen provided a historical account of the different pricing scales car sharing providers have incurred for curbside parking.

The mainstreaming and scale of car sharing has meant, according to Shaheen, that a model of *car sharing as a business,* is considered appropriate under the 2015 context. One of the reasons why Professor Shaheen considers the car sharing industry to be a fully-fledged *business* is because of its scale. It is not uncommon (at least in some North American cities) for these businesses to apply for hundreds of curbside spaces at a time, and given they are operating their private business on what is essentially public space, it is considered reasonable for a government authority managing that space to charge accordingly.

Kristen provided an introduction to his work with AGL, part of which involves planning for an electric car sharing service. Initially this would focus on commercial fleets, rather than individual users. It was noted that although the economic case for moving to an all electric fleet is not currently present in Australia, there may be other motivating factors for businesses to consider an AGL leased fleet of electric vehicles. These reasons are primarily related to the social and environmental creditability associated with a zero emission fleet[9]. For AGL's existing customers, opportunities were identified in which their electricity account can be linked to their electric car charging, to facilitate transfers and credits between stationary electricity consumption and electricity consumed by vehicles. This may be useful for AGL's solar customer, in which surplus energy generated through solar panels can be

[9] Zero emission to the extent that the electricity is generated from renewable, non-carbon sources.

stored in the battery of an electric vehicle, rather than fed into the electric grid (which is poorly renumerated relative to the cost of a unit of energy).

In recent years, one-way car sharing has emerged as a more efficient method of short-term car sharing (see Section 4) and this was something Professor Franken noted as an area likely to grow in the future. It is considered more efficient from a user fee perspective (only pay when actually driving).

Professor Franken spoke of a *convergence of interests* related to shared transport, in which a synergy between organisations, the public, and local government agencies can co-exist and help foster desirable outcomes.

An industry shift has been identified in which car manufacturers are now beginning to move from *producers* to *service providers*. This is already apparent in Europe and North America, where, as highlighted in Section 5.1 Daimler Chrysler offers *Car2Go* and BMW offers *DriveNow* – both of which offer one-way trips. The usefulness of such services in the Melbourne context is underlined by the fact, highlighted earlier, that the average rental period is six hours, yet the time actually spent driving is one hour (City of Melbourne, 2015b).

5.2. Bike sharing

Professor Shaheen, in addition to being an expert in shared car use, is also one of the world's leading scholars on bike sharing (e.g. see Shaheen, Cohen, & Martin, 2013). Technology was seen as an opportunity to help make bike sharing more user friendly, with electric bicycles, GPS and smartphone payment helping people sign up and use bike sharing. Professor Shaheen felt that more could be done to create pricing structures that allowed people to take longer trips without financial penalty, especially at times when demand is low.

Professor Franken identified that these DTT relate to bicycles as well as cars. He mentioned that modern bike sharing systems, which facilitate one way rental (i.e. the user is not required to drop the bike at the same location they began their journey) offers significant potential to increase the efficiency of the transport system. Moreover, he noted that for cities like Amsterdam (which is in the somewhat unique position of having more bicycles than people), bike sharing holds the promise of reducing the crowding of city streets with parked private bicycles.

5.3. Public transport

Professor Currie was able to readily identify the benefits offered by real-time, mobile devices (e.g. auto-alerts to public transport passengers regarding a delay), but was also sceptical of some of the claims made by technology companies currently operating in the transport sector. Much of this scepticism related to the lack of independent, 3rd party verification of their usage data.

On the relationship between technology and public transport, Professor Currie spoke about the emergence over the last 5 – 10 years of real time information, delivered to passengers via their Internet connected device (e.g. Smartphone). It was also identified that public transport providers are *'crowdsourcing'* their services, by offering location specific, mobile phone based online surveys to passengers, to better calibrate service levels to passenger need. Related to this, operators now have the ability to be able to send live updates to users, based on their previous travel history, in order to provide customised information to passengers regarding delays and cancellations.

5.4. Multi modal journey planning

One of the major themes that emerged from the interview with Timothy Papandreou was the work of the SFMTA in assisting industry in providing *interoperability* between different modes, through the use of an App. The model discussed was one in which all modes of transport would be housed in the one App, which would be designed to facilitate *in App payment* (similar to the platform identified in Section 4.4. using the example of *RideScout*). This would move beyond the one agency App (e.g. PTV App), such that when a user enters their desired destination, *all* mobility options are presented, including walking, cycling (private *and* public bike), taxi, Uber (including all variations), public transport, and private and shared car. Importantly, the App is intended to offer multi-modal combinations, which may include a component of Uber, in order to access a rail network, to complete a journey. The user is able to find and pay for the transport services using nothing other than a smartphone. Timothy identified *RideScout* as well as their partner company *GlobalSherpa* as providing the SFMTA with a multimodal journey information platform that includes in App mobile payment. Timothy mentioned that SFMTA is set to launch such a service by the end of 2015 or beginning of 2016 (beta testing). If Uber and Lyft are interested, the SFMTA App will be able to be linked to these platforms so these services become part of the modes included in the App. If they are not interested, the API can work the other way, so that their Apps can be linked to SFMTA, rather than the SFMTA linked to their App. APIs can work both ways. So, the Uber customer that has nothing to do with SFMTA can use the Uber API, so that the payment, processed through the Uber App can be a valid form of payment to get on a train, when a journey involves both Uber and public transport. In such a situation, *Uber* sends the money to *RideScout*, who then sends it to the *SFMTA*. This scenario, which embeds many of the core principles of integrated transport planning due to its focus on the door-to-door experience of the user (Givoni & Banister, 2010) requires three elements:

1. Open data.
2. Clean, ‘digestible’ data. This requires a protocol, such as the *Google Transit Protocol* (GTP). This is presented as an open API.[10]
3. Payment system (e.g. GlobeSherpa).

The next area (after the above) that SFMTA would like to move ahead with is *mobile porting and unlocking.* This describes a situation in which a mobile phone essentially acts as the ‘fob’ or smartcard that has previous been required to access mobility services such as bike sharing, car share vehicle or public transport. The goal is for the smartphone to be the only device required to move between and pay for all modes of transport. A related project that is currently being undertaken by the SFMTA is to use all public transport nodes as Wi-Fi hotspots.

An important part of the SFMTAs role in all these developments is the enhancement of the customer experience. The SFMTA sees themselves as having an important role to play in this because many of the disruptive mobility companies see their service as the ‘next big thing’. The customer however does not necessarily share this view, and are more likely to be concerned with safely getting from A to B. The SFMTA therefore attempts to create the conditions for an *integrated travel experience*. Ultimately, from the user experience, it all needs to act as one system, to paraphrase Timothy Papandreou.

5.5. Service on demand, ride sourcing

In relation to ride sourcing services, Professor Currie raised concerns about the possibility that drivers may be travelling without passengers to move towards areas that offer more likely pick up locations, and thereby impact on congestion. One might imagine that this is not any different to the behaviour of traditional taxis. Additionally, equity questions were raised in the event that ride sourcing services favour inner city areas with higher demand, to the exclusion of outer suburban low-income areas. An analysis from millions of taxi and Uber trips in New York City (not discussed as part of the interview)

[10] The SFMTA does not use timetabling information, but rather the specialist service *NextBus* (a private technology company).

suggest traditional taxis and Uber serve a very similar geographic and demographic market (Silver & Fischer-Baum, 2015).

Emerging technologies in transport are also being applied to what Professor Currie refers to as *demand responsive transport services*. More information on UK research on demand response transport can be found in Appendix B.

Timothy Papandreou mentioned that many of the characteristics of ride sourcing services represent significant improvements in service quality compared to the traditional taxi industry. This includes:

- Clean vehicles, inside and out
- Clean drivers
- Cashless payment
- Reduced wait times.

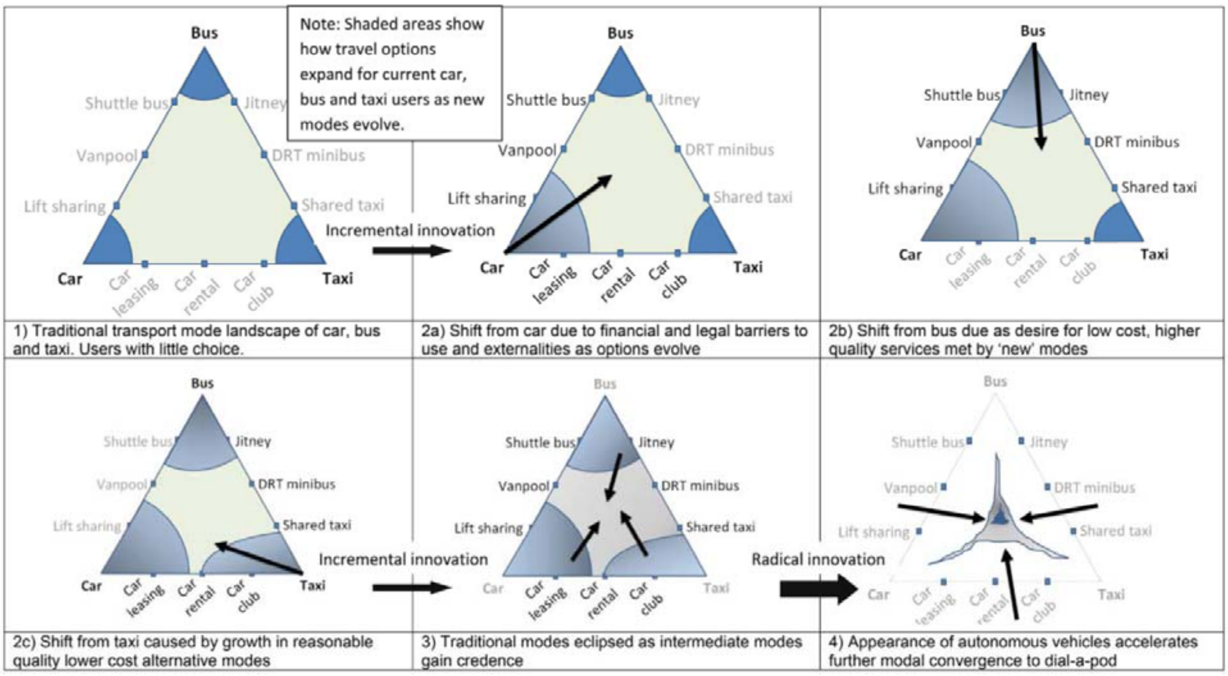
Timothy highlighted that there are still some advantages that traditional taxis have over the new ride sourcing companies. For instance, they do not use *surge pricing*[11]. However, traditional taxis refusal to offer pooled services[12] and this has reduced their relative value proposition in San Francisco, as it gives give Lyft and Uber a major advantage, from a price perspective, and an environmental outcome.

5.6. Mobility as a service

In terms of the future of DTT, Professor Currie suggested a *convergence model* may occur, in which motorised modes of transport (car, bus and taxi) could become blurred, with hybrid forms of transport that share characteristics of each of these modes, as illustrated in Figure 5.1, using the work of Dr Marcus Enoch.

[11] Surge pricing increases the cost of rides when demand is high, in an effort to attract more drivers to an area, and encourage drivers to work at peak times (e.g. Friday and Saturday evenings).
[12] Two or more independent passengers with different drop off locations share a ride.

Figure 5.1 The convergence model of transport



Source: Enoch (2015)

Based on current trends, Professor Shaheen foresees a *convergence* in which shared, connected and autonomous mobility combine to offer a *mobility-as-a-service*. Such a service was seen to provide greater utility (compared to the driver owned model) for most people. This convergence, although arrived at independently, is similar to the conclusion reached by scholars such as Dr Marcus Enoch and Professor Currie highlighted earlier (also see Enoch, 2015). Again, the idea that *micro transit* may become more efficient through the use of GPS enabled Internet connected devices and therefore offer a more viable business model was introduced. Moreover, the prospect of providing such services as an autonomous vehicle and thereby eliminating the largest cost (the driver) is likely to enhance the cost effectiveness of *demand responsive transit.*

A bundled, door to door, integrated mobility solution was one idea explored during the conversation with Kristen. In this *mobility as a service* model, all transport services are groups together, including public transport access, electric car usage, including agreements with parking providers and toll operators.

5.7. Parking

Professor Currie noted that app based parking applications are now available (e.g. Parkapedia), as well as more policy driven applications, such as *SF Park* (see Box 2 in Section 5.7), which is essentially an implementation of the concept originally advanced by Professor Donald Shoup (2005). Such developments, in which the cost of parking is adjusted based on demand has the potential to flatten peaks and increase the likelihood of maintaining a small proportion of available spots at any one time.

The City of San Francisco is considered a leader in parking policy within the US. One of the final components of this interview involved discussion of the impact of emerging technologies on car parking. Three factors were outlined as essential if government and the community wish to fully benefit from the emerging transport technologies that are on offer:

1. Enable shared ride solutions to train stations. Like Melbourne, train stations around San Francisco experience higher levels of car parking demand relative to supply. Facilitating ride sharing options to train stations will help free up car parking around the station For instance, if an Uber service was able to take three people to a train station, that frees up to three car parking places at a train station. If that Uber driver could make three trips during peak hour, that amounts to nine people who have arrived at a train station without one parking space required. Timothy mentioned that there could be an argument for public subsidy, to bring the cost of these rides down to something that is acceptable to the travelling public (considering that they then become customers of the train service). The public transport agency needs to do an assessment of the benefits of such an initiative, to work out what it is worth to them and whether there is the carriage capacity to take additional passengers.
2. Employers with large car parking capacity should be encouraged to consider reducing their need for this space, via the use of ride sourcing services, in conjunction with public transport. The benefit to the company relates to the opportunity this space creates for them to repurpose it, or, if they have no immediate use, to sell or lease it. Timothy mentioned that in all the market research conducted by the SFMTA, few want to drive to work, so a solution such as this might be tapping into people's openness to get to work without having to drive. This is a solution that might work in suburban settings in which public transport is not a time competitive option, but ride sourcing and on demand micro transit might be able to meet commuting needs.

On street car parking reform. This is perhaps the most pertinent point for the City of Melbourne. As part of his responsibilities with the SFMTA, Timothy seeks opportunities to reduce the total number of on street car parks and better manage existing ones, aided by car sharing and dynamic pricing mechanisms. A 'traditional' car sharing car (e.g. Flexicar or GoGet), it was argued, takes at least nine cars off the road. If a car sharing pod can be on every second block in San Francisco (needs to be based on intensity of land use factors), it would be possible to eliminate a quarter of on street spaces, without reducing access for people who are driving. This arrangement does require a Public Private Partnership in which the agency cross subsidises the car sharing services. For ride sourcing services, if they can 'pulse' in and out of particular areas, on street car parking could be further reduced, and repurposed for other productive uses (e.g. footpath widening, café, parklets).

A summary of *SF Park* is provided in Box 2.

In the past five years, the City of San Francisco has implemented a program of dynamic pricing for on street parking. Known as SF Park, it is based on the work of the world's leading parking policy researcher, Professor Donald Shoup (see Shoup, 2005), in which the price is based on demand, with the goal of having 15% of all spaces available at any given time. By balancing supply and demand through price, it reduces the amount of circling involved in looking for a curbside parking space.

The results of SF Park show traffic congestion has reduced by 10%, as has dangerous driving (as motorists looking for car parking often display less attention on other aspects of the road traffic environment).

The SF Park experience has been that people do not care as much as initially thought about the price of parking (up to a point), but place greater value on its availability. SF Park has increased the number of spaces available in many locations, which has resulted in fewer people circling, looking for parking spots. Some high demand areas of the city have seen sharp increases in the cost of parking, while other areas have seen a reduction in the cost of parking.

SF Park also enables people to top up their spot via a smartphone App, allowing people to stay for an extended period. This has resulted in a reduction in the number of fines issued. Contrary to opinion both within and outside local government, longer stays has not seen a reduction in retail revenue. The conventional wisdom was that less car parking turnover would reduce the number of shop customers and therefore negatively impact on retail income. However, in the five years of SF Park, the experience has been that by allowing people to top up and stay longer, people are able to do other things in the city, which increases the amount of money spent per car driver. Three to four hours was found to be the 'sweet spot' according to Tim Papandreou, the Director of Innovation at the SFMTA (2015). One hour, according to Papandreou only allowed the person parked to achieve one task before needing to return to their vehicle, whereas three to four hours was sufficient to achieve several business or social tasks. Three key outcomes from the SF Park experience include:

1. Greenhouse gas emissions reduced by 30%
2. Congestion went down by at least 5 – 10%
3. Public transport vehicle speeds increased and travelled more reliably through the areas in which SF Park operates.
4. Collisions with pedestrians and cyclists did not increase – despite the number of cyclists increasing over the period.

Some 29% of the SFMTA operating budget is fees and fines. The revenue derived from parking helps pay for public transport services. Overall, the SF Park trial did result in high parking fees (up 15%) and this additional income helped to offset the reduction in fine revenue to the municipality. Sales tax and property tax went up in the areas with SF Park, although this may have been due to other factors. The ability for people to top up using the App reduced fine revenue by about $5M, but some $6 in extra sales and property taxes helped off set this. Ultimately, SF Park enabled people to stay in the City longer, spending more money.

SF Park has won a large number of awards, including the 2013 Public Parking Program of the Year, the 2013 Sustainia100 Top 10 Innovations in Cities, the International Parking Institute Top 10 Innovative US Parking Programs 2013, the Harvard Kennedy School's Top 25 Innovations in Government 2013, the 2012 Bay Area MTC Excellence in Motion Award of Merit, the 7x7's Best of San Francisco 2012, the 2012 Living Labs Global Award, the 2012 MFAC Good Government Awards, the 2012 Excellent.gov Awards-Excellence in Innovation: Mobility, the 2011 Department of Defence Technology Symposium Best of Show Award, the 2011 SF Weekly Web Award – Best Local Government Site, and the 2012 ITDP Sustainable Transport Award. More details on Awards can be found at the SF Park Awards webpage (http://bit.ly/1M5AfnP).

Box 2 SF Park, San Francisco

5.8. Autonomous (driverless) vehicles

Professor Currie was sceptical about predictions that autonomous vehicles would form a large proportion of the national fleet over the next one or two decades, and suggested it may be at least 30 years before the majority of vehicles are autonomous. He mentioned that whilst there is some evidence that autonomous vehicles may increase the road capacity, by around 11% (by reducing the distance between cars), the benefits of this are unlikely to be easily recognised, as they will be surpassed by growth in the number of cars. Perhaps the more important benefit offered by autonomous vehicles, as identified by Professor Currie was the potential to change the *vehicle ownership model.* The standard practice, it was argued by Professor Currie, has been for individuals to purchase their own vehicles, culminating in very high levels of vehicle ownership in Australia. The autonomous vehicle offers the potential to provide mobility without the need for ownership. Several motor vehicle manufacturers have begun offering car sharing options (as identified in Section 5) and this is perhaps a sign that these companies are recognising that *access not ownership* is becoming important to the market, especially younger adults. This was a point that emerged as a common theme throughout all the expert interviews conducted as part of this project.

Professor Currie also recognised that autonomous vehicles, at least in theory, may no longer need to park, and this has the potential to increase VKT, identifying the same scenario introduced in Section 4.6.2 and Section 4.6.3. This scenario presents a real risk of eroding the potential benefits of autonomous vehicles and points to the need for governments to consider pricing car use via a form of road user charges

The autonomous vehicle was something unlikely to achieve substantial market penetration for up to 50 years according to Professor Franken, which is broadly consistent with the earlier assessment from Professor Currie. Professor Franken noted that the emergence of fully autonomous vehicles may change the way 'drivers' value time, as they may engage in other activities, rather than solely focused on driving. This may have the effect of extending what is known as the Marchetti Constant (Marchetti, 1994), which in effect means that rather than people having a 'travel time budget' of perhaps one hour per day, it may grow to something substantially larger than this. This was a reoccurring point throughout the discussions held as part of this project. Indeed it was pointed out that this effect may be amplified should people choose to live further from their work for instance, thereby exacerbating congestion levels.

. Whilst this is largely a repeat of the issues raised in Section 4.6.3, it is noteworthy that the literature reviewed in that section, as well as all the interviews with experts arrived at a very similar scenario.

The key question, which is a reoccurring theme throughout this project, is to what degree will autonomous vehicles make the private ownership model redundant? Separate to this interview, it has emerged that planners within the Victorian Government have begun examining the same question, and have raised the possibility of congestion becoming very much worse should the private ownership model continue after the transition to an autonomous vehicle fleet (e.g. see Whiteman, 2015). The possible introduction of a road network pricing mechanism was put forward by Timothy as a method of managing the congestion issues that might arise from the gradual introduction of a driverless vehicle fleet. A road pricing mechanism, it was suggested, could include a range of pricing options, not dissimilar to surge pricing, in which vehicles are subject to a high fee based on congestion levels. These can be pre-trip based calculations, so there are options available to avoid these changes, either by using a different mode, different travel time, or different route.

On a related issue, Timothy and the SFMTA are in talks with *Uber* and *Lyft* to see whether trips that involve travel through the most congested roads at the most congested time of day can have a surge pricing model applied, allowing for a split revenue stream between the ride sourcing platform and the SFMTA.

At a more general level, Timothy has been working with his team exploring what the transport environment might look like in 10 – 20 years (in terms of a mobility market place), and what the SFMTA can do to capture the possibilities it will offer. A key question to be addressed is *'How do we want people to commute in the future?'* and then develop an implementation plan to realise that vision. Timothy sees a future in which the opportunities provided by these emerging mobility technologies may help us to transform our streets such that they may only need to be 1/3 as wide, with the space repurposed into separated bike lanes, plantings, parklets, micro business enterprise, even property development applications for very large intersections. One of the real difficulties according to Timothy will be the transition period we are about to enter, in which there might be 10% driverless vehicles and 90% at some other, lesser stage of autonomous vehicle This could, according to Professor Graham Currie, last for up to four decades. The next years 2015 – 2025 are probably not going to be quite as *'interesting'* according to Timothy Papandreou as the ten years from 2025 – 2035, when these technologies approach mainstream adoption. Ultimately, it was concluded, it is not *transport* itself, that ought to be the focus, but rather how emerging technologies can enable our cities to be more *economically competitive*, *liveable* and *sustainable*. A mobility strategy focused on economic competitiveness offers planners the ability to go much deeper in terms of policy solutions than when the focus is only on reacting to transport issues of the day. Timothy concludes by arguing that '*Transport is a key part of economic competitiveness and the goal should be to reduce and minimise the need to have to drive a car, by yourself, all the time. For reasons of physics and geometry, this needs to be the goal'.*

5.9. Professor Susan Shaheen, University of California, Berkeley

A key theme emerging from the discussion with Professor Shaheen was the degree to which DTT companies have *responsibilities* to regulators and the community more generally. Central to these responsibilities is the reliance that so many DTT companies have on public utilities, namely public streets. It was the view of Professor Shaheen that in exchange for the use of public infrastructure, ride sourcing services and other platforms have a responsibility to both contribute to the costs of maintaining that infrastructure, as well as share information that is in the public interest. For instance, Professor Shaheen described how the Californian Public Utilities Commission recently sued Uber for $US7.3m for not providing the necessary data for it to perform an equity analysis (DeAmicis, 2015). The information requested by the Californian Public Utilities Commission included data on the number of requests it received for disabled access vehicles, crashes, rider post code, the cost passengers pay for their trips, and the proportion of times a request for a disabled access vehicle was provided when requested (DeAmicis, 2015).

Professor Shaheen made the point raised by other interviewees; road user pricing is likely to emerge as a necessary tool to manage the congestion that may result from comparatively cheap, autonomous mobility, even under a shared/pooled transport model. It is plausible that a road pricing model might also include costs to ride sourcing platforms, for their use of public infrastructure.

In summary, Professor Shaheen is optimistic about the potential for technology platforms to enhance the sustainability of urban transport systems and reduce the need for vehicle ownership. Regulators have a right to impose requirements on ride sourcing services in order to ensure providers are not creating avoidable *inequities of access* or other unintended consequences. Professor Shaheen suggested that DTT companies should be required to share data, in exchange for the use of public access (e.g. streets), a view shared by others in these expert interviews.

5.10. Professor Koen Franken, Utrecht University, The Netherlands

Professor Franken, a leading European expert in the field of innovation and the sharing economy was keen to highlight the context within which DTT are currently operating. In particular, the *peak car* phenomenon (Goodwin & Van Dender, 2013) has seen young people postpone car ownership, and Professor Franken identified that it may well be the case that a growing number of people simply choose to never own a car. This is in part a reflection of changing priorities, in which car ownership is less a signifier of individual identity than it used to be (possibly replaced with mobile device ownership). In Europe Professor Franken noted that there is a shift towards *private lease* for those that do want exclusive access to a car, and a move away from outright ownership. The shift towards private lease arrangements has been influenced by cost reductions. Indeed the cost of car use – whether in the form of exclusive or shared use is becoming cheaper, and this raises issues regarding the role of government in managing the changes that are currently taking place in the car market. This is coming into sharp focus on the issue of autonomous vehicles. Professor Franken argued that the policy outcomes emanating from the rapid development in DTT are largely in the hands of government, via the policy levers they control. In essence, government, it was argued, can help make these DTT '*big or small'*, and can alter the way in which they are used, based on an analysis of whether they are likely to supporting the strategic objectives of government.

The role of government, according to Professor Franken, when faced with the emergence of autonomous vehicle availability, will be to create the necessary incentives to encourage shared rather than private ownership. This, he says, involves a combination of changes to fiscal policy, parking policy (including constraints on supply and increases in price), and road user charging. Whilst the road user charging issue is fraught politically, the prospect of not enacting such a policy may result in congestion levels that threaten the productivity of cities (to an even greater extent than currently). Moreover, if the road user charge is applied in a context of reduced car ownership, this is less likely to be felt directly by individuals in the same way as it would should private motor ownership levels be preserved. Ultimately, under a *mobility as a service* model, a road user charge would be embedded in the cost of the service, and therefore potentially more palatable compared to the private car ownership framework that characterises the current paradigm.

In the future, Professor Franken noted that it is conceivable that a city such as Amsterdam could become *private car free*. The opportunities provided by car sharing would be central to achieving such a goal, but would be expected to account for a minority of trips, with walking, cycling and public transport accounting for the majority of mode share.

5.11. Timothy Papandreou, Director, Office of Innovation, San Francisco Municipal Transportation Agency, San Francisco

Timothy has had a long-standing interest in shared mobility and disruptive transport. This two decade long professional involvement in disruptive transport, coupled with his position within the SFMTA, which finds itself at the centre of the DTT industry (the headquarters of Uber, Lyft and large car sharing companies are in San Francisco). As the Director of Innovation at the SFMTA, Timothy is well placed to contribute to the current project, as many of the issues faced by Melbourne in the coming years have already emerged in San Francisco. This telephone interview took place while Timothy was in London attending a Google workshop on the future of mobility (hosted by the *New Cities Foundation*) and the major topics of discussion are presented in the subsections below.

5.11.1. Local government's role in fostering an integrated system

The first point Timothy sought to make was the need for local government to adopt a strategic approach to transport innovation. Too often, it was felt, agencies can be captured by *legacy*, resulting in largely reactive responses to short-term circumstance. As part of Timothy's role, he has been working on partnering with new mobility services (e.g. ride-sourcing providers). Timothy mentioned that there is a mentality within new mobility Start Ups to *'handle everything themselves'*, but was at pains to point out that they need to be '*integrated into the transport system',* rather than operating in competition with it. Moreover, Timothy has witnessed instances in which safety (e.g. driver training) and accessibility, for people with special needs have not been adequately considered by new mobility Start Ups, and felt there was a role for government in helping new entrants meet necessary standards. As private entities, the profit motive has at times seen safety and accessibility issues not given the priority required by government, or expected by the community. Timothy has been working to assist these new entrants into the industry, in order for them to become '*ubiquitous'*, rather than *'boutique'*.

Vehicle efficiency is another area in which the SFMTA would like to see some industry standards created and adhered to. It was Timothy's view that the benefits of DTT will only be fully realised when low and zero emission technology is the universal standard adopted by emerging mobility providers. Finally, the sharing of data developed by companies such as *Uber* with public agencies responsible for the network is considered essential.

5.11.2. Developing an Emerging Transport Strategy for San Francisco

Timothy mentioned that the SFMTA are currently working on a report similar to the City of Melbourne, which is intended to form a SFMTA ***Emerging Transportation Strategy***. This Strategy will seek to:

1. House all emerging mobility ideas and providers.
2. Position the SFMTA so they can take on the key issues and benefit from new opportunities to increase the sustainability, safety and equity of the transport system.

The desired outcomes from this ***Emerging Transportation Strategy*** include:

1. A set of core principles (or 'rules of engagement') that can be presented to disruptive mobility companies, who will be asked to adhere to them – perhaps not immediately, but as something to work towards. Companies that seek to work within the City of San Francisco will be asked to develop a timeline to meet the safety criteria that will be developed as part of this Strategy (on street and in vehicle safety). These rules of engagement will also include affordability and accessibility criteria. Importantly, SFMTA will also seek to maximise interoperability criteria, in order to increase the efficiency of multi-modal connections and enhance the door-to-door experience of travellers. Vehicle efficiency, as highlighted above is also expected to be included within the rules of engagement.
2. Online documenting and dash boarding. Consistent with the themes emerging from discussions with Professors' Currie and Shaheen, the SFMTA is keen to see an increase in the availability of ride data. Although there are likely to be aspects of this data commercial transport platforms are likely to withhold, the SFMTA would like to seek agreement on quarterly reports provided to the SFMTA, verified using a trusted 3rd party.

5.11.3. Creating an urban innovation lab

In addition to the ***Emerging Transportation Strategy***, the City of San Francisco is developing an ***urban innovation lab****.* This is a collaboration between the public, private and university sector. This living laboratory will include a number of different portfolios, including *transport* (i.e. it will include a range of local government responsibilities; commercial/enterprise, land use planning, as well as transport). A number of different theories and ideas will be tested on the ground in this lab, including the technical aspects of disruptive innovation, such as sensor technology in public infrastructure, drones, and autonomous vehicles.

The key learning's that emerge from this lab will be shared with some of San Francisco's peer cities. Partnerships with other cities will allow other jurisdictions to learn from one another. Timothy mentioned that the issue for the City of Melbourne is that the State Government is actually in control of much of the transport services that operate within and across the municipality, whereas the SFMTA is in control of almost all transport services within the City of San Francisco.

For a city to join as a partner in the ***urban innovation lab***, there are a few requirements (no exhaustive), as listed below:

1. An open data policy.[13]
2. Culture of partnerships – this needs to be formalised and may mean that some projects do not follow the normal Council procurement cycle. For instance, a company that is developing remote sensing technology may partner with government in such a way that the government agency offers their street poles to the company, in order to test its technology. This can happen even before a *Request for Proposal* process, because the technology is so new. Another example is working across government to deliver a public Wi-Fi program.
3. Creating a culture of '*agnostic mode preference bias'* – no one mode is better than another. Timothy elaborated on this by saying that it is about picking the right mode (or combination of modes) for the right trip. Timothy suggested that it may benefit the City of Melbourne to work closely with other Melbourne municipalities as the city workforce and visitor base is largely composed of residents from these surrounding local government areas.

[13] The City of Melbourne already has an Open Data policy and a public website (http://bit.ly/QjLxxH)

6. Impacts and Implications for the City of Melbourne

The disruptive technologies in transport discussed in this report will have wide-ranging impacts on the municipality. The degree to which these innovations will support or hinder the City of Melbourne in achieving its strategic objectives is still very much dependent on the policy tools applied, at the local, state and national level. The impacts outlined below are accompanied by one or more suggested actions and have been designed to support and complement the eight goals that form the basis of the Council Plan 2013 – 17 (City of Melbourne, 2013), which are:

1. A city for people
2. A creative city
3. A prosperous city
4. A knowledge city
5. An eco-city
6. A connected city
7. Resources are managed well
8. An accessible, transparent and responsive organisation.

More specifically, the actions accompanying each impact from disruptive transport have been designed to support the key directions of the Transport Strategy (City of Melbourne, 2012), which are:

1. Integrate transport and land use planning
2. Go anywhere, anytime public transport for inner Melbourne
3. Support public transport, walking and cycling as the dominant modes of transport in inner Melbourne
4. Develop high-mobility pedestrian and public transport streets in the central city.
5. Make Melbourne a cycling city.
6. Foster innovation, low-impact freight and delivery in central Melbourne.

The core aims and principles of the City of Melbourne have been carefully considered in the following impacts and actions outlined below, with a view of strengthen the City of Melbourne's strategic position to meet the needs of a growing city.

Potential areas for the City of Melbourne to consider in further detail:

6.1. Reduced car parking demand

The reduction in car ownership linked to the emergence of shared mobility platforms and autonomous vehicles is widely anticipated to reduce demand for car parking. This includes both short term curbside and off street, as well as residential and commuter parking.

6.1.1. Remote sensing and dynamic pricing of on-street parking

Adapt curbside car parking to include remote sensing, open APIs and dynamic pricing, similar to *SF Park* described in Box 2. Given it may take several decades before the transition towards shared use autonomous vehicles is complete, significant potential exists for the City of Melbourne to strengthen their revenue stream by incrementally pricing curbside parking based on demand and allowing users to top up their car parking remotely, via a smartphone App. See Box 2 for additional justification for this recommended action.

6.1.2. Adaptable parking structures in new developments

Investigate mechanisms for new developments to include retrofit compatible car parking, to meet the parking needs of today, with the likely reduction in future need. This recommendation is based on the typical built form service life of 80 – 100 years and the weight of expert opinion that autonomous vehicles are likely to account for around 80% of all vehicles by 2040 – 2050.

6.2. Growing demand for car sharing among residents and businesses

The technology, cultural and economic trends described in this report suggest that it is more than plausible that demand for car sharing in the city of Melbourne will increase significantly in the next five to 10 years. This effect is strengthened by the City of Melbourne's introduction of a car parking *maximum* rather than minimum for new developments (City of Melbourne, 2015a, see Schedule 1 to the Parking Overlay, p. 1 of 2). This is widely seen as a positive planning mechanism to reduce the level of car use. The City of Melbourne have recognised the likelihood of car sharing demand growing between now and 2021, with management (see City of Melbourne, 2015b) recommending a doubling of on-street spaces between 2015 and 2021 (from 50 to 100)[14]. It was also recommended that off street spots increase from 40 currently to 1,130 by 2021, although this is at the discretion of car sharing providers.

Given international trends documented in Section 5.1, it is likely a mature car sharing market in the City of Melbourne will include a more diversified mix of options, with one-way and peer-2-peer car sharing opportunities increasing over the next decade, as documented in the consultant report to the City of Melbourne (2015b).[15]

6.2.1. Facilitate one-way car sharing enterprise

Create a dialogue with new and existing members of the car sharing industry to discuss one-way car sharing impacts and possible mechanisms to increase the availability of one-way car sharing plans. Review current operations, performance and trends related to one-way car sharing in North America and implications for the City of Melbourne.

6.2.2. Investigate peer-2-peer car sharing options for the city of Melbourne

Research potential benefits, costs and implications of peer-2-peer car sharing, in order to optimise the use of the existing private motor vehicles for shared purposes. This may include international trends, consumer law issues, and dialogue with municipality residents, businesses as well as private enterprise.

6.2.3. Conduct car sharing market research

Monitor demand for car sharing among existing and new residents, to better understand its current and potential impact for reducing car use.

[14] only an additional nine within the Hoddle Grid.

[15] Economic analysis found for each $1 the City of Melbourne spends on car sharing, $3.42 is gained (user and community benefit).

6.3. Increasing availability and use of electric vehicles

There has been a significant increase in performance and reduction in price of electric vehicles over the last 12 months and this is widely expected to continue. The world's largest motor vehicle manufacturers either have, or are about to launch a wide variety of plug in electric vehicle models. In addition, non-traditional car manufacturers, primarily led by technology companies such as *Google* and *Apple* are widely expected to release passenger vehicles[16]. *Tesla Motors* introduced their *Model S* in Australia in 2015 and have announced they will be launching their *Model X* (an SUV) in late 2016. They are currently installing a system of *'superchargers'*[17] in Victoria and NSW.

Electric vehicle adoption rates in Australia are one of the lowest in the OECD (International Energy Agency, 2013). Whilst the value proposition for electric vehicles is expected to remain lower in Australia than most other developed economies, the city of Melbourne has a demographic more likely to be early adopters, including higher education and income levels (Gardner, Quezada, & Paevere, 2011). The City of Melbourne Transport Strategy (City of Melbourne, 2012) note the positive contribution electric vehicles can make to air and noise pollution, as well as greenhouse gas emissions when charged with renewable electricity.

6.3.1. Electric vehicle charging facilities

Investigate the suitability of voluntary or mandatory installation of electric charging facilities for new residential and commercial developments with onsite car parking facilities. This is consistent with Strategy 1.3 of Clause 21.09-05 of the Melbourne Planning Scheme: *'Support provision of re-charging facilities powered by renewable sources of energy for electric powered vehicles'* (City of Melbourne, 2015a). Liaise with Transport for London and the City of San Francisco regarding the program of installing on street electric charging facilities. Investigate the current and future need, including equity consideration, for the provision of on-street electric vehicle charging facilities

6.4. Increasing congestion

The congestion impact of DTT on the city of Melbourne remains unclear and is largely depending on the policy tools used by government to manage it. As previously mentioned, in the absence of pricing mechanisms, the overwhelming weight of professional opinion suggests autonomous vehicles may significant increase congestion levels in the city of Melbourne. Justification for the following recommended actions to counter the potentially exacerbated congestion levels caused by DTT can be found in Section 4.6.3.

6.4.1. Road user pricing

Examine the impacts (costs and benefits) of a road user-pricing scheme. Currently, the Victorian Government has a congestion levy, applied to stationary vehicles (per car park). Shifting the focus from stationary vehicles to moving vehicles is likely to be a more effective congestion management tool (Turner, 2004) and may help to preserve revenue in an environment in which demand for car parking is lessened (for the reasons outlined in Section 4.6). A road user pricing policy is beyond the sole preserve of the City of Melbourne and therefore, once a position is developed internally, a dialogue with relevant stakeholders, including other LGAs and the Victorian Government may be necessary. Additionally, as detailed in Section 4.6.3, the Federal Treasury is likely to experience a reduction in revenue from fuel excise as the national vehicle fleet slowly adopts electric vehicles and

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[16] Both companies have maintained a high degree of secrecy over their vehicle plans and it is not yet know in what form their market proposition related to motor vehicles will take. However, both have extensive investments in battery technology, suggesting an electric vehicle is likely.
[17] See Tesla Motors Supercharger webpage (http://bit.ly/21XI2Ri)

therefore have an interest in this issue, not to mention the cost of current congestion on national productivity.

6.5. Increasing use of bike sharing program

Melbourne's bike sharing program (MBS) has operated for more than five years and has failed to achieve the level of ridership initially forecast. Bike sharing directly supports many of the directions outlined in the Council Plan and Transport Strategy. Whilst ultimate responsibility for bike sharing remains with the Victorian Government, the following actions are recommended.

6.5.1. Engage with Victorian Government to better integrate MBS with the wider public transport system

Engage with the State Government to integrate MYKI and MBS, such that MBS becomes the fourth mode of public transport in Melbourne, and included within the same cost structure.

6.5.2. Lobby for MBS expansion

Engage with IMAP Councils and the State Government to research the costs and benefits associated with expansion of the scheme, to include suburbs with 5 – 7km of the City (a 30 minute ride).

6.5.3. Lobby PTV for enhanced MBS capabilities

Engage with the State Government to encourage an investigation of world's best practice bike sharing to help inform future MBS expansion. This should include the merits of technological advances that have become available since the initial introduction of MBS (e.g. GPS integration, electric assist bike sharing hardware and bike unlocking via smartphone).

6.6. Increasing small parcel freight deliveries

The growth in online shopping and lower levels of car ownership is likely to result in rising demand for deliveries.

6.6.1. Develop more efficient last mile freight solutions

Continue to work with the freight industry, the technology sector and university logistics researchers to develop innovative solutions to improve the efficiency of last mile freight within the city of Melbourne.

6.6.2. Collaborate with stakeholders to explore delivery by drone

Work with other local governments, the Victorian Government and the Australian Civil Aviation Safety Authority (CASA) on drone delivery regulations, with the view of creating a controlled pilot scheme.

6.6.3. Encourage innovation in delivery solutions for city of Melbourne businesses

Work with technology platform companies to help create an efficient connection between city of Melbourne businesses and customers using sustainable transport. *UberRush,* shown as an option in Figure 4.3, offers an example of how mobile Internet communications can facilitate an efficient link between provider and consumer.

6.7. Growth in ride sourcing and ride sharing

App based ride sources services (e.g. Uber) are rapidly growing their business in Melbourne and it is expected that they will soon launch new services, such as UberPool (discussed in Section 4) as well as on demand delivery services. In the longer term (5 – 10 years), it is also widely anticipated that

Uber and similar platforms will take advantage of autonomous vehicle availability, converting their fleet to be comprised largely of 'robo-taxis' (no driver), and such a model is expected to provide a compelling value proposition (in terms of convenience and cost competitiveness). Whilst this is largely seen as a positive development, the following actions are recommended to support the strategic direction of Council.

6.7.1. Lobby for a position on *Taxi and Hire Car Ministerial Forum*

Request to have a Council representative on the Victorian Government's *Taxi and Hire Car Ministerial Forum* currently set up to tackle the issues raised by disruption of the industry.

6.7.2. Develop code of practice for the ride sourcing industry

Establish a set of requirements the City of Melbourne would like to see current and new App based taxi like services adhere to, including a *code of practice,* data sharing protocol including 3rd party verification of ride sourcing industry claims on usage data.

6.7.3. Lobby for data sharing across the ride sourcing industry

Work positively with the ride sourcing industry to share data is in the public interest and help supports the City of Melbourne it its strategic objectives.

6.7.4. Taxi rank review

Review Council's taxi rank policy annually to include an assessment of how current disruptive forces in the industry may impact on their relevance, size and location. Consider the needs of both traditional taxi services and new market entrants.

6.7.5. Understand the ride sourcing market

Conduct market survey with users of ride sourcing services (e.g. Uber) to better understand trip patterns, reasons for use, and modes these services are replacing.

6.7.6. Investigate App based on demand 'micro transit'

Engage with PTV and other Melbourne municipalities regarding the potential effectiveness of App based, on demand bus services (as feeder to rail), particularly for outer suburban areas with poor access to high frequency rail into central Melbourne. It is not the intention for these services to necessarily operate within the municipality.

6.8. Updating traffic models

As part of our analysis for this project we have communicated with some of the most commonly used traffic modelling software providers (e.g. AIMSUN and PTV Group). This correspondence has confirmed that disruptive transport innovation is a '*hot topic'* (to quote one of the companies) within this field, and they are in the process of updating their models to account for current and future developments that may influence transport demand, such as shared transport and autonomous vehicles. The latter is an area of intense focus given the potential to dramatically change travel patterns (as discussed in Section 4.6.3.)

6.8.1. Engage with traffic modelling providers

Communicate with the City of Melbourne's traffic modelling software providers to ensure they are able to account for current and future developments related to car sharing and autonomous vehicles.

6.8.2. Collaborate with Victorian Government

Engage with the Victorian Government regarding the macroscopic, network planning implications of developments in shared, autonomous vehicles, and consequent changes to the Victorian Transport Model.

6.9. Increasing demand for open data, APIs, and transport Apps

The ubiquity of the smartphone has created greater demand and opportunity for real time travel information. To harness this opportunity to help make smarter transport choices the following recommended actions are offered.

6.9.1. Further develop and promote the use of open data platform

Work with the Victorian Government to encourage a whole-of-government approach to Open Data, including the development of APIs related to all modes of transport, with a view of creating possibilities for 3rd party developers to create multi-modal journal planning Apps.

6.9.2. Work with PTV on smartphone ticketing and payment

Engage with Public Transport Victoria regarding the merits of offering in-App payment for public transport services (the smartphone becomes the ticket), similar to the outcome achieved in Portland and Chicago (see Section 4. Embedded in such a development should be an auto-alert function in which users are notified or delays or cancellations, using trip history data.

6.9.3. Greater engagement with the technology sector

Host ‘hackathons’ and Open Data events in which App developers, Big Data specialists and planners collaborate to develop transport Apps that support sustainable mobility decisions.

6.10. Overarching suggestion

6.10.1. Establish an urban innovation precinct

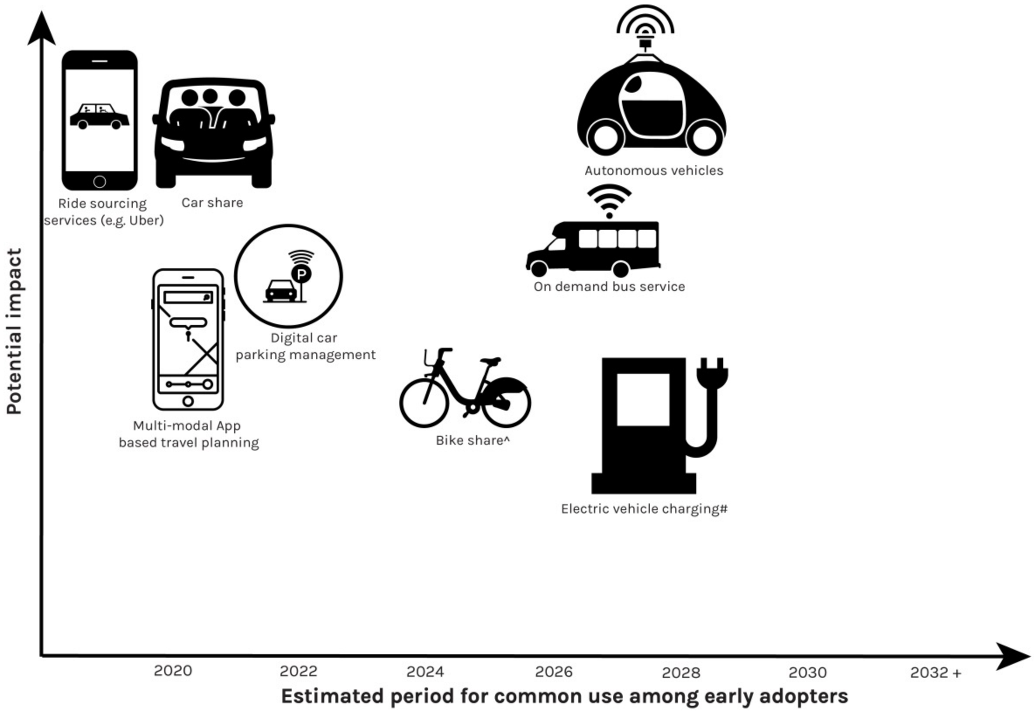
The development of an urban innovation lab is recommended as a practical action the City of Melbourne can take to trial and operationalise many of the individual suggestions included in this report.. This is consistent with the actions taken by leading cities (e.g. San Francisco) and will provide an excellent opportunity for the City of Melbourne to support the objectives in the Council Plan and Transport Strategy. The creation of an *urban innovation lab* within the City of Melbourne is a project of State and National significance and directly supports core themes within the innovation package announced by the Prime Minister on the 7th December 2015. A *living laboratory* of urban innovation has the potential to be a driver of economic, environmental and social benefits. The following specific sub-actions are recommended:

- Work internally and collaboratively across each of City Operations, City Design and Projects, City Strategy and Place, City Communities and City Economy and Activation to determine the appetite for the development of an urban innovation precinct. Should the result of this activity be positive, subsequent actions are suggested below.
- Develop a conceptual proposal, detailing the aims and key themes proposed (e.g. built environment, mobility, digital enterprise, public space/street design etc.), as well as site, scale and potential partners. Developing estimated outcomes, in terms of economic benefit relative to cost (benefit cost analysis) may also help gain future government support.
- Seek partnership with C40 cities to cross-pollinate ideas with those cities also embarking on a similar approach (e.g. San Francisco).

- Engage with the university sector, as well as State and Federal Government regarding partnership and funding opportunities.

A summary chart showing indicative timing and consequence of the key emerging technologies included in this report is provided in Figure 6.10.

Figure 6.2 Schematic timing and impact of emerging transport technology



Source: Institute for Sensible Transport (2016)

NB: This chart is illustrative only and substantial uncertainty exists across each of the technologies and their associated policy environments. It is applicable to Melbourne only.

^ Considerable uncertainty exists regarding the future and size of the Melbourne Bike Share program.

Highly dependent on the policy environment and external factors (e.g. price of petrol).

7. Conclusion

This report, the first of its type in Australia, has sought to capture the latest developments in the rapidly advancing field of disruptive transport technologies (DTT). Expert interviews and a review of the literature created a foundation for describing the latest trends related to ride sourcing services (e.g. Uber), car sharing innovations, multi-modal travel planning Apps and autonomous vehicles.

A workshop with City of Melbourne staff provided a valuable opportunity to explore the potential impacts DTT might have on the City of Melbourne and actions that can be taken to ensure the outcomes arising from the increased uptake of transport innovation supporting the strategic directions of Council.

The overarching opportunity presented by these new technology platforms and capabilities is the potential they hold for fundamentally altering the car ownership and usage model that has prevailed in the post World War Two era. New car sharing possibilities, including one-way, by-the-minute rental and peer-2-peer options provide significant advances on current business models and increase the value proposition to new users. Ride sourcing services such as Uber are another addition to help bring the benefits afforded by car travel without the need for ownership. Multi-modal, real time travel information and in App payment opens significant opportunity to encourage smarter transport choices.

Autonomous vehicles present the greatest disruptive force of all the transport technologies included in this report. Autonomous vehicles are widely anticipated to be the most significant change to the travel experience since the invention of the car itself. Market availability of driverless cars is expected within the next 5 – 10 years and this report has found that such vehicles could replace up to 18 conventional cars, while lowering transport costs, and opening up a diversity of mobility choices likely to attract both current drivers, as well as those too young or old to operate a vehicle. In addition to the safety benefits, autonomous vehicles are expected to make shared mobility (as opposed to privately owned vehicles) a very compelling option for the majority of travellers in the coming decades, primarily due to cost and convenience factors.

Autonomous vehicles do however present a double-edged sword. In the absence of additional demand management tools, their introduction is likely to exacerbate congestion within the City of Melbourne and erode the productivity and liveability benefits that make the City of Melbourne an attractive place to live, work and visit.

A reduction in the demand for car parking is a widely anticipated consequence of the changes currently taking place with the DTT field. This has direct financial consequences for the City of Melbourne and a range of car parking reform measures have been recommended to adjust to likely changes in travel behaviour related to car parking.

Road user pricing has emerged as an almost inevitable consequence of the changes currently taking place in the transport sector. Whether governments wait until congestion cripples the economic productivity of our cities or act pre-emptively to manage congestion remains unclear. What is clear however is that for the City of Melbourne as well as other levels of government, the revenue base, in car parking fees and fines, fuel excise and as well as transport network efficiency are all threatened by the introduction of electrically powered, privately owned autonomous vehicles.

Finally, the set of suggestions contained in this report are best operationalized through the establishment of an *urban innovation laboratory* and the City of Melbourne is ideally positioned to take a leadership role in its formation. The disruptive transport innovations currently available and on the horizon represent an exciting opportunity to realise the City of Melbourne's ambition to be a connected, creative, eco-city and the policy recommendations made in this report provide a blueprint for achieving this vision.

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Appendix A - Methodology

A.1 Literature review

A search was conducted using the Scopus, ScienceDirect and Routledge databases based on the following terms:

- "Disruptive transport"
- "Disruptive innovation" AND "transport
- "Transport innovation" AND/OR "disruptive"
- "On demand" AND "transport"
- "Mobile technology" AND "transport
- "Sustainable transport" AND "disruptive" OR "innovation".

The results of this search were used as a starting point and the bibliography of the found publications was used to deepen the search process. Other publications used to help inform the development of this report include:

- *Disruptive Mobility*, 2015, by Barclays Bank
- *The United States and China: The Race to Disruptive Transport Technologies*, 2011, by Accenture
- *Going Dutch: A New Moment for Carsharing in the Netherlands*, 2014, Ecoplan International
- *Car-sharing in London – Vision 2020,* 2014, Frost & Sullivan
- *Disruptive technologies: Advances that will transform life, business and the global economy*, 2013, McKinsey & Company
- *Automated vehicles: Human Factors Challenges and Solutions*, 2015, ARRB Group.
- *The Uber Economy*, 2015, The Atlantic.
- *CityMobil2: Cities demonstrating automated road passenger transport,* 2015, European Union.
- *Not just a taxi? For-profit ridesharing, driver strategies, and VMT*, 2014, Transportation.
- *App-Based, On-Demand Ride Services: Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco*, 2014, University of California.
- *One-way carsharing's evolution and operator perspectives from the Americas,* 2015, Transportation.
- *How a rapid modal convergence into a universal automated taxi service could be the future for local passenger transport*, 2015 Technology Analysis & Strategic Management.

The review of relevant literature formed the basis for determining the DTT that are included in this report, and acted as a foundation for assessing their impacts on local government. In keeping with the aims of this report, a decision has been made to broaden the types of innovations classified as *disruptive innovation*, even if they may not always meet the strict classification of disruptive innovation, as outlined in Section 4.

A.2 Interviews with leaders in transport innovation and technology

The pace with which transport innovation is developing is such that many important developments have not yet been captured in the public literature. As a consequence, telephone interviews were conducted with leading experts in the field. These interviews have been distilled, to uncover emerging themes relevant to the City of Melbourne (see Section 6). Interviews were held with the following individuals.

- **Professor Susan Shaheen**, Co-Director, Transportation Sustainability Research Center and Adjunct Professor, University of California, Berkeley.
- *Distinguishable attribute:* Leading academic on disruptive transport sector, especially car share and ride sourcing (e.g. Uber).
- **Professor Graham Currie,** Chair of Public Transport
- Public Transport Research Group, Institute of Transport Studies,
- Monash University.
- *Distinguishable attribute:* Leading academic on public transport, knowledge of the Melbourne context, with an interest in car parking and app-based transport technologies.
- **Timothy Papandreou**, Director Strategic Planning & Policy, San Francisco Municipal Transportation Agency (SFMTA)
- *Distinguishable attribute:* Policy leader within an agency at the global hub of DTT (San Francisco Bay Area).
- **Professor Keon Franken**, Professor of Innovation Studies at Utrecht University, The Netherlands.
- *Distinguishable attribute:* European leader in sustainable business innovation, particularly disruptive technologies associated with transport.
- **Kristian Handberg**, Connected Mobility Specialist – New Energy, AGL.
- *Distinguishable attribute:* Expert on plugin electric cars.

A.3 Local government best practice in disruptive transport technology

The conversations with the individuals identified above, in addition to the review of the recent literature assisted in capturing examples of international best practice in facilitating DTTs, with a particular emphasis at the local government level. San Francisco was chosen as the case study municipality.

A.4 Workshop with City of Melbourne

A key part of this project was a workshop with City of Melbourne staff in which the concept and background information on DTT were introduced. Staff were then asked to work in groups to explore the pathways through which disruptive technology may impact on the City of Melbourne and what responses could help harness these technologies to assist in supporting organisational strategic objectives. A synthesis of the workshop outcomes is provided in Section 7.

Appendix B - Interviews with leaders in emerging transport technologies

B.1 Professor Graham Currie, Monash University, Australia

Professor Currie was able to readily identify the benefits offered by real-time, mobile devices (e.g. auto-alerts to public transport passengers regarding a delay), but was also sceptical of some of the claims made by technology companies currently operating in the transport sector. Much of this scepticism related to the lack of independent, 3rd party verification of their usage data. In relation to ride sourcing services, Professor Currie raised concerns about the possibility that drivers may be travelling without passengers to move towards areas that offer more likely pick up locations, and thereby impact on congestion. One might imagine that this is not any different to the behaviour of traditional taxis. Additionally, equity questions were raised in the event that ride sourcing services favour inner city areas with higher demand, to the exclusion of outer suburban low-income areas. An analysis from millions of taxi and Uber trips in New York City (not discussed as part of the interview) suggest traditional taxis and Uber serve a very similar geographic and demographic market (Silver & Fischer-Baum, 2015).

Professor Currie noted that app based parking applications are now available (e.g. Parkapedia), as well as more policy driven applications, such as *SF Park* (see Box 2 in Section 6.5.6), which is essentially an implementation of the concept originally advanced by Professor Donald Shoup (2005). Such developments, in which the cost of parking is adjusted based on demand has the potential to flatten peaks and increase the likelihood of maintaining a small proportion of available spots at any one time.

Professor Currie was sceptical about predictions that autonomous vehicles would form a large proportion of the national fleet over the next one or two decades, and suggested it may be at least 30 years before the majority of vehicles are autonomous. He mentioned that whilst there is some evidence that autonomous vehicles may increase the road capacity, by around 11% (by reducing the distance between cars), the benefits of this are unlikely to be easily recognised, as they will be surpassed by growth in the number of cars. Perhaps the more important benefit offered by autonomous vehicles, as identified by Professor Currie was the potential to change the *vehicle ownership model.* The standard practice, it was argued by Professor Currie, has been for individuals to purchase their own vehicles, culminating in very high levels of vehicle ownership in Australia. The autonomous vehicle offers the potential to provide mobility without the need for ownership. Several motor vehicle manufacturers have begun offering car sharing options (as identified in Section 5) and this is perhaps a sign that these companies are recognising that *access not ownership* is becoming important to the market, especially younger adults. This was a point that emerged as a common theme throughout all the expert interviews conducted as part of this project.

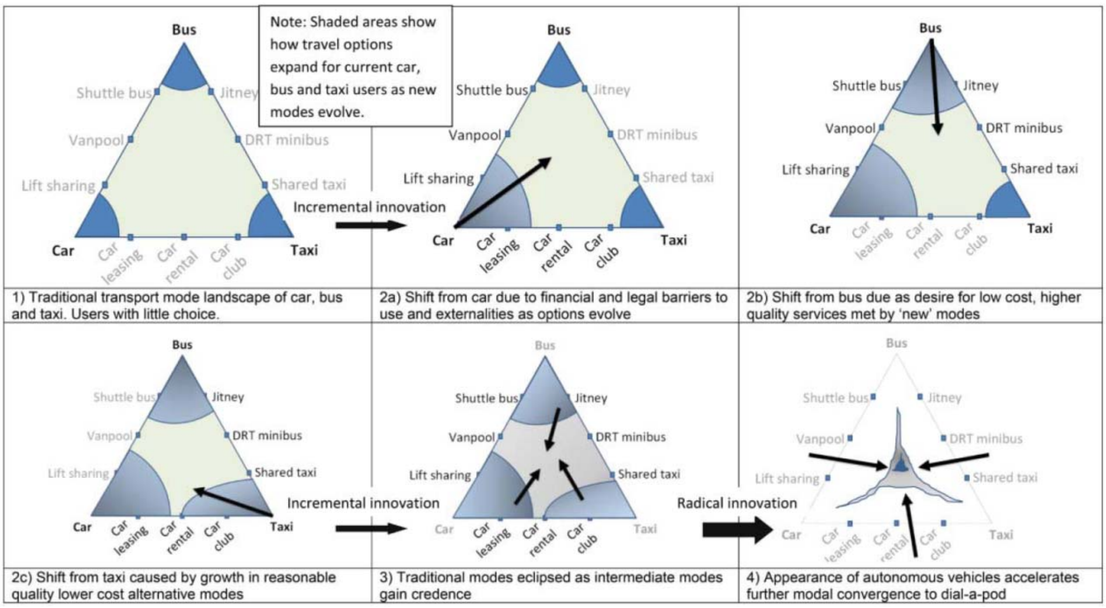
Professor Currie also recognised that autonomous vehicles, at least in theory, may no longer need to park, and this has the potential to increase VKT, identifying the same scenario introduced in Section 5.6.2 and Section 4.6.3. This scenario presents a real risk of eroding the potential benefits of autonomous vehicles and points to the need for governments to consider pricing car use via a form of road user charges.

On the relationship between technology and public transport, Professor Currie spoke about the emergence over the last 5 – 10 years of real time information, delivered to passengers via their Internet connected device (e.g. Smartphone). It was also identified that public transport providers are *'crowdsourcing'* their services, by offering location specific, mobile phone based online surveys to passengers, to better calibrate service levels to passenger need. Related to this, operators now have the ability to be able to send live updates to users, based on their previous travel history, in order to provide customised information to passengers regarding delays and cancellations.

Emerging technologies in transport are also being applied to what Professor Currie refers to as *demand responsive transport services*. This is a type of DTT highlighted in Section 4.3.3 using the example of the US operator *Bridj.* Using vehicles capable of holding approx. 14 passengers, these services use an App based platform to allow passengers to request and pay for a ride. Demand responsive transport services have, according to Professor Currie, at least until the emergence of App enabled services, been phenomenally *unsuccessful* and it is too early to say whether the arrival of services like *Bridj* offer a sustainable business model in the long term.

In terms of the future of DTT, Professor Currie suggested a *convergence model* may occur, in which motorised modes of transport (car, bus and taxi) could become blurred, with hybrid forms of transport that share characteristics of each of these modes, as illustrated in Figure B.1, using the work of Dr Marcus Enoch.

Figure B.1 The convergence model of transport



Source: Enoch (2015)

B.2 Professor Susan Shaheen, University of California, Berkeley

A key theme emerging from the discussion with Professor Shaheen was the degree to which DTT companies have *responsibilities* to regulators and the community more generally. Central to these responsibilities is the reliance that so many DTT companies have on public utilities, namely public streets. It was the view of Professor Shaheen that in exchange for the use of public infrastructure, ride sourcing services and other platforms have a responsibility to both contribute to the costs of maintaining that infrastructure, as well as share information that is in the public interest. For instance, Professor Shaheen described how the Californian Public Utilities Commission recently sued Uber for $US7.3m for not providing the necessary data for it to perform an equity analysis (DeAmicis, 2015). The information requested by the Californian Public Utilities Commission included data on the number of requests it received for disabled access vehicles, crashes, rider post code, the cost passengers pay for their trips, and the proportion of times a request for a disabled access vehicle was provided when requested (DeAmicis, 2015).

Much of Professor Shaheen's research has involved car sharing in San Francisco, including the requirements car sharing companies have for curbside car parking. Professor Shaheen provided a historical account of the different pricing scales car sharing providers have incurred for curbside parking. These have been described in earlier work by Shaheen et al. (2010) as occurring in three categories.

1. Car sharing as a public good/environmental benefit: Initially, when most car sharing providers were small not-for-profits, they were typically offered free parking, on the condition that they provided evidence of the impact their programs had on reducing car ownership and use. In this pricing category, public agencies viewed car sharing as contributing to the public good and therefore were prepared to offer government support in the form of free parking.
2. Car sharing as a sustainable business: Under this model, car sharing providers were required to pay a contribution to the authority for the use of on street curbside parking. It is acknowledged that car sharing still provides an environmental benefit, but because it is also a revenue generating enterprise, it is considered reasonable to charge for the use of a curbside car space. Government generally still require data from the car sharing provider in relation to the impact their programs have on car ownership and use.
3. Car sharing as a business: Government support is minimised and car sharing is seen as a commercial operator, responsible for covering the cost of their parking requirements.

The mainstreaming and scale of car sharing has meant, accord to Shaheen, that the third model; *car sharing as a business,* is considered appropriate under the 2015 context. One of the reasons why Professor Shaheen considers the car sharing industry to be a fully-fledged *business* is because of its scale. It is not uncommon (at least in some North American cities) for these businesses to apply for hundreds of curbside spaces at a time, and given they are operating their private business on what is essentially public space, it is considered reasonable for a government authority managing that space to charge accordingly.

Based on current trends, Professor Shaheen foresees a *convergence* in which shared, connected and autonomous mobility combine to offer a *mobility-as-a-service*. Such a service was seen to provide greater utility (compared to the driver owned model) for most people. This convergence, although arrived at independently, is similar to the conclusion reached by scholars such as Dr Marcus Enoch and Professor Currie highlighted earlier (also see Enoch, 2015). Again, the idea that *micro transit* may become more efficient through the use of GPS enabled Internet connected devices and therefore offer a more viable business model was introduced. Moreover, the prospect of providing such services as an autonomous vehicle and thereby eliminating the largest cost (the driver) is likely to enhance the cost effectiveness of *demand responsive transit.*

The degree to which the services identified above *compete with* or *complement* traditional forms of public transport remains a largely unanswered question. Services such as UberPool (see Section 4) may bring the cost of the service to something approximating public transport, potentially undermining the viability of these services, especially those occurring in more dispersed locations. It is noted that services such as Uber are unlikely to have the space efficiency to replace existing rail services to CBD locations (Walker, 2015). One option promoted by public transport expert Jarrett Walker (not mentioned in the interview with Professor Shaheen) is for App based on demand ride sourcing services to focus on lower density, dispersed locations in which the efficiency of running high capacity, low ridership bus services is less viable. Indeed Walker even suggests they could even operate under contract from public transport agencies (Walker, 2015).

Professor Shaheen made the point raised earlier by other interviewees; road user pricing is likely to emerge as a necessary tool to manage the congestion that may result from comparatively cheap, autonomous mobility, even under a shared/pooled transport model. It is plausible that a road pricing model might also include costs to ride sourcing platforms, for their use of public infrastructure.

Professor Shaheen, in addition to being an expert in shared car use, is also one of the world's leading scholars on bike sharing (e.g. see Shaheen, Cohen, & Martin, 2013). Technology was seen as an opportunity to help make bike sharing more user friendly, with electric bicycles, GPS and smartphone payment helping people sign up and use bike sharing. Professor Shaheen felt that more could be done to create pricing structures that allowed people to take longer trips without financial penalty, especially at times when demand is low.

In summary, Professor Shaheen is optimistic about the potential for technology platforms to enhance the sustainability of urban transport systems and reduce the need for vehicle ownership. Regulators have a right to impose requirements on ride sourcing services in order to ensure providers are not creating avoidable *inequities of access* or other unintended consequences. Professor Shaheen suggested that DTT companies should be required to share data, in exchange for the use of public access (e.g. streets), a view shared by others in these expert interviews.

B.3 Kristen Handberg, Connected Mobility – New Energy, AGL

Kristen provided an introduction to his work with AGL, part of which involves planning for an electric car sharing service. Initially this would focus on commercial fleets, rather than individual users. It was noted that although the economic case for moving to an all electric fleet is not currently present in Australia, there may be other motivating factors for businesses to consider an AGL leased fleet of electric vehicles. These reasons are primarily related to the social and environmental creditability associated with a zero emission fleet[18]. For AGL's existing customers, opportunities were identified in which their electricity account can be linked to their electric car charging, to facilitate transfers and credits between stationary electricity consumption and electricity consumed by vehicles. This may be useful for AGL's solar customer, in which surplus energy generated through solar panels can be stored in the battery of an electric vehicle, rather than fed into the electric grid (which is poorly renumerated relative to the cost of a unit of energy).

A bundled, door to door, integrated mobility solution was one idea explored during the conversation with Kristen. In this *mobility as a service* model, all transport services are groups together, including public transport access, electric car usage, including agreements with parking providers and toll operators.

Whether or not AGL choose to further explore electric car fleet management and mobility initiatives, it is clear that many of the principles that provide the conceptual framework for AGL's ideas are consistent with international trends related to *access not ownership* business models (Bridges, 2015; Shaheen, Chan, & Micheaux, 2015).

B.4 Professor Koen Franken, Utrecht University, The Netherlands

Professor Franken, a leading European expert in the field of innovation and the sharing economy was keen to highlight the context within which DTT are currently operating. In particular, the *peak car* phenomenon (Goodwin & Van Dender, 2013) has seen young people postpone car ownership, and Professor Franken identified that it may well be the case that a growing number of people simply choose to never own a car. This is in part a reflection of changing priorities, in which car ownership is less a signifier of individual identity than it used to be (possibly replaced with mobile device

[18] Zero emission to the extent that the electricity is generated from renewable, non-carbon sources.

ownership). In Europe Professor Franken noted that there is a shift towards *private lease* for those that do want exclusive access to a car, and a move away from outright ownership. The shift towards private lease arrangements has been influenced by cost reductions. Indeed the cost of car use – whether in the form of exclusive or shared use is becoming cheaper, and this raises issues regarding the role of government in managing the changes that are currently taking place in the car market. This is coming into sharp focus on the issue of autonomous vehicles. Professor Franken argued that the policy outcomes emanating from the rapid development in DTT are largely in the hands of government, via the policy levers they control. In essence, government, it was argued, can help make these DTT '*big or small'*, and can alter the way in which they are used, based on an analysis of whether they are likely to supporting the strategic objectives of government.

Professor Franken identified that these DTT relate to bicycles as well as cars. He mentioned that modern bike sharing systems, which facilitate one way rental (i.e. the user is not required to drop the bike at the same location they began their journey) offers significant potential to increase the efficiency of the transport system. Moreover, he noted that for cities like Amsterdam (which is in the somewhat unique position of having more bicycles than people), bike sharing holds the promise of reducing the crowding of city streets with parked private bicycles.

In recent years, one-way car sharing has emerged as a more efficient method of short-term car sharing (see Section 5.1) and this was something Professor Franken noted as an area likely to grow in the future. It is considered more efficient from a user fee perspective (only pay when actually driving).

Professor Franken spoke of a *convergence of interests* related to shared transport, in which a synergy between organisations, the public, and local government agencies can co-exist and help foster desirable outcomes.

An industry shift has been identified in which car manufacturers are now beginning to move from *producers* to *service providers*. This is already apparent in Europe and North America, where, as highlighted in Section 5.1 Daimler Chrysler offers *Car2Go* and BMW offers *DriveNow* – both of which offer one-way trips. The usefulness of such services in the Melbourne context is underlined by the fact, highlighted earlier, that the average rental period is six hours, yet the time actually spent driving is one hour (City of Melbourne, 2015b).

The autonomous vehicle was something unlikely to achieve substantial market penetration for up to 50 years according to Professor Franken, which is broadly consistent with the earlier assessment from Professor Currie. Professor Franken noted that the emergence of fully autonomous vehicles may change the way 'drivers' value time, as they may engage in other activities, rather than solely focused on driving. This may have the effect of extending what is known as the Marchetti Constant (Marchetti, 1994), which in effect means that rather than people having a 'travel time budget' of perhaps one hour per day, it may grow to something substantially larger than this. This was a reoccurring point throughout the discussions held as part of this project. Indeed it was pointed out that this effect may be amplified should people choose to live further from their work for instance, thereby exacerbating congestion levels.

The role of government, according to Professor Franken, when faced with the emergence of autonomous vehicle availability, will be to create the necessary incentives to encourage shared rather than private ownership. This, he says, involves a combination of changes to fiscal policy, parking policy (including constraints on supply and increases in price), and road user charging. Whilst the road user charging issue is fraught politically, the prospect of not enacting such a policy may result in congestion levels that threaten the productivity of cities (to an even greater extent than currently). Moreover, if the road user charge is applied in a context of reduced car ownership, this is less likely to be felt directly by individuals in the same way as it would should private motor ownership levels be preserved. Ultimately, under a *mobility as a service* model, a road user charge would be embedded in the cost of the service, and therefore potentially more palatable compared to the private car ownership framework that characterises the current paradigm.

In the future, Professor Franken noted that it is conceivable that a city such as Amsterdam could become *private car free*. The opportunities provided by car sharing would be central to achieving such a goal, but would be expected to account for a minority of trips, with walking, cycling and public transport accounting for the majority of mode share.

B.5 Timothy Papandreou, Director, Office of Innovation, San Francisco Municipal Transportation Agency, San Francisco

Timothy has had a long-standing interest in shared mobility and disruptive transport. This two decade long professional involvement in disruptive transport, coupled with his position within the SFMTA, which finds itself at the centre of the DTT industry (the headquarters of Uber, Lyft and large car sharing companies are in San Francisco). As the Director of Innovation at the SFMTA, Timothy is well placed to contribute to the current project, as many of the issues faced by Melbourne in the coming years have already emerged in San Francisco. This telephone interview took place while Timothy was in London attending a Google workshop on the future of mobility (hosted by the *New Cities Foundation*) and the major topics of discussion are presented in the subsections below.

B.5.1 Local government's role in fostering an integrated system

The first point Timothy sought to make was the need for local government to adopt a strategic approach to transport innovation. Too often, it was felt, agencies can be captured by *legacy*, resulting in largely reactive responses to short-term circumstance. As part of Timothy's role, he has been working on partnering with new mobility services (e.g. ride-sourcing providers). Timothy mentioned that there is a mentality within new mobility Start Ups to *'handle everything themselves'*, but was at pains to point out that they need to be '*integrated into the transport system',* rather than operating in competition with it. Moreover, Timothy has witnessed instances in which safety (e.g. driver training) and accessibility, for people with special needs have not been adequately considered by new mobility Start Ups, and felt there was a role for government in helping new entrants meet necessary standards. As private entities, the profit motive has at times seen safety and accessibility issues not given the priority required by government, or expected by the community. Timothy has been working to assist these new entrants into the industry, in order for them to become '*ubiquitous'*, rather than *'boutique'*.

Vehicle efficiency is another area in which the SFMTA would like to see some industry standards created and adhered to. It was Timothy's view that the benefits of DTT will only be fully realised when low and zero emission technology is the universal standard adopted by emerging mobility providers. Finally, the sharing of data developed by companies such as *Uber* with public agencies responsible for the network is considered essential.

B.5.2 Developing an Emerging Transport Strategy for San Francisco

Timothy mentioned that the SFMTA are currently working on a report similar to the City of Melbourne, which is intended to form a SFMTA ***Emerging Transportation Strategy***. This Strategy will seek to:

1. House all emerging mobility ideas and providers.
2. Position the SFMTA so they can take on the key issues and benefit from new opportunities to increase the sustainability, safety and equity of the transport system.

The desired outcomes from this ***Emerging Transportation Strategy*** include:

1. A set of core principles (or 'rules of engagement') that can be presented to disruptive mobility companies, who will be asked to adhere to them – perhaps not immediately, but as something to work towards. Companies that seek to work within the City of San Francisco will be asked to develop a timeline to meet the safety criteria that will be developed as part of this Strategy (on street and in vehicle safety). These rules of engagement will also include affordability and accessibility criteria. Importantly, SFMTA will also seek to maximise interoperability criteria, in order to increase the efficiency of multi-modal connections and enhance the door-to-door experience of travellers. Vehicle efficiency, as highlighted above is also expected to be included within the rules of engagement.
2. Online documenting and dash boarding. Consistent with the themes emerging from discussions with Professors' Currie and Shaheen, the SFMTA is keen to see an increase in the availability of ride data. Although there are likely to be aspects of this data commercial transport platforms are likely to withhold, the SFMTA would like to seek agreement on quarterly reports provided to the SFMTA, verified using a trusted 3rd party.

B.5.3 Creating an urban innovation lab

In addition to the ***Emerging Transportation Strategy***, the City of San Francisco is developing an ***urban innovation lab****.* This is a collaboration between the public, private and university sector. This living laboratory will include a number of different portfolios, including *transport* (i.e. it will include a range of local government responsibilities; commercial/enterprise, land use planning, as well as transport). A number of different theories and ideas will be tested on the ground in this lab, including the technical aspects of disruptive innovation, such as sensor technology in public infrastructure, drones, and autonomous vehicles.

The key learning's that emerge from this lab will be shared with some of San Francisco's peer cities. Partnerships with other cities will allow other jurisdictions to learn from one another. Timothy mentioned that the issue for the City of Melbourne is that the State Government are actually in control of much of the transport services that operate within and across the municipality, whereas the SFMTA is in control of almost all transport services within the City of San Francisco.

For a city to join as a partner in the ***urban innovation lab***, there are a few requirements (no exhaustive), as listed below:

1. An open data policy.[19]
2. Culture of partnerships – this needs to be formalised and may mean that some projects do not follow the normal Council procurement cycle. For instance, a company that is developing remote sensing technology may partner with government in such a way that the government agency offers their street poles to the company, in order to test its technology. This can happen even before a *Request for Proposal* process, because the technology is so new. Another example is working across government to deliver a public Wi-Fi program.

Creating a culture of '*agnostic mode preference bias'* – no one mode is better than another. Timothy elaborated on this by saying that it is about picking the right mode (or combination of modes) for the right trip. Timothy suggested that it may benefit the City of Melbourne to work closely with other

[19] The City of Melbourne already has an Open Data policy and a public website (http://bit.ly/QjLxxH)

Melbourne municipalities as the City of Melbourne workforce and visitor base is largely composed of residents from these surrounding local government areas.

B.5.4 Moving towards an access all modes App

One of the major themes that emerged from this interview was the work of the SFMTA in assisting industry in providing *interoperability* between different modes, through the use of an App. The model discussed was one in which all modes of transport would be housed in the one App, which would be designed to facilitate *in App payment* (similar to the platform identified in Section 4.4 using the example of *RideScout*). This would move beyond the one agency App (e.g. PTV App), such that when a user enters their desired destination, *all* mobility options are presented, including walking, cycling (private *and* public bike), taxi, Uber (including all variations), public transport, and private and shared car. Importantly, the App is intended to offer multi-modal combinations, which may include a component of Uber, in order to access a rail network, to complete a journey. The user is able to find and pay for the transport services using nothing other than a smartphone. Timothy identified *RideScout* as well as their partner company *GlobalSherpa* as providing the SFMTA with a multimodal journey information platform that includes in App mobile payment. Timothy mentioned that SFMTA is set to launch such a service by the end of 2015 or beginning of 2016 (beta testing). If Uber and Lyft are interested, the SFMTA App will be able to be linked to these platforms so these services become part of the modes included in the App. If they are not interested, the API can work the other way, so that their Apps can be linked to SFMTA, rather than the SFMTA linked to their App. APIs can work both ways. So, the Uber customer that has nothing to do with SFMTA can use the Uber API, so that the payment, processed through the Uber App can be a valid form of payment to get on a train, when a journey involves both Uber and public transport. In such a situation, *Uber* sends the money to *RideScout*, who then sends it to the *SFMTA*. This scenario, which embeds many of the core principles of integrated transport planning due to its focus on the door-to-door experience of the user (Givoni & Banister, 2010) requires three elements:

1. Open data.
2. Clean, ‘digestible’ data. This requires a protocol, such as the *Google Transit Protocol* (GTP). This is presented as an open API.[20]
3. Payment system (e.g. GlobeSherpa).

The next area (after the above) that SFMTA would like to move ahead with is *mobile porting and unlocking.* This describes a situation in which a mobile phone essentially acts as the ‘fob’ or smartcard that has previous been required to access mobility services such as bike sharing, car share vehicle or public transport. The goal is for the smartphone to be the only device required to move between and pay for all modes of transport. A related project that is currently being undertaken by the SFMTA is to use all public transport nodes as Wi-Fi hotspots.

An important part of the SFMTAs role in all these developments is the enhancement of the customer experience. The SFMTA sees themselves as having an important role to play in this because many of the disruptive mobility companies see their service as the ‘next big thing’. The customer however does not necessarily share this view, and are more likely to be concerned with safely getting from A to B. The SFMTA therefore attempts to create the conditions for an *integrated travel experience*. Ultimately, from the user experience, it all needs to act as one system, to paraphrase Timothy Papandreou.

[20] The SFMTA does not use timetabling information, but rather the specialist service *NextBus* (a private technology company).

B.5.5 Ride sourcing services and traditional taxis

Timothy mentioned that many of the characteristics of ride sourcing services represent significant improvements in service quality compared to the traditional taxi industry. This includes:

- Clean vehicles, inside and out
- Clean drivers
- Cashless payment
- Reduced wait times.

Timothy highlighted that there are still some advantages that traditional taxis have over the new ride sourcing companies. For instance, they do not use *surge pricing*[21]. However, traditional taxis refusal to offer pooled services[22] and this has reduced their relative value proposition in San Francisco, as it gives give Lyft and Uber a major advantage, from a price perspective, and an environmental outcome.

B.5.6 Car parking and emerging transport technologies

The City of San Francisco is considered a leader in parking policy within the US. One of the final components of this interview involved discussion of the impact of emerging technologies on car parking. Three factors were outlined as essential if government and the community wish to fully benefit from the emerging transport technologies that are on offer:

1. Enable shared ride solutions to train stations. Like Melbourne, train stations around San Francisco experience higher levels of car parking demand relative to supply. Facilitating ride share options to train stations will help free up car parking around the station For instance, if an Uber service was able to take three people to a train station, that frees up to three car parking places at a train station. If that Uber driver could make three trips during peak hour, that amounts to nine people who have arrived at a train station without one parking space required. Timothy mentioned that there could be an argument for public subsidy, to bring the cost of these rides down to something that is acceptable to the travelling public (considering that they then become customers of the train service). The public transport agency needs to do an assessment of the benefits of such an initiative, to work out what it is worth to them and whether there is the carriage capacity to take additional passengers.
2. Employers with large car parking capacity should be encouraged to consider reducing their need for this space, via the use of ride sourcing services, in conjunction with public transport. The benefit to the company relates to the opportunity this space creates for them to repurpose it, or, if they have no immediate use, to sell or lease it. Timothy mentioned that in all the market research conducted by the SFMTA, few want to drive to work, so a solution such as this might be tapping into people's openness to get to work without having to drive. This is a solution that might work in suburban settings in which public transport is not a time competitive option, but ride sourcing and on demand micro transit might be able to meet commuting needs.
3. On street car parking reform. This is perhaps the most pertinent point for the City of Melbourne. As part of his responsibilities with the SFMTA, Timothy seeks opportunities to reduce the total number of on street car parks and better manage existing ones, aided by car sharing and dynamic pricing mechanisms. A 'traditional' car sharing car (e.g. Flexicar or GoGet), it was argued, takes at least nine cars off the road. If a car sharing pod can be on every second block in San Francisco

[21] Surge pricing increases the cost of rides when demand is high, in an effort to attract more drivers to an area, and encourage drivers to work at peak times (e.g. Friday and Saturday evenings).
[22] Two or more independent passengers with different drop off locations share a ride.

(needs to be based on intensity of land use factors), it would be possible to eliminate a quarter of on street spaces, without reducing access for people who are driving. This arrangement does require a Public Private Partnership in which the agency cross subsidises the car sharing services. For ride sourcing services, if they can 'pulse' in and out of particular areas, on street car parking could be further reduced, and repurposed for other productive uses (e.g. footpath widening, café, parklets).

A summary of *SF Park* is provided in Box 2.

In the past five years, the City of San Francisco has implemented a program of dynamic pricing for on street parking. Known as SF Park, it is based on the work of the world's leading parking policy researcher, Professor Donald Shoup (see Shoup, 2005), in which the price is based on demand, with the goal of having 15% of all spaces available at any given time. By balancing supply and demand through price, it reduces the amount of circling involved in looking for a curbside parking space.

The results of SF Park show traffic congestion has reduced by 10%, as has dangerous driving (as motorists looking for car parking often display less attention on other aspects of the road traffic environment).

The SF Park experience has been that people do not care as much as initially thought about the price of parking (up to a point), but place greater value on its availability. SF Park has increased the number of spaces available in many locations, which has resulted in fewer people circling, looking for parking spots. Some high demand areas of the city have seen sharp increases in the cost of parking, while other areas have seen a reduction in the cost of parking.

SF Park also enables people to top up their spot via a smartphone App, allowing people to stay for an extended period. This has resulted in a reduction in the number of fines issued. Contrary to opinion both within and outside local government, longer stays has not seen a reduction in retail revenue. The conventional wisdom was that less car parking turnover would reduce the number of shop customers and therefore negatively impact on retail income. However, in the five years of SF Park, the experience has been that by allowing people to top up and stay longer, people are able to do other things in the city, which increases the amount of money spent per car driver. Three to four hours was found to be the 'sweet spot' according to Tim Papandreou, the Director of Innovation at the SFMTA (2015). One hour, according to Papandreou only allowed the person parked to achieve one task before needing to return to their vehicle, whereas three to four hours was sufficient to achieve several business or social tasks. Three key outcomes from the SF Park experience include:

4. Greenhouse gas emissions reduced by 30%
5. Congestion went down by at least 5 – 10%
6. Public transport vehicle speeds increased and travelled more reliably through the areas in which SF Park operates.
7. Collisions with pedestrians and cyclists did not increase – despite the number of cyclists increasing over the period.

Some 29% of the SFMTA operating budget is fees and fines. The revenue derived from parking helps pay for public transport services. Overall, the SF Park trial did result in high parking fees (up 15%) and this additional income helped to offset the reduction in fine revenue to the municipality. Sales tax and property tax went up in the areas with SF Park, although this may have been due to other factors. The ability for people to top up using the App reduced fine revenue by about $5M, but some $6 in extra sales and property taxes helped off set this. Ultimately, SF Park enabled people to stay in the City longer, spending more money.

SF Park has won a large number of awards, including the 2013 Public Parking Program of the Year, the 2013 Sustainia100 Top 10 Innovations in Cities, the International Parking Institute Top 10 Innovative US Parking

Programs 2013, the Harvard Kennedy School's Top 25 Innovations in Government 2013, the 2012 Bay Area MTC Excellence in Motion Award of Merit, the 7x7's Best of San Francisco 2012, the 2012 Living Labs Global Award, the 2012 MFAC Good Government Awards, the 2012 Excellent.gov Awards-Excellence in Innovation: Mobility, the 2011 Department of Defence Technology Symposium Best of Show Award, the 2011 SF Weekly Web Award – Best Local Government Site, and the 2012 ITDP Sustainable Transport Award. More details on Awards can be found at the SF Park Awards webpage (http://bit.ly/1M5AfnP).

Box 2 SF Park, San Francisco

B.5.7 The impact of autonomous vehicles on congestion

The SFMTA sees a risk in autonomous vehicles potentially exacerbating congestion, for the same reasons outlined in Section 4.6.2 - 4.6.3. Timothy outlined how a car that does not require the occupant to have any driving responsibilities would allow them to do other things. Whilst this would bring time saving benefits to the user, it could change the value of time, therefore increasing an individual's tolerance for longer or more congested commutes. This may even result in people choosing housing options further from their place of work, increasing total VKT and congestion. Whilst this is largely a repeat of the issues raised in Section 4.6.3, it is noteworthy that the literature reviewed in that section, as well as all the interviews with experts arrived at a very similar scenario.

The key question, which is a reoccurring theme throughout this project, is to what degree will autonomous vehicles make the private ownership model redundant? Separate to this interview, it has emerged that planners within the Victorian Government have begun examining the same question, and have raised the possibility of congestion becoming very much worse should the private ownership model continue after the transition to an autonomous vehicle fleet (e.g. see Whiteman, 2015). The possible introduction of a road network pricing mechanism was put forward by Timothy as a method of managing the congestion issues that might arise from the gradual introduction of a driverless vehicle fleet. A road pricing mechanism, it was suggested, could include a range of pricing options, not dissimilar to surge pricing, in which vehicles are subject to a high fee based on congestion levels. These can be pre-trip based calculations, so there are options available to avoid these changes, either by using a different mode, different travel time, or different route.

On a related issue, Timothy and the SFMTA are in talks with *Uber* and *Lyft* to see whether trips that involve travel through the most congested roads at the most congested time of day can have a surge pricing model applied, allowing for a split revenue stream between the ride sourcing platform and the SFMTA.

At a more general level, Timothy has been working with his team exploring what the transport environment might look like in 10 – 20 years (in terms of a mobility market place), and what the SFMTA can do to capture the possibilities it will offer. A key question to be addressed is *'How do we want people to commute in the future?'* and then develop an implementation plan to realise that vision. Timothy sees a future in which the opportunities provided by these emerging mobility technologies may help us to transform our streets such that they may only need to be 1/3 as wide, with the space repurposed into separated bike lanes, plantings, parklets, micro business enterprise, even property development applications for very large intersections. One of the real difficulties according to Timothy will be the transition period we are about to enter, in which there might be 10% driverless vehicles and 90% at some other, lesser stage of autonomous vehicle This could, according to Professor Graham Currie, last for up to four decades. The next years 2015 – 2025 are probably not going to be quite as *'interesting'* according to Timothy Papandreou as the ten years from 2025 – 2035, when these technologies approach mainstream adoption. Ultimately, it was concluded, it is not *transport* itself, that ought to be the focus, but rather how emerging technologies can enable our cities to be more *economically competitive*, *liveable* and *sustainable*. A mobility strategy focused on economic competitiveness offers planners the ability to go much deeper in terms of policy solutions than when the focus is only on reacting to transport issues of the day. Timothy concludes by arguing that '*Transport is a key part of economic competitiveness and the goal should be to reduce and minimise the need to have to drive a car, by yourself, all the time. For reasons of physics and geometry, this needs to be the goal'.*

Appendix C - Resources on disruptive technologies in transport and tools to keep updated on latest developments

The following agencies and individuals have a demonstrated interest in the area of disruptive transport and should be monitored on a regular basis to remain up-to-date on the latest developments regarding the innovations detailed in this report.

1. Australian Road Research Board (ARRB). The Australian Driverless Vehicle Initiative (ADVI) is a partnership that includes a range of leading national and international organisations working on issues related to the introduction of autonomous vehicles.

   www.arrb.com.au/advi

   e: driverlesscars@arrb.com.au

2. ITS Australia. The 23rd ITS World Congress 2016 will be held in Melbourne (10th – 14th October) and will include a number of themes of direct relevance to this project, including:

   A. Challenges and Opportunities of Big Open Data

   B. Automated Vehicles and Cooperative ITS

   C. Vehicle and Network Security

   D. Environmental Sustainability

   E. Smart Cities and New Urban Mobility

   F. Mobile Applications

   G. Future Freight including Aviation and Maritime

   H. Policy, Standards and Harmonisation

   www.itsworldcongress2016.com

3. RideScout: A US based technology company that developments multi-modal transport applications.

   www.ridescout.com

4. Keep in contact with the the following individuals, who are active researchers on disruptive mobility (leading researchers on autonomous vehicles). There Twitter handles may offer an effective method of keeping informed of the latest developments in disruptive transport technologies.

   A. Dr Daniel Fagnant, University of Utah

   B. Dr Kara Kockelman, University of Texas

   C. Brian Johnson, U.S. Auto and Auto Parts equities researcher at Barclays

   D. Professor Susan Shaheen, University of California

   E. Dr Jeremy Whiteman, Department of Economic Development, Jobs, Transport and Resources, Victorian Government

   F. Rutt Bridges, Author of Driverless Car Revolution: Buy Mobility, Not Metal

   G. Travis Kalanick, Uber Technologies

H. Gabe Klein, Former Commissioner of Transportation, Chicago and executive at Zipcar.

I. Timothy Papandreou, Director of Innovation, SFMTA

J. Dr Marcus Enoch, expert on demand responsive transport at Loughborough University. See http://www.drtfordrt.org.uk/publications.php

5. Australian Institute of Traffic Planning and Management (AITPM)

   aitpm@aitpm.com

   www.aitpm.com.au

6. Innovative Mobility Research (IMR): Covers news and research related to innovations in mobility, including car sharing, bike sharing, autonomous vehicles and electric vehicles. They are affiliated with the Transportation Sustainability Research Center at the University of California

   http://innovativemobility.org/

   @InnovMobility

7. New Cities Foundation: This group, based in Geneva but with officers in a number of global capitals, is focused on creating a better urban future for all by fostering urban innovation and entrepreneurship. They do this by building and empowering our global network, convening events and conducting pragmatic research.

   http://www.newcitiesfoundation.org/

8. Establish Google Alerts for the following terms, which will then send you news items featuring these terms:

   A. Autonomous vehicles

   B. Tesla

   C. Driverless cars

   D. RideScout

   E. Car sharing

   F. Ride sourcing

   G. Uber

   H. GlobeSherpa

   I. Elon Musk

   J. Pop up transit

   K. Demand responsive transit

A data file (Endnote library) containing the references included in this project can be made available upon request.

Appendix D – Overview of project

Phase 1

Definition & description of disruptive technologies in transport (DTT)

Description of different classes & phases of DTT (e.g. P2P, App-based)

Semi-structured interviews with DTT leaders, including Professors' Susan Shaheen, Graham Currie, Koen Franken, Tim Papandreou & Kristian Handberg

Major DTT developments and trends, including selected case studies of specific relevance to the CoM

Local government best practice examples in facilitating desirable DTT innovation

Phase 2

Impact of DTT on CoM business in terms contributing to strategic goals

Impact of DTT on residents, works and visitors to the CoM

Phase 3

Recommendations to assist the CoM capitalise on current & emerging DTT

Provisions of information/resources on DTT and tolls to keep updated on latest developments

Appendix E– Long text descriptions

Text alternatives for graphs, figures and complex images within Emerging Transport Technologies report.

E.1 Figure 4.1 Disruptive innovation versus sustaining technologies

This relationship graph has a horizontal axis titled ‘Time’ and vertical axis titled ‘Product Performance’. There are no units or intervals along either axis but both axes end with an arrow pointing in a continued direction off the graph.

There are two dashed lines running parallel in an upward direction from the Product Performance axis to the end of the Time axis. The top line is labelled ‘Performance demanded at the high end of the market’; the bottom line is labelled, ‘Performance demanded at the low end of the market’.

Another two solid lines run parallel in an upward direction across the chart and end with arrows pointing in a continued direction of the graph. These lines have a steeper upward gradient than the dashed lines. The top line is labelled, ‘Progress due to sustaining technologies’; the bottom line is labelled, ‘Progress due to disruptive technologies’. The top solid line commences close to the same spot as the bottom dashed line. The bottom solid line commences below the bottom dashed line and further along the Time axis.

The channel between the two solid lines and where they intersect with the channel between the two dashed lines is labelled, ‘Disruptive technological innovation.’

E.2 Figure 4.2 UberPool – the ‘perpetual ride’

The diagram shows a car picking up passenger 1, driving on to collect passenger 2, driving on to drop off passenger 1, driving on to pick up passenger 3, driving on to drop off passenger 2, then driving on.

E.3 Figure 4.3 Selecting UberPool and other services, New York City

The screenshot is of the Uber app showing a pick up location with blank destination. The map pinpoints the pick up location with the option to ‘set pick up location’, marked with a time of 3 minutes. Options for the type of service are below the map and are: uberT, uberPOOL (which is currently selected), uberX, UberBLACK and UberRUSH. Other screenshot information shows text of “Share your ride save 25%” and “1-2 people.”

E.4 Figure 4.4 RideScout mobile App travel information, Washington, D.C.

The screenshot on the left shows a map of Washington D.C. Pick up and destination addresses are listed above. Multiple varied coloured dots are placed all over the map representing different types of transport, the pick up and destination locations and an option button to ‘search rides’. The screenshot on the right of the figure shows the estimated journey time, estimated cost for the varied transport options, and ‘calories burned’ estimate for bike riding.

E.5 Figure 4.5 Four types of future vehicles and estimated usage/costs

The figure is divided into four images that represent traditional, family autonomous, shared autonomous and pooled share autonomous vehicles.

The top left of the figure shows information on traditional vehicles. There are two bullet list items. The first bullet item states, “limited self-driving capabilities”, and the second bullet item states, “work or personal use.” Further information on the types of vehicles for work or personal use states, “work: pickups, large SUVs, commercial vans. Personal: cars/CUVs, performance.

A flow chart shows the typical use of a family with two cars. Car one is shown making a journey to work and home again, totalling two journeys. Car two is shown making a journey to school, then onto a social engagement, back home, back to school and home again, totally five journeys.

The top right of the figure shows information on family autonomous vehicles. Vehicles / household is shown as 2.1 down to 1.2 and annual miles / vehicle is shown as 12,000 down to 24,000 miles.

A flow chart for one vehicle shared by multiple family members shows 10 journeys to and from home in total. They are journeys 1 and 2 to work, 3 and 4 to school, 5 and 6 to a social engagement, 7 and 8 to school and 9 and 10 to work. Journeys 1, 3, 5, 6, 8 and 10 carry passengers and all others are empty vehicle trips.

The bottom left of the figure shows information on shared autonomous vehicles (SAVs). A ratio of 9:1 is shown of traditional vehicles displaced by SAV; 8 per cent additional vehicle miles travelled due to empty trips; annual miles / vehicle is shown as12,000 down to 64,000 miles; a sedan would cost $0.44 mile ride cost to consumers per SAV; and a two-seater would cost $0.16 mile ride cost to consumers per SAV.

A flow chart for “robot taxis” with average wait time of 1 minute shows the car picking up and dropping off passengers three times in succession, with each trip between a drop off and pick up shown as an empty vehicle.

The bottom right of the figure shows information on pooled shared autonomous vehicles (PSAVs). A ratio of 15-18:1 is shown of traditional vehicles displaced per PSAV; 40-50 per cent reduced vehicle miles travelled due to shared rides; annual miles / vehicle is shown as 12,000 down to 64,000 miles; a sedan would cost $0.21 per mile ride cost to consumers per PSAV; and a two-seater would cost $0.08 per mile ride cost to consumers per PSAV.

A flow chart for “perpetual ride” with average wait time of 5 minutes shows the car picking up twice, then dropping off, picking up, dropping off and continuing on.

E.6 Figure 4.6 Monthly cost versus monthly miles driven

The table below represents data displayed as a lined graph in figure 4.6. The header row represents the maximum monthly miles driven for each type of vehicle. Cost is shown per vehicle in data cells.

	0 miles	750 miles	1250 miles	1750 miles	2500 miles	3000 miles
Tesla	530	560	600	650	725	800
SAV	0	200	400	600	750	950
Purpose SAV	0	80	150	225	325	400

E.7 Figure 4.7 Number of trips made by all modes other than 'car as driver' on an average weekday in Melbourne Statistical District (MSD)

Age Group	Vehicle Driver	Vehicle Passenger	Walking	Bicycle	Train	Tram	Bus	Other
0->4	-	640,568	112,838	6,658	3,373	1,844	2,978	271
5->9	-	610,042	112,489	9,642	7,936	1,083	9,361	315
10->14	-	511,534	131,343	19,891	18,381	6,550	62,247	4,665
15->19	98,632	264,063	88,129	14,799	65,808	23,202	57,560	7,090
20->24	444,349	123,342	69,699	8,712	77,031	30,321	15,532	6,478
25->29	540,068	101,286	124,505	32,206	89,295	38,245	14,522	3,502
30->34	631,351	90,040	135,927	25,625	72,873	23,985	8,381	9,100
35->39	765,733	74,031	126,794	26,219	58,810	21,792	3,849	10,361
40->44	830,239	85,696	113,565	21,700	43,017	19,665	6,716	4,795
45->49	797,561	60,977	74,228	13,877	40,210	17,973	7,594	5,117
50->54	631,268	61,871	77,173	13,683	31,149	9,586	6,218	7,493
55->59	529,361	77,113	65,488	6,358	23,488	12,155	4,211	3,845
60->64	398,504	75,944	79,206	3,886	16,184	11,090	4,569	4,704
65->69	236,476	66,978	70,411	3,478	11,397	4,262	2,436	2,842
70->74	225,534	72,486	62,043	900	9,576	7,144	7,959	1,414
75->79	128,508	25,457	36,735	288	6,767	3,559	6,144	2,599
80->84	58,847	24,590	16,783	1,717	1,559	1,924	2,843	2,577
85->89	21,722	13,359	8,433	-	415	1,913	1,876	3,285
90->94	1,184	9,848	318	-	-	-	226	248
95->99	-	587	-	-	-	-	-	-

E.8 Figure 5.1 the convergence model of transport

The convergence model of transport is divided into six sections, each with an equilateral triangle showing the label of Bus at the top vertex, Car at the bottom left vertex and Taxi at the bottom right vertex. Along the side between the Bus and Taxi labels are points for Jitney, DRT minibus and Shared taxi. Along the side between the Taxi and Car labels are points for Car club, Car rental and Car leasing. Along the side between the Car and Bus labels are points for Lift sharing, Vanpool and Shuttle bus.

A note for the model states, "Shaded areas show how travel options expand for current car, bus and taxi users as new models evolve."

The first triangle in the model has a caption of "1) Traditional transport mode landscape of car, bus and taxi. Users with little choice." Each area of the triangle towards the vertices is equally shaded. An arrow labelled, "Incremental innovation" points to the next triangle.

The second triangle has a caption of, "2a) Shift from car due to financial and legal barriers to use and externalities as options evolve." The area of triangle towards the Car vertex has an increased shaded area with a paler shade. An arrow from this vertex also point upward into the centre of the triangle.

The third triangle has a caption of, "2b) Shift from bus due as desire for low cost, higher quality services met by 'new' modes." The shaded areas near the Car and Taxi vertices are the same as the previous triangle, but the shaded area for Bus has increased but the colour is paler. The shade colour for Car is also paler. An arrow from this vertex points downwards into the centre of the triangle.

The fourth triangle has a caption of, "2c) Shift from taxi caused by growth in reasonable quality lower cost alternative modes. " The shaded area near the Bus vertex is the same, the shaded area near the Car vertex has increased, and the shaded area near the Taxi vertex has increased only along the bottom side of the triangle towards the Car vertex. All shaded areas are the same paler shade. An arrow from the Taxi vertex points upwards towards the centre of the centre of the triangle. An arrow labelled, "Incremental innovation" points to the next triangle.

The fifth triangle has a caption of, "3) Traditional modes eclipsed as intermediate modes gain credence." All shaded areas and tone remain the same as the previous triangle. An arrow from within each shaded area points towards the centre of the triangle; the centre colour of the triangle is darker than previous triangles. An arrow labelled, "Radical innovation" points to the final triangle.

The sixth triangle has a caption of, "4) Appearance of autonomous vehicles accelerates further modal convergence to dial-a-pod." There are no shaded areas at the vertices. A two-toned concentrated shaded area appears in the centre of the triangle with thin offshoots heading towards each vertex. Arrows from outside each triangle side now point inwards to the central shaded area.

E.9 Figure 6.10 Schematic timing and impact of emerging transport technology

This relationship graph has a horizontal axis titled 'Estimated period for common use among early adopters' and vertical axis titled 'Potential impact'. Both axes end with an arrow pointing in a continued direction off the graph. There are no units or intervals along the vertical axis but the horizontal axis commences in the year 2020 and increases by two-years until 2032. The year 2032 is followed by a plus symbol.

Within the L-shaped body of the axes, starting in the top left corner directly above the year 2020 are images representing Ride sourcing services (e.g. Uber) and car sharing. Beneath these and moving further into the future is Multi-modal app-based travel planning, and Digital car parking management. Lower down on the potential impact axis and further into the future is Bike Share. Bike share is marked with a note stating “considerable uncertainty exists regarding the future and size of the Melbourne Bike Share program.” Further into the future rating as high potential impact is Autonomous vehicles; directly below this is On demand bus services, and below this again is Electric vehicle charging. These last three images are roughly above the 2028 label on the early adopters axis. Electric vehicle charging is marked with a note stating “Highly dependent on the policy environment and external factors (e.g. price of petrol).